Lecture Notes in Logistics
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Herbert Kotzab
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Dynamics in Logistics

Proceedings of the 4th International Conference LDIC, 2014 Bremen, Germany

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Editors

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Editors
Herbert Kotzab
University of Bremen
Bremen
Germany

Jürgen Pannek
Universität Bremen
Bremen
Germany

Klaus-Dieter Thoben
Bremer Institut für Produktion
und Logistik (BIBA)
Bremen
Germany

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Preface

Continuing in the footsteps of the three previous international conferences on Dynamics in Logistics, LDIC 2014 was the fourth event in this series to be held in Bremen (Germany) from February 10 to 14, 2014. The conference was accompanied by a "Doctoral Workshop" as well as the "InTraRegio International Dialog Event" and the "MAPDRIVER Kickoff Meeting" as satellite events. Similar to its predecessors LDIC 2007, LDIC 2009, and LDIC 2012, the Bremen Research Cluster for Dynamics in Logistics (LogDynamics) of the University of Bremen organized the conference in cooperation with the Bremer Institut für Produktion und Logistik (BIBA), which is a scientific research institute affiliated to the University of Bremen.

The conference is concerned with the identification, analysis, and description of the dynamics of logistic processes and networks. The spectrum reaches from the modeling and planning of processes over innovative methods like autonomous control and knowledge management to the new technologies provided by radio frequency identification, mobile communication, and networking. The growing dynamic confronts the area of logistics with completely new challenges: it must become possible to rapidly and flexibly adapt logistic processes and networks to continuously changing conditions. LDIC 2014 provided a venue for researchers from academia and industry interested in the advances in dynamics in logistics induced by new technologies and methods. The conference addressed research in logistics from a wide range of fields including engineering, business administration, computer science, and mathematics.

The LDIC 2014 proceedings consist of 72 papers including 10 young researcher papers selected by a strong reviewing process. The volume is organized into the following main areas:

- Shared Resources, Planning, and Control,
- Synchronization,
- Technology Application in Logistics,

- Transport and Green Logistics,
- Supply Chain Management, and
- Frameworks, Methodologies, and Tools.

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Herbert Kotzab
Jürgen Pannek
Klaus-Dieter Thoben

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Part I
Shared Resources, Planning and Control

A Micro- and Macroeconomic View on Shared Resources in Logistics

Jörn Schönberger, Herbert Kopfer and Herbert Kotzab

Abstract In this paper, we introduce the concept of “shared resources” which is used to prevent structural resource scarceness in the field of logistics. Due to the unlimited growth of value creation activities, capacity limits of infrastructures (for traffic, communication and energy) are reached and emission rights become scarce. However, public infrastructure investments decrease while private investments become more difficult since individual private investors are unable to provide sufficient capital. In conclusion, innovative resource providing concepts are needed in logistics. The major innovation of this chapter is the proposal of an innovative resource management concept to make today’s logistics systems and processes sustainable with respect to the upcoming scarceness of input resources (e.g. infrastructure) and output resources (e.g. emission rights).

Keywords Logistics · Shared resources · Scarceness · Common pool resources

Introduction

Logistics is responsible for all value creating and auxiliary processes when it comes to achieve a spatial and temporal balance between demanded products and provided products. Due to the high degree of labor share, it is necessary to move goods from production sites to markets. That is why the logistics sector as an industrial branch

J. Schönberger · H. Kopfer
Chair of Business Administration, Transport and Logistics,
Technical University of Dresden, Würzburger Strasse 35, 01187 Dresden, Germany

H. Kotzab (✉)
Department of Logistic Management, University of Bremen, Wilhelm-Herbst-Strasse 12, 28359 Bremen, Germany
e-mail: kotzab@uni-bremen.de

H. Kotzab
Glasgow Caledonian University, Glasgow, UK

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was significantly growing during the past decades. The trend toward low price products though requires intensive storage of finished (or semi-finished) products until the product is requested from the market realizing economies of scale by largest lots in production.

So far, production efficiency has been improved so that the available quantities often exceed the requested quantities. However, product shortages and/or shortages expectations are detected with increasing frequency. Since, the quantities are available (produced) it can be concluded that this shortage happens during the distribution stage in a value creation chain. Thus, the product shortage is identified to be related to the logistics activities in a value creation chain.

Especially, the logistics sector faces obvious resource scarceness problems which become immediately visible. Traffic jams indicate that the specific resource "road" is scarce or even partly exhausted at certain times. The resulting congestion prolong transfer times to the next transshipment terminal, and late arrivals there causes additional delays in the material flow since the transshipment facilities are already blocked and so on. Short local process disruptions finally result in process delays spread over whole value creation networks. On the other hand, and in contrast to the aforementioned resource scarceness there are unused resources like semi-filled trucks that maintain unused capacities which cannot be exploited by the operators.

Although, it is obvious that the resource scarceness needs to be managed by the logistics sector, it remains unclear why this scarceness appears more often in our today's economic systems. It is a fact that this growing resource scarceness negatively impacts the performance of the logistics sector in modern societies. Finally, a performance decrease of the logistics sector compromises the economic prosperity and growth of our society. Consequently, we need to understand the underlying reasons for the observed scarceness of logistics resources and to propose strategies to overcome this menace.

The primary goal of this chapter is to understand the mechanisms that finally lead to the observed resource shortage which leads to the following two research questions:

1. What are the underlying trends in the market conditions for the logistics sector that contribute to the observed scarceness of resources needed for logistics processes?
2. What are the longer term impacts of the ongoing trend to keep resources as scarce as possible as a result of the involvement of private investors in the provision of formerly general public resources?

First, we discuss several ongoing trends in the European economic systems that contribute to a structural resource shortage in the logistics sector. Among other drivers, the shift of resource provision from public to private is identified as a major driver of these trends which are going to be addressed in the following. Furthermore, we investigate to which extend cooperatively managed resources can be exploited to protect the performance of the logistic sector under the changed conditions.

Logistic Resource Scareness from a Microeconomic Perspective

Demand-Orientation and Workload Dependency of the Logistic Sector

When using the term resource we refer to the general definition of a *resource* given in (Wernerfeldt 1984): "By a resource is meant anything which could be thought of as strength or weakness of a given firm." All resources of a firm (or of an equivalent organization form like a cooperation or project or joint venture) that contribute to the realization of logistic services are called *logistics resources*.

During the starting phase of the industrialization, massive investments have been directed into the set up work and extension of production systems. These investments were hedged by nearly unlimited demand from the market. The existing scarceness of production resources led to relative scarceness of products. For this reason, product selling prices were set so high that significant margin contributions were realized. The largest part of the achieved profits remains within the production sector. The other two basic values creating function transport and storage (referred to as "logistics") have been assigned auxiliary functions for the support of production systems.

Going back to the aforementioned observation, today's (regional or global) comprehensive value creation models are based on the assumption, that logistics services like transport, storage, and other accompanying activities are available when needed and the costs for the utilization of these services are quite low. As a consequence, provider of logistics services are expected to adjust their maintained resource capacities to the demand that is mainly triggered and determined by the output realized from the production part of a value creation process. However, recent economic trends lead to scarceness of logistics resources which contradicts the underlying assumption that logistics services are available at unlimited capacity whenever needed at quite low costs.

External impacts leading to reductions of the production output or to a significant increase of the produced quantities appear frequently. To hedge the performance of logistics systems against these workload variations, providers of logistics resources try to adjust their resources to the demand in order to preserve their market position (demand orientation of logistics resources). In situations where the workload is increased, resources are in danger to be exhausted causing additional costs like overtime hour surcharges. In situations of decreasing demand, parts of the resources remain unproductive. Since logistics activities are (still today) considered often as support functions, it is hardly possible to cover the additional expenses related to resource adjustments to the leading customers from production. Thus, providers of logistics services try to increase the efficiency of the available resources, but this strategy starts to fail because human resources as well as technical resources are reaching their natural performance limits. Workload peaks cannot be managed anymore so that temporary resource scarceness appears.

Trends Leading to Scarceness of Logistic Resources

The following market trends support the process of logistics resource shortage extension.

Trend 1: Continued Deregulation of Markets (Regulatory Politics). The logistics sector is severely affected by the deregulation of markets as the consequence of the integration of national markets in the European Community. Access to logistics relevant infrastructures like transportation systems of road, track, and water has been regulated by national laws for several decades because each national government wanted to protect the national value creation. Also military needs played an important role in the protection and regulation of access to national infrastructures. In this context, infrastructures have been provided and maintained by the national government, and national providers of logistics services were granted exclusive access to these infrastructures. No explicit access costs must be paid by the users from the logistics sector. Prices for logistics services were not determined on the market, but regulated by national law.

In the context of the integration of European markets, the deregulation of infrastructure access plays a central role. Access to national infrastructures is now possible to logistics service providers from other member states. Existing imbalances of labor costs and prices are used by foreign logistics service providers to enter so far closed markets and to gain significant market shares. Often the pressure exerted on prices cut down profits of logistics service providers who have operated profitable before. Often, sustainable price reductions for logistics services have been established as a result of deregulation (Aberle 2009).

The deregulation of access to logistics affine infrastructure finally leads to reduced profits, so that providers of logistics services must manage their resources more carefully. Inefficient usage of resources must be prevented in order to ensure the survival of companies from the logistics sector. Consequently, these companies hesitate to extent the capacity of their resources if load peaks appear if this is somehow possible. The demand for transport and other logistics services is still increasing, so that such a behavior finally leads to scarceness of the maintained resources in workload peak situations.

Trend 2: Increasing Prices for Energy Consumption and Emissions (Energy Politics). The fulfillment of fragmented and geographically distributed customer demand requires excessive transportation (e.g. case of Amazon, Ebay, and Dell). The ongoing penetration of these transport-oriented distribution concepts finally leads to an increase and intensification of logistics services, which accounts for 10–15% of the overall product-related costs (Mantzos et al. 2003). The intensification of transportation implies an increase of the consumed energy. In EU27, the logistics sector reveals a very high amount of consumed energy (European Commission 2010) which is expected to grow further. Transportation contributes the largest part of the overall energy consumption within this sector.

Fossil energy is limited and the peak-oil, which indicates the beginning of fossil energy scarceness, is expected to be reached already so that the price for fossil energy starts climbing up.

Trend 3: Increasing Pressure for Internalization of External Costs (Fiscal Policy). It has been decided at the beginning of the twentieth century that investments into infrastructure were of public interest. Motivation for this assignment was twofold: (1) The growth of the production sector requires support; (2) A well-developed infrastructure was a prerequisite for military power.

The production sector did not contribute to the installation and maintenance of today's infrastructure. Therefore, production-related costs do not include costs for the installation of the distribution system. The internalization of traffic-infrastructure costs was not intended (with the exception of the civil air transportation).

The possibility to ignore any infrastructure-related costs in product-prize calculations has led to an often global segmentation of production and value creation processes within the past seven decades. Value creation chains are global today exploiting least labor costs at different regions of the world.

During the past two decades, the extent of public funding that is directed to the extension and maintenance of infrastructures has been cut down in most the European countries. Some countries (e.g. Germany) started to take money for the usage of major roads. Other countries extend the involvement of private investors into the installation and renovation of critical infrastructure components like tunnels or bridges. Often, the access to these infrastructures requires the payment of a certain fee. Since taxes are not reduced, the costs for the execution of transportation processes raise up so that so far external costs for infrastructure provision is partially internalized.

The increase of the amount of energy consumed by the logistics sector is accompanied by a continuous extension and intensification of harmful emissions like greenhouse gases and noise (Wie and Tobin 1998). This happens despite continuous technological innovations and improvements (Aberle 2009). It is social need and political will to prevent sustainable damage of the ecological system, and the limitation of the overall amount of emissions is enforced by regulations and laws. The application of the concept of emission right trading is the most important tool to limit the overall amount of harmful emissions at short hand and to reduce it in the longer perspective (Wie and Tobin 1998). The need to buy the right to emit harmful substances (or noise) leads to scarce "output resources," since the overall number of emission certificates is limited. The price for the right to emit harmful substances (or noise) will finally grow up making energy consumption more expensive.

Logistics Resource Scarceness from a Macroeconomic Perspective

Tragedy of the Commons

Over long periods societies are frequently faced with situations in which important resources become scarce. Periods of dryness are typically followed by periods of starvation. Also manmade shortages are observed, e.g., overfishing of the oceans and overfertilization that result in slow extension of crop failures. Especially, with respect to manmade (anthropogenic) scarceness it has been shown that the shortage is the result of a long lasting and uncontrolled usage of resources that originally were not scarce, but nobody felt responsible to take care for such a resource because the considered resource has had no explicit owner. Such a resource is called a "common-pool resource" (CPR) in macroeconomics (Ostrom 2008), and the descent of common pool resources due to overstress by uncontrolled access to such a resource is discussed as the "tragedy of the commons" (Hardin 1968).

Resource Supply in Logistics

The resources used by the logistics sector have been classified into three categories: environmental resources, infrastructure resources, and private resources. The ownership associated with resources from each category as well as the responsibilities of funding for the installation and maintenance of the resources are shown in Table 1.

Environmental resources have no owner in the legal sense. In the past, no funding was directed to resources of this kind. Infrastructure resources are setup and maintained by public source funding and have been owned by the general public of a nation (the funding came of taxes and other duties of the national citizens). These two categories of resources were accessible for all potential users. There had been no explicit access and consumption control. Private resources have had an explicit owner who is responsible for the funding of the installation and maintenance of its resource. This owner has the right to grant or deny access to its resources.

Table 1 Historically grown responsibilities for the provision of logistics resources

Resource category	Ownership	Funding	Access
Environmental (e.g. air, water)	General public	–	Uncontrolled
Infrastructure (networks for transport or communication, security and emergency services)	General public of a nation	Public resources	Almost uncontrolled
Private (e.g. supra-structures and/or mobile resources)	Private	Private investors	Controlled

Obviously, private investors want to gain profits with the resources they provide. Therefore, it is reasonable that they control access to their resources effectively in order to assign access rights to those users who are willing to pay the maximal compensation for the resource consumption. Furthermore, it is reasonable to assume that capacity of private resources tends to be scarce, since the private investors assume a limited demand for the usage of the capacity of their resources. In case that the actual demand exceeds the forecasted demand, potential users will be in competition for the access to these resources.

The control of access to CPRs is possible, but often quite expensive so that it is not reasonable to define a connection between the usage and payment of resource utilization for a certain transaction.

CPRs have been investigated in depth in the context of a sustainable management of socioeconomic systems. Examples for analyzed CPRs are the management of water systems and fishery areas (Ostrom 2008) as well as drinking water reservoirs (Künneke and Finger 2009) and forests. All these investigations have been motivated by the need to overcome an already happened or expected shortage of resources as a result of uncontrolled and myopic consumption of originally rich resources. The recent situation of the environmental and infrastructure resources required by the logistics sector is similar, and these two resources can be interpreted as CPRs (different users compete for the capacity of these resources and access control to these resources is very costly).

Transforming the Notion of Common Pool Resources to Logistics

Since, we have found out that environmental as well as infrastructure resources have transformed from formerly unrestricted resources to CPR it is reasonable to establish a connection between the shortages of these logistics resources with the shortages of other CPRs. The terminal point of this progress is referred to as "tragedy of the commons" (Hardin 1968). As soon as this point is reached, the considered resources are irreversibly destroyed. As it has been mentioned before, previous investigations have developed strategies to stop the process of CPR shortage effectively. The major innovation was to assign owner(s) to those resources that are endangered and to obligate and reward a new owner for establishing a resource management that makes the resource utilization sustainable (Altrichter and Basurto 2008). Such a resource protection is mainly based on effective access control to the endangered resources (the CPRs).

The installation of resource control systems must be comprehensive for all resources. With respect to environmental resources as well as infrastructures, first step in this direction can be found that affects the logistics sector. First, most of the European countries have installed access control systems to major road connections. So far, the major motivation for detecting infrastructure is to get tolls for the infrastructure usage. Access blockages are currently not subject of discussion. However, the access can be balanced over time by setting quite high tolls during travel peak times.

The determination of property rights is motivated by the implication that owners of a resource have an intrinsic interest for the sustainable management of their property. Public-private-partnerships (Gerstlberger and Schneider 2008) which are recently used, e.g., in the extension of the German highway network are an example in which the ownership of an infrastructure is transferred from general public to private investors. Here, access control to the motorways are used to gain tolls from automobilists, and the private investors get a portion of the overall sum of collected tolls as long as they maintain their property in a shape that has been agreed with the government. If the resource cannot be used as expected due to damage or inappropriate winter services, the transferred sum of collected tolls from the government to the private investor is reduced. This gives motivation for the private investor to maintain the setup infrastructure and to keep it in a good shape.

The second concept for the installation of access control for CPR does not require any transfer of ownerships to private partners. Instead, access is completely blocked to give the resource time to recover (e.g. environmental resources). It is also possible that the governmental organizations specify a toll for using public resources with the goal to install a market-based regulation of access to a scarce resource. This market-based assignment of utilization opportunities for a scarce resource enables an access control to public resources that does not need an active role of the government during the assignment of utilization rights.

A recent example of market-based regulation of access control to scarce resources with respect to environmental resources is emission right trading. Emission certificates have been installed. Companies who are going to emit exhaust gases must pay for a certain certificate that allows the company to leave out a well-defined quantity of harmful emissions into the environment.

Although the control of access to infrastructure and environmental resources has not a long tradition, the installation of mechanisms for access control has already led to a shift in the responsibilities for the provision of logistics resources. Table 2 shows the recent ownerships of the three resource types as well as the updated

Table 2 Shifted responsibilities for the provision of logistics resources

Resource category	Ownership	Funding	Access
Environmental (e.g. air, water)	General public	Public sources and private investors (A)	Controlled (B)
Infrastructure (networks for transport or communication, security and emergency services)	General public of a nation and private investors (C)	Public resources and private investors (D)	Controlled (E)
Private (e.g. supra-structures and/or mobile resources)	Private	Private investors	Controlled

funding responsibility and also information about the applied access control. Recently, established modifications of historically grown responsibilities compared to the assignments given in Table 2 are printed in bold.

(A) Funding is now directed to the recovery and protection of environmental resources. It is tried to recover previous anthropogenic damages and to reset the original state of damaged zones. Funding comes from governmental organizations as well as from private investors (e.g. via revenues from emission certificates).
(B) For the first time, control of the access to environmental resources is applied (e.g. by restricting emissions to quantities covered by acquired certificates).
(C) Private companies are now allowed to become owners of infrastructures resources (e.g. via public-private-partnerships for infrastructure projects).
(D) Private companies participate in the funding of infrastructure resources.
(E) Access to infrastructure is subject of control now. The aim of establishing control is twofold: determination of usage tolls as well as blocking or limiting the access.

Conclusion and Outlook

In this chapter, we have found answers of the initially stated research questions concerning the analysis of the performance of the logistics sector in the future. Regulatory politics, measurements of energy politics as well as the pressure to reduce public funding of infrastructure projects affect the logistics sector. Situations, in which logistics resources become scarce or unavailable, are detected more frequently.

The reduction of the general public funding in infrastructure is accompanied by increasing private investments in infrastructure resources. The capacity of private funded infrastructure resources is adjusted to carefully estimate future demand quantities. Thus, such resources are potentially scarce.

In the longer term context, it is necessary to equip the logistics sector with tools to manage frequently appearing resource scarceness. We have proposed to install business models based on so-called “shared resources” for the logistics sector. Shared resources are cooperatively managed by two or more independent partners. The interchange of information about available capacities as well as demand to be fulfilled contributes to the maximization of the efficiency of the available resources. Imbalances between demanded and available capacity volume are reduced. Although there are some applications in the logistics sector applying successfully a cooperative resource management basic impacts, potentials and mechanism of the common management of resources require basic and fundamental research.

References

Aberle G (2009) Transportwirtschaft, 5th edn. Oldenbourg Verlag, München

Altrichter M, Basurto X (2008) Effects of land privatisation on the use of common- pool resources of varying mobility in the Argentine Chaco. Conserv Soc 6:154–165

European Commission (2010) EU energy and transport in figures 2010. Publications Office of the European Union, Luxemburg

Gerstlberger W, Schneider K (2008) Öffentlich Private Partnerschaften. Zwischenbilanz, empirische Befunde und Ausblick. Edition Sigma, Berlin

Hardin G (1968) The tragedy of the commons. Science 162:1243–1248

Künneke R, Finger M (2009) The governance of infrastructures as common pool resources. Paper presented on the fourth Workshop on the Workshop (WOW4), 2–7 June 2009, in Bloomington

Mantzos L, Capros P, Zeka-Paschu M (2003) European energy and transport trends to 2030. European Commission

Ostrom E (2008) The challenge of common-pool resources. Environment 50(4):8–22

Wernerfeldt B (1984) A resource-based view of the firm. Strateg Manag J 5:171–180

Wie B, Tobin RL (1998) Dynamic congestion pricing models for general traffic networks. Transportation Research Part 32B:313–327

The Regulation of Shared Resources—Impacts on the Logistics Sector

Sören Brandt and Jochen Zimmermann

Abstract Within the logistics sector, access limitation problems have so far only been handled via bottom-up coordination. With the implementation of the European Union's Emission Trading Scheme (EU ETS) a regulatory top-down approach for coordinating the use of shared resources got implemented. We analyze the new regulations using three core characteristics to examine whether the market-based mechanism could be used to coordinate similar economic problems. Insights about the major issues of sharing problems illustrate potential effects on the logistics sector.

Keywords Shared resources · EU ETS · Coordination · Limitation of resources

Sharing Concepts and the Logistics Sector

Today, society perceives greenhouse gas emissions as an increasing hazard for the environment. The implemented sociopolitical regulations have led to restrictions for the output of greenhouse gas emissions, and have created a new regulation of environmental resources. Other remaining environmental resources have also been substantially decreasing over the last years. This situation is a type of sharing problem and can be analysed as tragedy of the commons (Hardin 1968). It describes a situation where the strict limitation of resources is the only solution to prevent their complete loss.

There are two different approaches for solving the access limitation problem. The first uses a privatisation of public resources with the aim of persuading a central coordinator or broker to take care of a sustainable and long lasting use via

S. Brandt (✉) · J. Zimmermann
Faculty of Business Studies and Economics, Department of Accounting and Control,
University of Bremen, Hochschulring 4, 28359 Bremen, Germany
e-mail: sbrandt@uni-bremen.de

J. Zimmermann
e-mail: jzimmermann@uni-bremen.de

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bottom-up coordination. The second approach applies market-based self-regulation. It assigns the use of limited resources with a usage charge to solve the sharing problem (Schönberger 2012). The market-based approach takes the form of a regulatory top-down standardisation.

Surveillance and usage charges expose companies to a new situation of competition not only in terms of sales, but also in terms of the supply of limited resources: it affects margins, cooperation, prices and other risk factors. This new sharing concept poses further challenges, as the logistics sector has relied on bottom-up approaches for the coordination among companies. Hence, companies have to take the new challenges into account not only in terms of an organisational change, but also in terms of rethinking coordination and cooperation.

Market-based sharing concepts need a political decision about access limitation and its implementation. In practice, only one major field in which this regulatory sharing concept has been implemented exists, namely the European Union Emissions Trading Scheme (EU ETS). We use the EU ETS as a tool for understanding the core issues of sharing problems within a situation of fragmented and inconsistent information distribution, and we will use our insights to inquire into its impact on the logistics sector.

The quality of the mechanism will be investigated by using the following three core characteristics:

– availability of information,
– decisions on allocation plans,
– distribution of costs and benefits in an equitable and fair manner.

Market-Based Instruments and the Coordination of Shared Resources

Since the end of the 1970s, market-based instruments have been discussed and are increasingly used as an alternative to more rigid regulations when pursuing environmental objectives (Stavins and Whitehead 1997). The objectives of market-based models include the coordination of the different interests of market participants and the implementation of environmental constraints set at a regulatory level. Market-based systems comprise trading systems, and provide incentives for market participants exceeding a simple compliance with emission limits. This promotes a cost-effective implementation of regulatory requirements (Kruger et al. 2007) and the coordination of shared resources within affected companies on an equal footing.

The discussion on instruments is still ongoing (Fischer and Springborn 2011). Stavins (1998) decomposed the question to what extent regulatory approaches can go towards solving the coordination of environmental resources. He discusses the role of individual governments, the resulting activities and the distribution of political responsibility. Even 15 years later, the question of the appropriate measures and the correct setting of emission caps vex the politically initiated resource allocation. The EU ETS is the only existing solution for the coordination and sharing problem, and will be discussed in the following section.

Distribution of Costs and Benefits—Implications for the Coordination of Shared Resources

In 1997, 84 nations signed the Kyoto Agreement to reduce greenhouse gas emissions, causing permanent damage to the environment. With this, the participating nations obliged to stick to defined levels of greenhouse gas emissions (Pizer 2005). To fulfil the main objectives of the Kyoto Agreement the EU introduced the EU ETS in 2003.[1] It became effective in 2005 and is aiming at the lasting reduction of CO_2 emissions throughout the EU (Böhringer et al. 2009). The EU ETS represents the worldwide largest market-based solution, addressing the reduction of environmental issues (Kruger et al. 2007).

Basis for the EU ETS is the U.S. Acid Rain Programme, which represents the worldwide first trading system for emissions of significant extent and got implemented in 1990. It is considered as an effective instrument for achieving sustainable solutions for environmental objectives, aiming at the reduction of CO_2 emissions (Ellermann and Buchner 2007). Due to regulatory bottlenecks, appearing in the form of trading systems for emission allowances, the state has established a new mechanism for coordinating the use and the consumption of shared resources. Up to now the combustion of fossil fuels for the energy production is generally not covered by statutory prohibitions. With the introduction of the EU ETS, the regulator intends to connect the use of fossil fuels with economic disadvantages. The objective is the sustainable reduction of fossil fuel use and thus the adherence of the pollution limits defined in the Kyoto Agreement (Veith et al. 2009) as well as fulfilling the societal claims for a limitation of greenhouse gas emissions. In terms of the systematic design it makes use of the findings of the research by Crocker, Dales and Montgomery from 1966, 1968, 1970 and 1972 (Veith 2010). Covering more than 11,000 power generating stations and industrial power plants, the EU ETS is the EUs basis for generating a cost-effective reduction of greenhouse gas within 31 participating countries.

Within this trading system, affected companies are required to hold an emission allowance for each tonne of CO_2 they emit. Meanwhile the EU ETS is in the third trading period (2013–2020), following a test phase (2005–2007) and an implementation phase (2008–2012). Within each phase a certain amount of emission allowances is provided for the affected companies, getting continuously reduced

[1]For an overview of the EU ETS regulations see http://ec.europa.eu/clima/policies/ets/index_en.htm.

(Dekker et al. 2012). The allocation is depending on the emission level each production unit generated in a determined base year. During the first two phases the allocation of emission allowances was nearly free of cost and very generous. In the second phase an adjustment of the emission limits analogous to the limits manifested in the Kyoto Agreement took place. However, this did not result in lasting effects on the part of companies affected by the emissions trading system. When the EU ETS was launched in 2005, the price for one emission allowance was in the range of 5.00 Euro, whereas it quickly came to an increase in the range of 20.00–30.00 Euros per emission allowance. After the publication of the emission output for the year 2005 it became obvious that the market was in an excessively allocated situation (Ellermann and Buchner 2007). As a consequence, the price for emission allowances fell sharply before setting at a level of 15.00 Euro for a few months. Already in the middle of 2007, the price for one emission allowance reached a level that was close to nothing (Hintermann 2010). This resulted from the almost free allocation in the years 2005–2012.

In contrast to the emissions trading scheme used in the U.S., the EU ETS offers the option of a decentralised influence and refinement of the framework. This decentralised definition of important factors such as the distributed amount of emission allowances and the basic design of distribution, offered individual member states the option to directly influence the mechanism on a national level (Ellermann and Buchner 2007; Kruger et al. 2007). Due to this regulatory leeway, single states were in the position to use a politically motivated interference while implementing environmental policy objectives. Out of an economic perspective the hybrid design in form of the national allocation modelling can lead to a situation of increased costs which is in conflict with the fundamental goals of the sharing mechanism, aiming at a cost-effective coordination of limited available resources. A solution was launched as a part of the redesign in the third trading period. Since 2013 the single allocation models have to follow a unified distribution system designed by the EU (Böhringer and Lange 2012). Additionally, one EU-wide emission cap, instead of 27 national caps, was established as part of the redesign.

Evaluating the base years used for the determination of future emission caps can be seen from two different perspectives. Right now, the shaping of the EU ETS is supporting production units which emitted enormous amounts of CO_2 in 1990. This is possible due to the fact that the base year used within the EU ETS is 1990. In contrast to this, the shaping of the market-based mechanism allows innovative companies which are constantly reducing emissions to generate additional earnings through the disposal of emission allowances not being necessary for the fulfilment of the stipulated regulatory specifications (Kruger et al. 2007). Achieving this is only possible when market prices within the market-based sharing concept are on an attractive level providing additional earnings for market participants. This contributes to an equitable and fair distribution of costs and benefits, which is defined as a quality characteristic of a sharing concept at the beginning of this chapter.

To achieve attractive prices for emission allowances, the EU has determined additional changes for the third phase which started in 2013. Due to the initial allocation, which was free of charge, and thus the resulting excessively allocated situation in the first periods, the EU decided to increase the share of auctioned emission allowances. In particular sectors the share of auctioned emission allowances will increase to 70 % in 2020, starting at 20 % in 2013. In addition to the increased share of auctioned allowances, a decrease of the overall cap of 1.74 % per year will take place, resulting in a total decrease of 21 % in 2020 compared to the situation of 2005 (Böhringer and Lange 2012). With this, the EU implemented regulations in response to the lessons learned in the past periods making the EU ETS to an effective instrument for the coordination of shared resources. Still one of the primarily questions is which sectors should be included in the future and how many allowances should be allocated at no charge (Dekker et al. 2012).

Implications for the Logistics Sector

The consumption of environmental resources can be analysed as utilisation of shared resources. Due to regulatory bottlenecks, appearing in the form of trading systems for emission allowances, a new mechanism to coordinate the consumption of shared resources was established. This mechanism gets enforced by the EU and can be analysed as a top-down regulatory approach. All affected market participants share the same database resulting in an objective configuration through the good availability of data. Consequently the established market-based mechanism fulfils the first quality characteristic of an efficient sharing concept stipulated at the beginning of this chapter. Furthermore, this compulsory market compliance hides the classic problems of coordinating shared resources along a typically fragmented value chain, resulting in an almost ideal-typical shaping and the reduction of uncertainty. Due to this, a consistent basis for all affected market participants can be provided resulting in the fulfilment of the second quality characteristic. Within the EU ETS the resource bottleneck is coordinated by using a market-based mechanism. The price for emission allowances operates as a mechanism for exclusion within the emissions trading scheme. Evaluating the effectiveness of this ideal-typical coordination mechanism is possible by analysing the outcomes and the behaviour among affected companies. Outcomes are recorded as the quality characteristics of the market for emission allowances.

Due to the introduction of the new coordination mechanism, reactions on different company levels can be expected. A distinction can be made between the internal reactions in relation to the organisation and management of shared resources and the reactions of each individual affected company, acting under competition, towards the competitors within the logistics sector. Hence the question arises to which extent affected companies in cooperative structured sharing networks are willing to exchange emission allowances with potential competitors. The design of interactions between companies and the existence of incentives encouraging cooperative behaviour apart from the compulsory market compliance set by the regulator are also decisive quality standards of the market-based mechanism.

Affected companies can strategically vary the intensity of cooperation with competitors in the logistics sector. The potential range of feasible and legally possible reactions includes the autarkical trading of a company as well as the complete linkage and integration of different companies belonging to a particular branch or region. Investigating this constructs can draw inferences about the requirements for disclosure and enforcement within the market for shared resources and shows which incentives contribute to the participating in cooperatively shaped sharing networks. Followed by the question which role the parent market-mechanism takes, it is possible to examine whether the market-mechanism could be transferred to other economic issues.

Logistic services are a cornerstone of a functioning value chain. Attributable to the high energy consumption within the logistics sector, companies are especially affected by the new regulatory standards of the EU. Today the German Renewable Energies Act (EEG) and the EU ETS are connected. The EEG was resolved in 2000 to pursue the objectives of sustainability and climate protection.[2] §1 (1) of the EEG defines the objective of establishing a sustainable energy supply in Germany. In addition to the reduction in the use of fossil fuels, the EEG also addresses the consideration of economic costs and the reduction of long-term external effects. Particularly the development of new technologies in terms of generating energy from renewable energy sources is one of the key features pursued by the EEG. The objective of §1 (2) is to continuously increase the share of renewable energy in total electricity consumption. By 2020 it is set to increase the proportion of renewable energies to 35 %. In 2050 the proportion is targeted to be 80 %. In addition the establishment of §1 (3) of the EEG regulates the increase of renewable energies to have a share of at least 18 % of the complete energy consumption in 2020. With the implementation of the EEG an increase in the use of renewable energies can be observed within the EU, leading to a decrease in the use of fossil fuels and a decreasing demand for emission allowances. Due to this, the price for emission allowances will further decline, resulting in an ineffective allocation of limited resources when the regulator is not adapting the cap for emission allowances. This gets also visible by taking a look at plans of the German finance ministry. It planned to raise 780 million Euro, mostly from the trading within the EU ETS, for a climate and energy fund addressing the climate-neutral development of buildings in Germany but only earned 300 million Euro in 2012 (Dehmer 2013). This happened due to the fact that the prices for CO_2 emission allowances in 2012 were only trading below a price of 10.00 Euro,[3] showing potential to improve the regulatory framework used for the coordination of limited resources.

Analysing the three major objectives stipulated at the beginning of this chapter, we examine the quality characteristics of a sharing concept. This has led to additional insights regarding market-based sharing concepts. Hence we are mapping a

[2]For an overview of the EEG see http://www.erneuerbare-energien.de/die-themen/gesetze-verordnungen.

[3]For market information see http://www.eex.com/de/Marktdaten/Handelsdaten/Emissionsrechte.

research agenda for an ongoing analysis of shared resources in the logistics sector. The main research topics can be illustrated as follows:

- The question whether a bottom-up or top-down approach should be used has to be answered on a regulatory level.
- Instruments have to be developed which take the volatility of the logistics sector into account.
- Incentives are not supposed to lead to distortion for single companies or sectors.
- The trade-off between persuading environmental objectives and company goals has to be reasonable.

Resulting from this, an improvement of the economical, ecological and social design of sharing systems can be expected. Examples include the efficient coordination of shared resources, the limitation of greenhouse gas emissions, the acceleration of an efficient capital allocation and the long-term securing of employment in the logistics sector and its affiliated sub-areas.

Conclusion

Taken as a whole, the investigated mechanism can be seen as a positive regulatory experience and a success in solving the access limitation problem of shared resources. Up to now only 50 % of the CO_2 output within the EU is covered by the present regulatory approaches, showing further potential for an expansion.

The implemented sharing mechanism contributes to the three core characteristics stipulated at the beginning of this chapter. It provides the availability of information by hiding the classic problems along a typically fragmented value chain. The mechanism creates a consistent basis for all affected market participants, and enhances decisions on allocation plans by reducing uncertainty. By using a trading system for coordinating the consumption of shared resources the mechanism contributes to the distribution of costs and benefits in an equitable and fair manner.

Due to its good transferability, the approach of market-based self-regulation can also be used to coordinate other economic issues, resulting in a growing publicity and the adaption across sectors. This could include limitations in the use of heavy fuel oil, diesel and kerosene in the shipping and aviation sector. A worldwide inclusion across countries and sectors will further improve the outcomes of regulatory implemented coordination systems and reduce disadvantages for single sectors or regions.

References

Böhringer C, Lange A (2012) Der europäische Emissionszertifikatehandel: Bestandsaufnahme und Perspektiven. Wirtschaftsdienst 92(13):12–16
Böhringer C, Rutherford TF, Tol RSJ (2009) The EU 20/20/2020 targets: an overview of the EMF22 assessment. Energy Econ 31(Supplement 2):268–273
Dehmer D (2013) The German Energiewende: the first year. Electr J 26(1):71–78
Dekker R, Bloemhof J, Mallidis I (2012) Operations research for green logistics—an overview of aspects, issues, contributions and challenges. Eur J Oper Res 219(3):671–679
Ellermann DA, Buchner BK (2007) The European union emissions trading scheme: origins, allocation, and early results. Rev Environ Econ Policy 1(1):66–87
Fischer C, Springborn M (2011) Emissions targets and the real business cycle: intensity targets versus caps or taxes. J Environ Econ Manage 62(3):352–366
Hardin G (1968) The tragedy of the commons. Science 162(3859):1243–1248
Hintermann B (2010) Allowance price drivers in the first phase of the EU ETS. J Environ Econ Manag 59(1):43–56
Kruger J, Oates WE, Pizer WA (2007) Decentralization in the EU Emissions Trading Scheme and lessons for global policy. Rev Environ Econ Policy 1(1):112–133
Pizer WA (2005) The case for intensity targets. Clim Policy 5(4):455–462
Schönberger J (2012) Verknappung und Limitation öffentlicher Güter: Herausforderungen, Perspektiven und Forschungsbedarf für eine engpass-orientierte Logistik. In: Ivanov D, Sokolov B, Käschel J (eds) Flexibility and adaptability of global Supply Chains, Tagungsband des 7. Deutsch-Russischen Logistik-Workshops St. Petersburg 2012, pp 426–433
Stavins RN (1998) Significant issues for environmental policy and air regulation for the next decade. Environ Sci Policy 1(3):143–147
Stavins RN, Whitehead B (1997) Market-based environmental policies. In: Chertow MR, Esty DC (eds) Thinking ecologically: the next generation of environmental policy. Yale University Press, New Haven, pp 105–117
Veith S (2010) The EU Emissions Trading Scheme: aspects of statehood, regulation and accounting. Peter Lang, Frankfurt
Veith S, Werner JR, Zimmermann J (2009) Capital market response to emission right returns: evidence from the European power sector. Energy Econ 31(4):605–613

Shared Transport Systems—A New Chance for Intermodal Freight Transport?

Aline Monika Gefeller and Jörn Schönberger

Abstract The term intermodal transport subsumes transport processes in which the carried goods are packed/stored in loading units like containers or swap bodies or trucks or trailers and these loading units are moved by truck in the local area distribution and collection as well as by train (or barge) during the main-haul process phase. In this paper, we are going to investigate the hypothesis that the reformation of the management and administration of intermodal transport chains can contribute to the promotion of this environmental-friendly and highway-disburdening kind of long distance freight transport. We propose to change the administration, and to manage a combined transport chain as a so-called shared system. The primary goal of the here reported research is to analyze the general applicability of the sharing principle in intermodal freight transport.

Keywords Multimodal transport · Intermodal transport · Shared transport system · Resources · Combined transport

Introduction and Motivation

At least two means of transport (road, rail, see or air) are combined in one transport chain in *multimodal transport* (Heiserich et al. 2011) for fulfilling a single origin to destination transport process. The term *intermodal transport* addresses transport processes in which the carried goods are encapsulated in loading units like containers or swap bodies or trucks or trailers (Kummer 2006). These loading units are transshipped between different types of means of transport during the execution of the multimodal transport process, but the goods contained in the loading units remain within their original loading unit throughout the complete transport chain.

A.M. Gefeller (✉) · J. Schönberger
University of Bremen, Bremen, Germany
e-mail: gefeller@uni-bremen.de

J. Schönberger
e-mail: jsb@uni-bremen.de

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In multimodal transport processes, handling activities (loading, transshipment) and transport activities are alternating. The primary motivation for setting up multimodal (intermodal) transport chains is obvious: combining the strengths of each involved transport means in order to overcome the weakness of single-mode transport chains.

The combination of truck-based road haulage and cargo train service in a transport chain is the most prominent realization of an intermodal transport chain (UIC 2012) in Europe. Here, the truck's ability to reach almost every place in a region is combined with the train's ability to travel at relative high speed and in an independent track. Furthermore, more than 6.7 millions of tons of CO_2 can be saved annually if trains are used for bridging long distances (UIC 2012). In an intermodal transport chain, the collection of the load in the origin region is assigned to a truck service. Transshipment from the truck to the train of a container, of a trailer, or of the complete truck is executed at a dedicated intermodal terminal in an early phase of the transport chain in the origin region. Transshipment from rail to road is performed in the destination region, so that the last phase of the transport chain is again executed by truck on the road. Such a setting is called combined transport ("Kombinierter Verkehr") or CT.

Several governmental programs have been setup to promote CT and to define incentive schemes with the goal to achieve a gain in the modal split for train transport (Kombiverkehr 2013): (i) tax reductions for trucks involved in CT chains apply, (ii) an increased maximal allowed total vehicle weight, and (iii) relaxation from driving prohibitions on weekends and during holiday for trucks involved in the execution of a CT process.

Several technical innovations for easing and accelerating the transshipment of loading units from trucks to trains and vice versa have been proposed and tested in prototypes like CargoBeamer (CargoBeamer 2013), Modalohr (Modalohr 2013), MegaSwing (Randelhoff 2012), Flexiwaggon (Randelhoff 2011).

Despite tremendous efforts to promote CT in Europe and despite an average annual growth of approximately 7 % (UIC 2012) its contribution to the total transport performance is quite low. CT accounts for approximately 44.711 million tkm (Burkhardt 2012) of 3.824.000 million tkm (Eurostat 2013) in 2011 which is a share of approximately 1.1 %. The setup and operation of CT chains seem to be unattractive under the current legal and economic conditions, and the incentives schemes installed for promoting CT seem to be inappropriate.

In this article, we are going to analyze the hypothesis that the reformation of the management and administration of CT chains has the potential to lift the contribution of this environmental-friendly and highway-disburdening kind of long distance mode of transport. For this reason, we propose to change the administration and to manage a CT chain as a so-called *shared system*. This approach of organization is currently applied successful to passenger transportation as bike-sharing (Ricker et al. 2012) as well as car-sharing (Ciari and Balmer 2008) and it is based on the principle of *using instead of owning* (Deffner and Götz 2013) that is in line with the idea of a *shareconomy* (Weitzman 1984) in which risks and benefits are shared among all market participants. In order to validate the aforementioned hypothesis, we first develop a catalog of criteria that covers customer requirements concerning CT operations. Next, we propose four generic transport system setups ranging from private to shared systems. We use the catalog of criteria to evaluate all four setups. We will demonstrate that shared systems outperform the other transport system organizations concerning customer satisfaction.

The primary goals of the here reported research are (i) to check if shared transport systems match (in theory) the requirements of CT and (ii) to identify structural similarities and commonalities between already existing shared systems and to identify discrepancies between the requirements of long distance freight transport (especially using CT) and abilities of today's shared systems.

The second section of this article summarizes the major weakness of today's CT systems. The third section compares structural properties of shared transport systems with the structural properties of traditionally operated and administrated transport systems. The fourth section discusses the opportunities and challenges for the installation of a shared system in combined freight transport.

Transport Systems Combing Road and Rail

Although, CT covers also integrations of maritime long haul transport with road-based collection and distribution services, we here focus on the combination of long haul train-transport services with truck-based short distance road services in the collection and distribution phase of a freight transport chain. Here, two modes of CT are distinguished: a complete truck (tractor and trailer in one piece) is loaded on a special wagon in the piggyback mode (accompanied CT), but in the so-called container mode only a non-motorized semi-trailer or swap-body is loaded on the train at a transshipment terminal (unaccompanied). While piggyback services are installed especially in short-distance services on dedicated relations (UIC 2012), the second mentioned container mode is used primarily in the long distance freight transport. The here reported research focus on CT in the unaccompanied mode which realizes more than 95 % of the CT services (UIC 2012) in Europe.

Road Haulage Versus CT: Comparing Demand

It is impossible to execute a fair comparison of costs for a pure road transport with a CT service. Since there are differences in the departing times of a train, it would be necessary to determine costs for a later arrival of the shipment if a part of the distance is bridged by a train and so on. Furthermore, different durations of the total transport have to be compared as well as reliability related issues (congestions on the road vs. disturbances on the rail tracks or during transshipment). Although it is hardly possible to determine mode-specific costs (for pure road transport as well as in CT) for a specific transport demand, there are empirical data to be evaluated for a rough comparison of the two transport modes. The following data from several sources are summarized in Gefeller (2012).

At first, the costs per km on the road are declared to be 1.14 EUR in road haulage compared to 1.15 EUR for a km in CT. If the total transport distance is larger than 300 km (domestic traffic) or 500 km (cross border traffic), then the CT becomes cheaper than the transport exclusively executed by truck. 60.4 % of the CT performance is realized in domestic services in European countries (UIC 2012), i.e., bridging distances around 500–800 km.

With respect to the transport duration, it is calculated on a theoretical base that a least transport distance of approximately 350 km is necessary to enable CT to outperform the road transport. This is mainly caused by the legal limitation of the driver's working hours declaring that a break must be made after 4.5 hours of driving. This working break consumed the time advantage of the truck caused by the duration of transshipment in CT.

The chance of delay in CT chains is twice as high as the delay probability of road-based transport.

In order to inform the shipper on the progress of the transport process execution, tracking and tracing systems have been developed. While 70 % of road-based transport is covered by these systems, only 15 % of all CT services can be surveyed by the shippers.

According to the aforementioned statements, CT services seem to offer benefits in costs and speed if the overall distance to be bridged is sufficiently long. However, the punctuality as well as the transparency of CT services compromise the quality of this mode of transport.

Barriers of International Rail Transport

Benefits from CT services can be gained, if the transport distance to be bridged is sufficiently long as discussed just above. However, transport services of these long distances are of the international transports and the national borders are crossed during the main-haul process phase executed on rail. Cross-border rail transport is typically slower compared to the domestic rail transport. Beside technical reasons (different widths of tracks or different power systems requiring technical reconfigurations of a train) especially organization issues slow down the average speed (Gefeller 2012). Often, it is necessary to change the conductor close to the border in order to satisfy specific national laws and operation rules. Furthermore, the national train control systems do not interoperate so that a train waiting to enter the rail system of another nation must be inserted manually into the control systems. Uncoordinated interfaces between national track systems are mainly responsible for these delays.

Managerial Deficiencies

In the early beginning of CT operations in Europe, there was the so-called CT operator business model (UIC 2012). The CT-operator was responsible for providing, organizing, and selling CT transport capacities. It does not operate own rolling stock or trucks.

Today, CT operators often integrate own assets in the CT services (logistics service provider in operator role) as claimed in UIC (2012). There is often no clear separation between the provision of rail service capacities that can be involved in CT services, and the usage/access to these resources. If the provision of rail service resources as well as the decision about the allocation of these resources is made by a forwarder then there is the danger of biased access granting decisions. An independent road haulage company that is searching for rail service resources to realize a CT service process might be excluded from these services by the aforementioned company, because it hopes to get a competitive advantage by excluding its competitor(s). Furthermore, the quasi-private provision of rail services contributes to keeping the total resource availability for rail services intransparent. Again, an external road haulage company is obstructed to get information about available resources of the rail services which makes it less obvious that available rail service capacities will be sold.

Often, rail service companies are organizing CT services, but their services are mainly oriented on the needs and requirements of their core business (operating rolling stock) but the specific needs of CT are ignored, e.g., temporal coordination at terminals, etc., is missing. The frequency of train services is quite low; often there is only one train departure per day scheduled for a destination. A short disruption in the collection and forward feeding phase on the road might lead to a delay of more than one day if the train connection is missed (Gefeller 2012). The chance for a delay in CT is quite higher than in pure road transport. It is necessary to offer a bigger portfolio of train services.

In summary, the primary management tasks in CT are to govern the interface between rail and road transport and to provide sufficient rail service capacity. It seems to be a good idea to separate the provision of rail service capacity from the operative allocation decisions because (i) the trust in such a rail service resource management will increase and (ii) the specialization in buying and selling rail services contribute to overcome some of the aforementioned problems related to the provision of a suitable high capacity of rail services that can be used in a more flexible manner. Such a form of organizing CT services is closely related to the original CT business model, which was the CT operator mentioned at the beginning of this subsection.

Desired Properties of a CT System

It is a vital prerequisite that the development and extension of CT services must be supported by the government as part of transportation policies. A clear statement about the desire to promote this mode of freight transport is necessary, but also effective incentive schemes (coded in specific laws and decrees) must be preserved or extended. However, the most important aspect in the promotion and innovation of CT services is the establishment of a clearly structured and elaborated business model for the management of CT services. Considering general requirements specified for an effective and efficient transport system together with the specific requirements from CT discussed just above, the needs and desires of potential users of combined short distance road/long distance rail transport services can be described more specifically. (i) it is necessary to offer the transport services to a **large number of customers** (ii) for a single customer an **easy and uncomplicated access** to the offered CT services is desired (iii) if there are CT services then these services **are offered to all customers** who need CT services (iv) customers are expecting the fulfillment of their demand, e.g., the **expected availability of service** is high (v) customers require **comprehensive and transparent information about the available services** in order to find out the service, best tailored to the requirements of a specific demand (vi) l**ow transaction costs** for booking and using a CT service are expected (vii) a **transparent tariff** for the determination of the service fees is needed (viii) a **strict and clear separation between the responsibilities for the provision of rail services, and the decision about the dispatching** of those services is necessary as discussed above.

Classification of Generic Transport System Setups

There are a lot of different engineering innovations offering cheap and quick transshipments (cf. introductory section). For this reason, we assume that the major obstacles for establishing a well-performing and accepted CT system are caused by an unsuitable management and setup of a CT system. This issue is investigated within the remainder of this section. We first present four general concepts (“phenotypes”) for setting up and controlling a transport system. Afterwards, we analyze these four generic management schemes with respect to the desired system properties outlined at the end of the previous section.

Phenotypes of Transport Systems

Each transport system management has to integrate and coordinate at least three involved groups. The **owners** (shareholders) of the system are primarily responsible

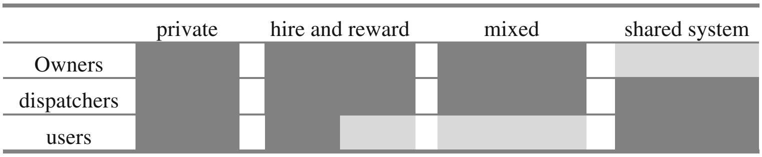

Fig. 1 Coalitions and relationship in the four generic transport system concepts

for providing and funding resources and making strategic design and capacity decisions. The **users** of the transport system specify the explicit demand and pay for the system usage. The **dispatchers** of the system are primarily responsible for the handling of transport demand and the deployment of resources. They control access to the resources of the transport system.

Depending of the intensity of interaction and cooperation among these groups, we can identify four generic setups of the administration and control of a transport system. Figure 1 compares these four setups in light of the relations among the three groups. For each setup, dark grayed groups are in close relationship providing coalitions and interactions in the provision and usage of resources.

If there are quite strong organizational and/or legal relationships among all three groups, then the transport system is called **private**. A private transport system is inaccessible for external users, but it serves only internal users. An example are so-called "own-account" transport systems setup and operated to realize transportation between different locations of a company typically with own or exclusively hired transport equipment.

In a **hire-and-reward (or carrier)** transport system, the owners and the dispatchers strongly collaborate, but the users are independent from both. This is all users are external users. They have to pay for the utilization of resources of the transport system. It is referred to road haulage companies as a representative example for a pure carrier network.

A transport system is called a **mixed-mode transport system** in case that owners and dispatchers are closely coupled, but if both internal as well as external users are served. Often, private transport systems offer residual capacity on the spot-market besides fulfilling longer term contracts.

Private transport systems are inaccessible to those who need transport services, but who are not in possession of the privilege to be an internal user. The two remaining concepts (hire and reward as well as mixed) are based on the idea to own specialized resources and to make profit by granting paid access to those, who need these resources. In order to maximize the total profit from the utilization of scarce transport resources, access to these resources is strictly controlled. Access is granted only to the most beneficiary demand according to the realized profit. Consequently, transport resource capacities are kept as scarce as possible leading to "artificial bottlenecks."

In order to avoid artificial bottlenecks and with the goal to offer transport opportunities to all users, so-called **shared mobility systems** are setup. Such a transport system is setup following the idea of "using instead of owning" (Deffner and Götz 2013). Here, the primary goal of setting up a transport system is to fulfill almost all demand for transport for a variety of customers like in bike- or car-sharing systems.

Analysis and Comparison of Organization and Access

Table 1 summarizes the major findings of the comparison of the four generic organization approaches for transport systems as a result of the analysis of representatives for the four generic transport system setups. Those attribute values that are important for the acceptance and usability of an intermodal transport system combining road and rail services are underlined. With respect to the number of fulfilled attributes, the concept of a shared transport system outperforms all other generic forms of organizing and administrating a transport system. However, managing a shared transport system requires a preregistration of later users in order to enable the provision of sufficient transport capacity that is large enough to serve the upcoming transport demand without the necessity to reject customer demand due to exhausted capacity.

Table 1 Evaluation results of the comparison of the four generic transport system concepts

	Private	Hire and reward	Mixed	Shared system
Access rights	Internal	External	Internal and external	Internal
Access control	Only to internal users	Profitability of demand	Profitability of demand	Only validated users
Management goal	Serving all demand	Serving only profitable demand	Generate margin contribution from external demand	Serving all demand
Expected resource availability	High	High	Moderate	High
Availability of information about free resources	After explicit demand specification	After explicit demand specification	After explicit demand formulation	Survey on all available resources
Transaction costs	Low	High	High/low	Low
Cost calculation	–	Transparent	Intransparent	Transparent
Separated responsibilities	No	Yes	No	Yes

Shared Mobility Systems for Freight—Challenges and Benefits

Shared transport systems are established in order to offer transport capacities and opportunities to serve individual transport demand whenever needed, but to free a user from the obligations related to the ownership of a transport resource. The primary goal of the management of a shared transport system is to serve all incoming demand independently of the achievable revenues. It is a distinguishing mark of a shared transport system to offer a clear and transparent fee calculation scheme and to inform all users about all available resources.

Existing Shared Transport Systems

Shared passenger transport systems are realized for bikes and cars in a lot of big cities around the world. Here, the shared transport system is established in order to supplement schedule-based public transport systems. Bike-sharing systems are established in urban regions where it is impossible or undesirable to use private cars or taxis due to congested streets or well-extended pedestrian areas or elaborated public transport systems. A system of rental and return stations is spread over the covered region. A customer must be registered before he/she can rent a bike. Especially, he/she has to agree to the rules of usage and the utilization tariff. Each registered user, who has a demand can go to a renting station, identifies himself/herself there and then the user gets a bike. After the user has finished the bike ride, the bike is returned at the renting or any other station where the returned bike is locked again. This bike can now be used by another user. Since pickups and returns of bikes can be done only at the designated stations such a modus operandi is called **station-based shared transport system**. There are also **station-less bike-sharing systems,** where rented bikes can be left locked, e.g., at any corner of two roads so that also one-way trips can be realized with a rented bike. Available bikes are located using modern information technologies. Rents are started and terminated also by data interchange with a service center via modern communication devices like smartphones.

Car-sharing systems offer vehicles to those people who do not own a private car, but who need a car from time to time. Car-sharing is more flexible than scheduled public transport services. Compared to traditional car rental car-sharing offers a more flexible and cheaper way to get access to a car. However, the number of available types of cars is low in car-sharing systems. After the car ride has been completed the rented car must be driven back to the car-sharing station where the next user will pick up the car. In general, the car has to be given back at the station where the current ride has been started. In few systems it is possible to return the car at another station (station-based shared transport system). Recently, first attempt are made to established station-less car-sharing systems.

In all setups bike or car-sharing systems cover only a certain region like a city or a greater area around a city. For long distance rides (especially one-way rides) it is necessary to rent a car from a car rental company.

Although the idea of “sharing” transport resources with others is known in freight transport systems, no shared transport system is reported. In freight transport, the term sharing mainly refers to situations in which independent companies help each other in the fulfillment of requests. In a groupage system (Kopfer and Pankratz 1999) available capacities are announced to all groupage system members but the final decision about the resource allocation is left to the resource owner. In other situations several shippers and/or carriers form a joint venture in order to benefit from balanced high capacity utilization. However, such a system does not fulfill the properties of a shared transport system as discussed before since only few customers are granted unlimited access to the transport resources.

In the remainder of this paper, we compare structural commonalities and discrepancies of combined freight transport systems with the exhibited properties of successfully established shared passenger transport systems.

Structural Commonalities with Already Existing Shared Systems

In passenger transportation, shared systems have been established as an alternative mode of transport in local areas. They offer an extended flexibility compared to public transport services (representing a hire-and-reward transport system configuration), but it becomes unnecessary to own a car (representing the “private transport system”) if such is car is not needed frequently.

Both bike-sharing as well as some car-sharing systems offer the one-way utilization of the resources. Such an opportunity is also required and needed in freight transportation with combined rail and road services in one-way-rail-services. However, as in bike- and car-sharing systems, repositioning activities of unused resources (Ricker et al. 2012) must be established in order to provide the empty capacities in rail services (the rolling stock) at those places where loading units want to board a train service.

The available vehicles and/or bikes can be found by a user by consulting an information system using sophisticated communication systems. That is, the transparency of available resources is quite high. This transparency is also needed in combined freight transport systems as discussed above.

There are only few or there is even one type of resource available in a car- or bike-sharing system. In consequence, one or only few resource types must be differentiated in the transport system. This fact contributes to a sufficient management of the resource availabilities at the different system access points (ride start points). In general, only one type or at most few types of railway wagon is/are needed in combined freight transport system for carrying trailers, swap-bodies or containers.

Finally, the organization of a bike- or car-sharing system is based on an elaborated management of the resource capacity. The installation of rental and return stations as well as the provision and maintenance of the cars and bikes but also the necessary repositioning of bikes and cars is in the responsibility of a company who has no own need to use these resources. Furthermore, all users contribute to the covering of (at least a part of) the costs for running and maintaining the shared transport system. Therefore, it can be assumed that all users are treated equal and in a fair manner. Such a form of organization is required in combined freight transport in order to overcome the critical resource provision and availability deficiencies and shortcomings.

Distinct Structures and Challenges

Although, we have identified several structural commonalities of the needs of shared CT systems with existing shared passenger transport systems, we are also aware of at least two significant structural distinctions.

First, the spatial extend of the network is significantly increased in intermodal freight transportation compared to passenger transportation systems in which bike-sharing and/or car-sharing systems are successfully operated. That is, longer distances have to be bridged and the repositioning of rolling stock requires a more sophisticated organization since the repositioning times are longer, more uncertain, and more expensive.

Second, railway operations are quite more complicated than transport operations in the road network. The right to use a track has to be announced toward the infrastructure provider before the operation is scheduled. The own rolling stock operations must be synchronized with the pre-booked infrastructure access and finally, international rail operations require the solving of several complicated organizational challenges as mentioned above.

Conclusion

Our initially stated research hypothesis has been validated. The organization of a CT as a shared transport system has the potential to improve the fulfillment quality and reliability of customer service requirements. The concept of a shared transport system seems to outperform other more traditional forms for organizing a CT network. We have revealed some important structural discrepancies between shared passenger transport systems, and the needs of shared freight transport systems especially in CT integrating rail and road operations. Nevertheless, a lot of structural commonalities between these two application fields have been discovered.

In a next research step, it is necessary to propose a business model for a shared freight transport system for CT. One idea involves the reanimation of the CT operator business model that has been used when CT was established. However, the funding of such an operator company must come from the whole set of prospective users in form of a type of membership. Only members are allowed to use the commonly provided rolling stock resources, but each member can organize upstream and downstream operation on the road with own resources for own account.

It is necessary to install a comprehensive resource availability information system. Furthermore, a transparent fee system has to be setup that covers the costs for running the shared railway operation system. If these costs are "too high" than there is no market for CT, and it is impossible to offer the required services at acceptable prices. In this situation, governmental extra funding or incentives are needed. However, the recipients of the extra funding are known: those companies, how are responsible for setting up and running the rolling stock and operating the transshipment terminals. In this situation, the target-oriented utilization of the additional funding is obvious since the company's only goal is to operate the needed rail services and terminals. Misuse of the extra funding is more or less impossible and the effectiveness of the funding can be controlled easily.

References

Burkhardt M (2012) Road-rail combined transport: new developments and best practices. http://www.unece.org/fileadmin/DAM/trans/doc/2012/wp24/ECE-TRANS-WP24-2012-Pres02e.pdf. Accessed 28 Oct 2013

CargoBeamer (2013) http://www.cargobeamer.com, Accessed 1 Nov 2013

Ciari F, Balmer M (2008) Concepts for a large scale car-sharing system: modeling and evaluation with an agent-based approach. Eidgenössische Technische Hochschule, Institut für Verkehrsplanung und Transportsysteme

Deffner J, Götz K (2013) Using instead of owning: the 'sharing' megatrend helps electromobility advance. http://www.isoe.de/en/media-activities/news-single/using-instead-of-owning-the-sharing-megatrend-helps-electromobility-advance. Accessed 30 Oct 2013

Eurostat (2013) EU transport in figures 2013. http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf. Access 28 Oct 2013

Gefeller MA (2012) Der europäische Schienengüterverkehr—Aus welchen technischen, wirtschaftlichen und politischen Gründen bleibt der Kombinierte Verkehr Schiene-Straße unter den Erwartungen? Diploma thesis, University of Bremen

Heiserich O-E, Helbig K, Ullmann W (2011) Logistik—Eine praxisorientierte Einführung, 4th edn. Gabler, Wiesbaden

Kombiverkehr (2013) http://www.kombiverkehr.de/web/Deutsch/Startseite/Wissen/
Kombinierter_Verkehr/Vorteile/. Accessed 1 Nov 2013

Kopfer H, Pankratz G (1999) Das Groupage-Problem kooperierender Verkehrsträger. In: Kall P, Lüthi H-J (eds) Proceeding of OR 98, Springer, pp 453–462

Kummer S (2006) Einführung in die Verkehrswirtschaft. UTB Verlag

Modalohr (2013) http://www.modalohr.com/, Accessed 1 Nov 2013

Randelhoff M (2011) Flexiwaggon—flexibel ohne Terminals. Zukunft Mobilität. http://www.zukunft-mobilitaet.net/1274/konzepte/flexiwaggon-flexibel-ohne-terminals/1274. Accessed 31 Oct 2013

Randelhoff M (2012) Megaswing—das eigene intermodale Terminal. Zukunft Mobilität. http://www.zukunft-mobilitaet.net/1400/konzepte/megaswing-das-eigene-intermodale-terminal. Accessed 30 Oct 2013

Ricker V, Meisel S, Mattfeld D (2012) Optimierung von stations-basierten Bike-Sharing Systemen. In: Proceedings of MKWI 2012, Braunschweig, GITO mbH Verlag Berlin, pp 215–226

UIC (2012) 2012 Report on Combined Transport in Europe. http://uic.org/IMG/pdf/2012_report_on_combined_transport_in_europe.pdf. Accessed 1 Nov 2013

Weitzman M (1984) The share economy: Conquering Stagflation, reprint. Harvard Publication Press, Boston

Application of Topological Network Measures in Manufacturing Systems

Till Becker

Abstract Manufacturing systems are complex networks of material flow. Complex network theory has been used as a descriptive and empirical research tool for various network types. However, due to the distinct origin of the various investigated networks (e.g., social networks, biological networks, the Internet), it is not clear if there is a meaningful application of network measures in manufacturing systems. This chapter investigates network modeling and network measures in manufacturing systems, and categorizes them according to their type of research.

Keywords Complex networks · Network modeling · Manufacturing systems

Introduction

Many real-life systems can be represented as networks or graphs, which consist in their basic form of nodes and links. Usually, nodes represent system entities, while links between them describe their interactions or dependencies. Network modeling has been applied to social, biological, geographical, traffic, and logistic systems, like, e.g., communication networks (Braha and Bar-Yam 2006), river networks (de Menezes and Barabási 2004), food chains in ecosystems (Williams et al. 2002), urban traffic (Lämmer et al. 2006), or supply chains (Meepetchdee and Shah 2007). This remarkably simple way of modeling allows for a quick and straightforward description of a complete system, even if it is highly complex. Analyzes and methods that have been developed for the application on networks can be used to gain a deeper understanding of the underlying system without additional modeling effort.

T. Becker (✉)
Global Production Logistics, School of Engineering and Science,
Jacobs University Bremen, Bremen, Germany
e-mail: t.becker@jacobs-university.de

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The vast spread of the network modeling technique has not fully arrived in the discipline of manufacturing systems, although it has been applied in related disciplines like supply chain design (Meepetchdee and Shah 2007). Therefore, it is necessary to investigate, if network modeling and analysis is applicable in the research on manufacturing systems and which concrete network-related methods from other disciplines can be transferred to the engineering of manufacturing systems.

As the goal of research for industrial economic activity is to describe, analyze, and shape the processes in companies and their interactions with their environment, one can identify the three layers of research: descriptive, analytical, and pragmatic (Bea and Haas 2005). Figure 1 displays the application of complex network theory in manufacturing systems research and the connections to the research goals. The actual network modeling of a real manufacturing system (i.e. depicting a manufacturing system as a set of work station nodes connected by material flow links) is the *descriptive* part. The network model can be further used in the *analytical* part as the foundation for analyses based on network measures. The analyses lead to the development of optimization implications, which form, together with their implementation to the real manufacturing system, the *pragmatic* part of the research. The optimization solutions are either fed back to the Network Modeling stage for further analysis or to the real Manufacturing System stage for implementation. A peculiarity of the network approach in manufacturing systems is the existence of numerous previously developed tools in other science disciplines, which have been using network modeling for a long time. Consequently, research in manufacturing systems can make use of an existing "Network Analysis Toolbox."

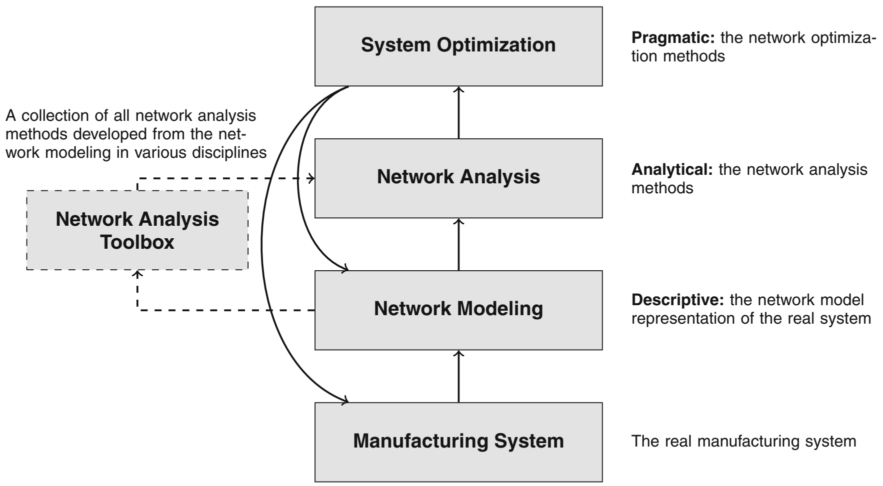

Fig. 1 The utilization of complex network modeling and analysis for manufacturing systems

The research questions addressed in this paper are:

- Can network measures be applied in descriptive, analytical, and pragmatic research on manufacturing systems?
- What are promising fields of further research in the area of network measures for manufacturing systems?

The remainder of this paper is structured as follows: the subsequent section introduces networks as a model for complex systems in general, presents a selection of basic network measures, and sketches the approach to model manufacturing systems as networks. The main part shows applications of centrality measures and subgraph analysis to real manufacturing system data, including a connection between network measures and system performance. The Conclusion Section interprets and summarizes the findings.

Complex Networks as a Modeling and Analysis Approach

Networks as a Representation of Complex Systems

Research on complex systems often uses approaches from graph theory or statistical mechanics (Albert and Barabási 2002), and can also be seen as an interdisciplinary field between those two research areas (Costa et al. 2007). Modeling systems as networks is part of graph theory, which originates from the work of Leonhard Euler in the eighteenth century. Contemporary network modeling and analyses focus mainly on the application of graph theory to highly complex systems. The development of information technology provides the possibility to collect, store, and process large amounts of data on the one hand, and offers enough computational power to perform statistical analyses, with this data, on the other hand (Albert and Barabási 2002). The combination of data availability, computational power, and methods from graph theory allow for the first time for a comprehensive analysis of topological (i.e. the network structure) and dynamical (i.e. the flow of elements through the network) features of complex systems from various sources. The comparison of evolved systems (e.g. biological or social systems) with anthropogenic, engineered systems is of particular interest, because the transfer of concepts like scalability, adaptability, self-organization, resilience, robustness, or reliability from evolved to engineered systems like manufacturing systems seems to offer promising optimization potential (Mina et al. 2006).

A network or graph consists of a set of nodes (or vertices) and a set of links (or edges) connecting pairs of nodes with each other, either unilateral (directed) or bilateral (undirected). If a complex system is modeled using the language of networks, it is necessary to define at least two things: (1) in which system elements are represented by nodes and (2) in which kind of interaction is depicted by links. Examples for complex systems modeled as networks are the World Wide Web (nodes: web pages, links: hyperlinks), the Internet (nodes: routers, links: connection between routers), telephone communication networks (nodes: persons, links: phone calls between persons), linguistic networks (nodes: words, links: adjacency relation of words in a text), and power networks (nodes: power plants and transformer stations, links: power lines) (Albert and Barabási 2002).

Topological Network Measures

If the descriptive part, the actual network modeling of a complex system, is concluded, an analytic assessment of the system is the next logical step. The network representation offers a variety of possibilities for analyzing the topological structure of the system. Common measures are centrality figures like degree or betweenness centrality, which quantifies how "central" a node is situated in the system, thus indicating its importance (Boccaletti et al. 2006). Each node in the network has a degree value, which indicates how many links are connected to this node. If a system is modeled as a directed network, the degree value can be split into the in-degree for the number of incoming links and the out-degree for the number of outgoing links. The degree distribution of the complete network reveals the relation between highly connected hub-nodes and rather isolated leaf nodes in the system.

Betweenness centrality (BC_v) of a node v indicates how many shortest paths traverse a node. The BC of a node is computed as the number of shortest paths σ between any pair of nodes i and j, that pass through the observed node, normalized by the total number of shortest paths between the two nodes (Freeman 1977).

$$BC_v = \sum_{ij} \frac{\sigma(i, v, j)}{\sigma(i, j)} \tag{1}$$

The advantage of BC over the degree is the consideration of paths, which also assign high BC values to nodes having less direct connection (thus a small degree), but, e.g., serve as a bridge between two network parts. Again, the distribution of BC values over the network can expose distinct structural characteristics of the entire system. BC can, e.g., be applied in manufacturing systems for anomaly detection (Vrabič et al. 2013).

A different way of assessing topological characteristics of a network is the determination of occurrence of network motifs. Motifs are 3-node subgraphs, and counting their occurrence in the network shows if there are prevalent local material flow patterns in a system, e.g., branches or confluences. An additional application scenario for motifs is categorization. Several studies have used network motifs to categorize complex systems by their motif pattern, especially in research on metabolic processes (see, e.g., Milo et al. 2004; Shen-Orr et al. 2002). In the field of logistics, Hammel et al. (2008) used the motif pattern of luggage handling systems for optimization purposes.

Manufacturing Systems as Networks

As mentioned earlier, there is a lot of scientific activity regarding network modeling and analysis in various disciplines, except for research on manufacturing systems, where network applications are sparse. There are more applications in the related field of supply chain due to the intrinsic network structure of supplier relationships in global manufacturing and trade (see, e.g., Xuan et al. 2011; Sun and Wu 2005; Meepetchdee and Shah 2007).

Existing network modeling approaches in manufacturing systems are the identification of autonomous clusters on a shop floor (Vrabič et al. 2012), anomaly detection in a shop floor (Vrabič et al. 2013), cross-disciplinary comparison of flow networks (Becker et al. 2011), and robustness evaluation of manufacturing systems (Becker et al. 2013).

The base frame for a manufacturing systems network model is the assignment of the manufacturing systems elements to the network elements. A manufacturing network (the network model representation of a manufacturing system) is a graph that consists of a set of nodes and a set of links. Each work station (i.e. machine, assembly station, quality gate, etc.) in the manufacturing systems is a single node, and each possible material flow between two work stations is a link, if at least one product or semi-finished product is routed directly between the two work stations. Depending on the desired granularity of the model, links can be either binary (i.e. present or not present) or assigned a link weight indicating the number of objects that are routed between the work stations. This basic network representation of a manufacturing system can usually be easily derived from scheduling data or production feedback data (see Becker 2012; Becker et al. 2013).

Network Measures in Manufacturing Systems

As pointed out in the previous section, network measures have been used in other disciplines to quickly assess and characterize complex systems according to certain topological features. Furthermore, it has been shown that manufacturing systems can be modeled as networks. The remainder of this section presents four analyses based on network measures involving manufacturing system network models derived from the feedback data of production control software. Table 1 summarizes the raw data collected from the six companies.

Table 1 Summary of the company datasets used in the network analyses

Company	Type	No. of operations	Company	Type	No. of operations
A	Job shop	77,119	D	Process	175,609
B	Job shop	28,294	E	Customizing	504,825
C	Job shop	60,081	F	Job shop	2329

Centralized or Decentralized Structures: Distribution of Node Degree

The individual degree of a node indicates how many connections to other elements exist in the system. In a manufacturing system setting, this means how many other work stations are predecessors or successors in material flow. The distribution of the degree values over the complete network reveals, if the material flow is rather equally distributed among the work stations or if there is a strong hub-and-spoke architecture in the system. The Lorenz curves displayed in Fig. 2 show that there are visible differences between the degree distributions of the manufacturing systems, some of them having a stronger separation between highly connected and less connected nodes and some not.

The random networks in Fig. 2 are networks generated using the Barabási-Albert preferential attachment model with the same amount of nodes and links as their corresponding company network (Barabási and Albert 1999). The conclusion from the comparison between the pairs of company networks and random networks is that manufacturing systems make up distinct networks with a stronger hub-and-spoke topology than one would expect from generic networks of the same size.

Identification of Central Nodes: Betweenness Centrality

Due to the consideration of paths in the network, in contrast to the determination of the degree based on neighboring nodes, the BC includes the complete network topology when measuring the importance of a node. Again, the inequality of the

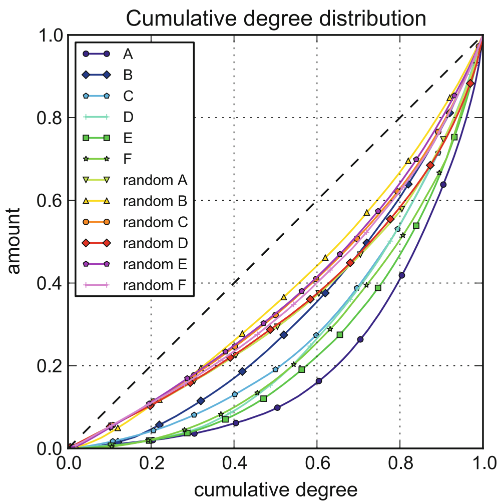

Fig. 2 Cumulative degree distribution of the manufacturing networks in comparison to randomized networks derived from the manufacturing networks (Figure adapted from Becker 2012)

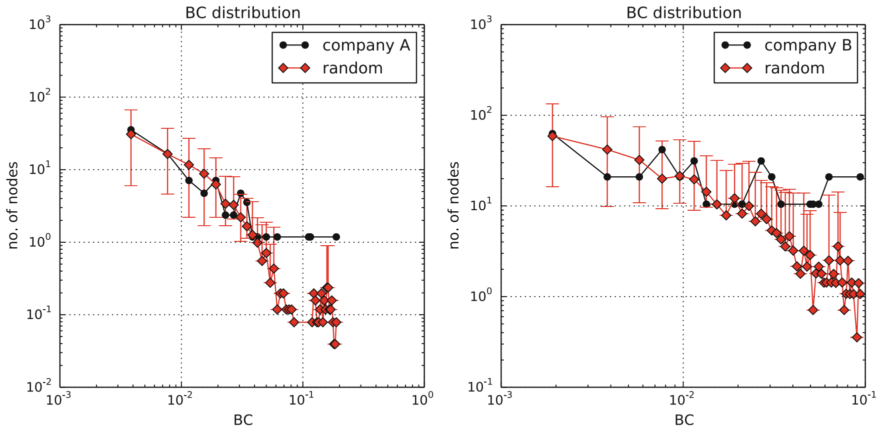

Fig. 3 BC distribution of company networks and respective random networks. For reasons of space, only companies A and B are shown (Figure from Becker 2012)

distribution of the centrality of nodes in the complete network becomes apparent in Fig. 3. A small number of highly central nodes face a high number of less connected nodes. This time, the random networks in the figures are derived from the original network by using a degree-preserving link switching algorithm: two pairs of connected nodes are selected randomly and their link targets are switched. This switching is repeatedly applied to the network. The result is a network, where every node still has the same degree, but the paths through the system have changed. It can be observed in Fig. 3 that the frequency of nodes with a low BC value does not deviate from the random, "natural" occurring scheme (the frequencies are inside the 0.2 and 0.8 quantiles of 30 randomly derived networks). However, nodes with a particular high BC are clearly overrepresented. This strengthens the previously gained insight from the degree distribution analysis that manufacturing system topology is nonrandom and favors the occurrence of a few highly connected work stations (Becker 2012).

Patterns of Material Flow: Network Motifs

Network motifs are 3-node subgraphs, in which frequency of appearance in a network indicates how material flow is organized on a local scale between small groups of network elements. All possible 13 variants of directed links between three nodes are depicted below the *x*-axis in Fig. 4a. The major purpose is to use the motif count for classification of networks. The *z*-score (Milo et al. 2004) indicates how much the motif is over- or underrepresented.

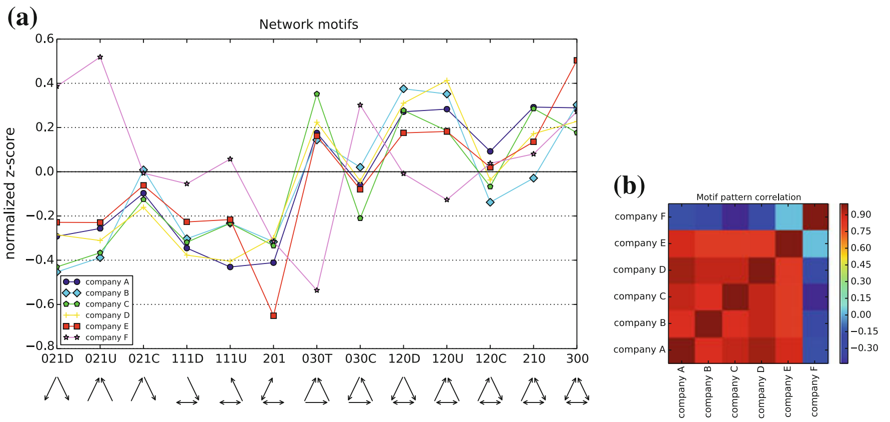

Fig. 4 Network motifs in manufacturing systems (Figure adapted from Becker 2012)

Figure 4a shows the motif z-scores for the company networks, and Fig. 4b shows the correlation among each pair of the 13-variate vectors. The high correlation among five of the six companies suggests that there is a distinct microscale material flow pattern in manufacturing systems, because other network types show different motif patterns (Milo et al. 2004; Becker 2012). Only company F deviates from this pattern, which is assumed to be caused by a high amount of unique products and individual repair orders.

Linking Network Measures and Performance: The Optimal Network Connectivity

A simulation study presented by Becker et al. (2012) using the six company networks as material flow networks investigated the relation between network topology and system performance in manufacturing systems. The study suggested that even for differing workload scenarios there is an optimal average network degree in the simulated manufacturing systems (see Fig. 5a).

The results of the simulation study could be reproduced when plotting the average work in process (WIP) against the average network degree in the real company datasets (see Fig. 5b).

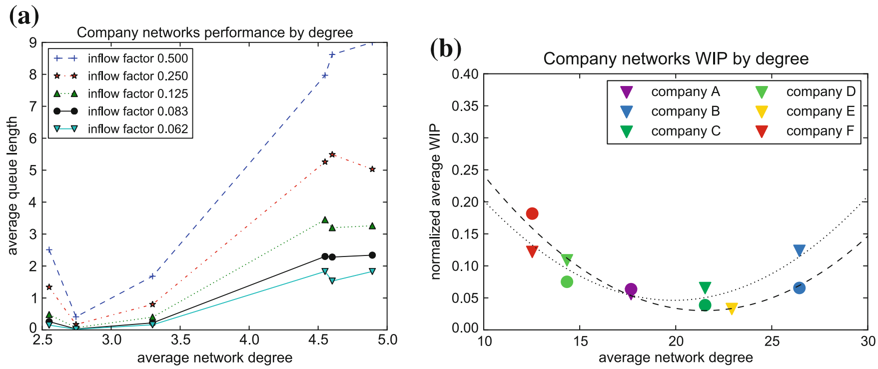

Fig. 5 **a** The material flow simulations based on the companies' manufacturing networks show that a network with an average degree between 2.5 and 3.5 has the lowest work in process (WIP) levels (indicated by the queue length at the work stations). **b** The same phenomenon is observed in the real company data, both using the number of orders as WIP (triangles) and the actual work content (*circles*). The *dotted* and the *dashed line* are the respective second degree least squares approximations (Figures adapted from Becker et al. 2012)

Conclusion

Network modeling and network analysis are widely used techniques in many disciplines for the research on complex systems. The first research question addressed the applicability of network modeling on descriptive, analytical, and pragmatic research in manufacturing. The answer is threefold: First, 11 application examples in this work use this way of modeling based on real company data. Therefore, one can state that network modeling is applicable for *descriptive* purposes in manufacturing systems. Second, the analyses of the distribution of the node degree and betweenness centrality, as well as the assessment of the motif count, show how network modeling satisfies the requirements for *analytical* research. Finally, making the link between manufacturing system performance and the topological structure of a manufacturing network represents a step toward the *pragmatic* research approach. However, additional work on descriptive and analytical research needs to be done in order to come up with mature pragmatic implications for manufacturing systems design and performance.

The network approach also has its limitations. As in every modeling attempt, the network model is a simplified representation of reality. The strength of network modeling, its minimalistic nature, is at the same time its weakness, because many features of the system are omitted. On the other hand, network modeling is flexible and extendable. Nodes and links can be perceived as objects that can carry additional information, e.g., capacities or priority rules, so that network modeling is not necessarily restricted to its simple form.

Further research is required to assign appropriate modeling techniques and analytical approaches to the network modeling framework presented in Fig. 1. The availability of network-related approaches from other scientific disciplines and the availability of large-scale manufacturing system data offer numerous possibilities to transfer these approaches to the realm of manufacturing systems.

References

Albert R, Barabási A-L (2002) Statistical mechanics of complex networks. Rev Mod Phys 74:47–97

Barabási A-L, Albert R (1999) Emergence of Scaling in random networks. Science 286:509–512

Bea FX, Haas J (2005) Strategisches management. UTB, Stuttgart

Becker T (2012) Parallels between manufacturing systems in industrial production and metabolic systems in biological cells: a network based unifying model from a production logistics perspective. Jacobs University Bremen, Bremen

Becker T, Beber ME, Windt K, Hütt M-T, Helbing D (2011) Flow control by periodic devices: a unifying language for the description of traffic, production, and metabolic systems. J Stat Mech Theor Exp 2011:P05004

Becker T, Beber ME, Windt K, Hütt M-T (2012) The impact of network connectivity on performance in production logistic networks. CIRP J Manufact Sci Technol 5:309–318

Becker T, Meyer M, Windt K (2013) A network theory approach for robustness measurement in dynamic manufacturing systems. The annual cambridge international manufacturing symposium, 19–20 Sept 2013

Boccaletti S, Latora V, Moreno Y, Chavez M, Hwang D-U (2006) Complex networks: structure and dynamics. Phys Rep 424:175–308

Braha D, Bar-Yam Y (2006) From centrality to temporary fame: dynamic centrality in complex networks. Complexity 12:59–63

Costa L, Rodrigues F, Travieso G, Boas P (2007) Characterization of complex networks: a survey of measurements. Adv Phys 56:167–242

De Menezes MA, Barabási A-L (2004) Fluctuations in network dynamics. Phys Rev Lett 92:028701

Freeman LC (1977) A set of measures of centrality based upon betweenness. Socicometry 40:35–41

Hammel C, Flemming A, Schulze F, Peters K (2008) Anwendung von Methoden aus der Theorie Komplexer Netzwerke für die Optimierung der Layouts von MFS. In: Subbert S (2008) 4. Fachkolloquium der WGTL an der Universität Chemnitz, WGTL, pp 81–91

Lämmer S, Gehlsen B, Helbing D (2006) Scaling laws in the spatial structure of urban road networks. Phys A: Stat Mech Appl 363:89–95

Meepetchdee Y, Shah N (2007) Logistical network design with robustness and complexity considerations. Int J Phys Distrib Logist Manag 37:201–222

Milo R, Itzkovitz S, Kashtan N, Levitt R, Shen-Orr S, Ayzenshtat I, Sheffer M, Alon U (2004) Superfamilies of evolved and designed networks. Science 303:1538–1542

Mina A, Braha D, Bar-Yam Y (2006) Complex engineered systems: a new paradigm. In: Braha D, Mina A, Bar-Yam Y (2006) Complex engineered systems, Springer, Berlin

Shen-Orr S, Milo R, Mangan S, Alon U (2002) Network motifs in the transcriptional regulation network of *Escherichia coli*. Nat Genet 31:64–68

Sun H, Wu J (2005) Scale-free characteristics of supply chain distribution networks. Mod Phys Lett B 19:841–848

Vrabič R, Husejnagić D, Butala P (2012) Discovering autonomous structures within complex networks of work systems. CIRP Ann-Manuf Technol 61:423–426

Vrabič R, Škulj G, Butala P (2013) Anomaly detection in shop floor material flow: a network theory approach. CIRP Ann-Manuf Technol 62:487–490

Williams RJ, Berlow EL, Dunne JA, Barabási A-L, Martinez ND (2002) Two degrees of separation in complex food webs. Proc Natl Acad Sci 99:12913–12916

Xuan Q, Du F, Li Y, Wu T-J (2011) A framework to model the topological structure of supply networks. IEEE Trans Autom Sci Eng 8:442–446

Optimization of a Factory Line Using Multi-Objective Evolutionary Algorithms

Andrew Hardin, Jason Zutty, Gisele Bennett, Ningjian Huang and Gregory Rohling

Abstract In this paper, we describe a simulation for an automotive manufacturing process using automated guided vehicles (AGVs). The simulation is used to optimize a generalized factory model layout using multi-objective evolutionary algorithms. The Pareto front of the optimization is analyzed, and layouts are compared to the industry standard transfer line in terms of objectives that include capital cost, energy usage, and product throughput. We seek to determine from the results whether genetic algorithms are a feasible tool for the optimization of manufacturing automobiles.

Keywords Optimization · Factory layout · Genetic algorithms

Introduction

Transfer line (or linear) factories are still based on the assembly line pioneered at the turn of the 20th century. Since then, many techniques have come about to improve upon the basic theory behind it, including assembly line balancing and computer-aided process plans. In the automotive industry, however, the fact remains, if one part of a transfer line has a fault, there is a tremendous loss in productivity.

A solution to this challenge is to remove the transfer line from the factory of the future. Rather than having automobile chassis move on a fixed line, they will be placed on an automated guided vehicle (AGV) for transport around a factory. They will be able to move from station to station based on a dependency task list, e.g., if one is occupied or faulted it will move to the next available that it has on its requirement list.

A. Hardin · J. Zutty (✉) · G. Bennett · G. Rohling
Georgia Tech Research Institute, Electro-Optical Systems Lab, Atlanta 30332, GA, USA
e-mail: jason.zutty@gtri.gatech.edu

N. Huang
Research and Development Center, General Motors Corp., Warren 48090, MI, USA

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Using AGVs as transports is not a new concept in manufacturing, dating back to the 1980s (Smith 2003), but its adoption in the automotive industry has been somewhat limited. Fiat used AGVs as early as 1978 for their robogate welding system (Camuffo and Volpato 1996), but as the welding system became more mature, it moved back to a fixed line to improve cost-effectiveness. Tesla uses SmartCarts manufactured by Daifuku Webb to move welded bodies of their model S sedan around the factory, but they traverse the factory in a mostly linear fashion. Still, this allows them to utilize many of the benefits of flexible manufacturing systems (FMS).

If the factory of the future is to be agile and utilize AGVs, the research question we seek to answer is whether genetic algorithms are a valid approach to optimize the layout of the factory in order to maximize throughput of produced cars while minimizing energy usage and capital cost while taking into account any external factors such as supplies and other resource availability. We chose to approach this problem using our own genetic algorithm framework, known as the Georgia Tech Multiple Objective Evolutionary Algorithm Framework (GTMOEA), running on top of a custom simulation.

Background

Genetic algorithms are a powerful heuristic that uses bio-inspired principles to solve complicated problems. Drira et al. (2007) showed examples of many applications of genetic algorithms to factory layout problems. A common tool in these applications is the use of a slicing tree to represent a floor plan. A slicing tree is a tree with two primitives representing horizontal and vertical splits of the factory floor. The terminal nodes represent the sectioned areas of the factory. These designs are very desirable from a genetic optimization point of view for their ease of mating and mutating but are very rigid in terms of the floor plans that can be represented. In order to cover a large area with stations of fixed size, they would need a deep tree structure and an ability to represent both empty space and stations in their slicing tree.

Evaluation of individuals is handled differently from application to application. Some evaluate objectives computed from the layout itself, for example, average distance to materials. This can be seen in Mawdesley et al. (2002). Here, genetic algorithms were used to represent (x, y) coordinate pairs of the placement of various structures throughout a construction site. The fitness measures in this paper were purely deterministic, weighted by distances that units would be required to transport and by what quantity they would be transporting. Others, such as Hamamoto et al. (1999), ran a simulation of a four-month production. In this paper, two genetic algorithms were used together, one to generate potential solutions and the other to lay out the solution. Objective scores, included traveling time and throughput, are computed from each simulation.

Azadivar and Wang (2000) also used a simulation for evaluation. They used slicing trees to create layouts for their factories overloading * and + to represent horizontal and vertical slices in their tree structures. In order to save expensive evaluation time, the authors implemented a hashing table, representing the individual trees as strings along with their fitness scores. When a new tree was produced via mating or mutation, the hash table would be referenced first to see if it had already been computed. Azadivar and Wang point out that a similar approach was used by Zhang (1997) and resulted in 45–70 % savings in the central processing unit (CPU) computation time. While this is an excellent technique in the reduction of repeated computations, it does nothing to reduce a single individual's computation time if it has not already been computed.

A common weakness associated with genetic algorithms is the amount of computation required in order to evaluate an individual's objective scores and compute its fitness. Our research builds on the work of Rohling (2004). Rohling showed that expensive objectives can be computed individually, greatly improving computation time. This is achieved by dynamic objective thresholding. Objectives are computed one at a time, and if an individual is determined not to be able to improve performance, the remaining objectives are not evaluated. It should be noted that the individual still maintains a fitness score from the objectives that were evaluated up to that point. This can be leveraged for factory layout problems by creating more interesting objectives, such as performance under different supply constraints or failure modes, each scenario requiring its own set of simulations.

Our research also makes use of the Georgia Tech Test Matrix Tool (TMT) data analysis capabilities in Clarkson et al. (2003). The TMT analysis tool discussed in this paper lends itself extremely well to investigation of a multi-objective space. This is a weakness of many other genetic algorithm approaches that we are able to handle very effectively. When in a multi-objective space, one solution is not necessarily better than another. TMT allows us to view our individual solutions in objective space and find which solutions on the Pareto front achieve the goals in the manner that best suits the problem. An individual is Pareto optimal when it has at least one objective that is considered to be better than all other individuals. The Pareto front is the set of all these individuals.

Simulation

We created a generic manufacturing performance simulation to model the performance of arbitrary factory configurations. An individual factory's configuration is a combination of the processing steps and dependencies for a given manufacturing process; a performance description of each of the manufacturing station types; a list of parts as inputs to and outputs from each step; a delivery schedule for parts to the factory; the quantity of each station type and position of each station type instance; a description of the desired factory outputs, called "orders"; and the quantities and behaviors of assembly transports (AGVs) and repair workers. This configuration information is encoded into an XML input file for the factory.

The manufacturing process for a particular "order" has a list of steps required to complete the process and a description of the dependency relationships between steps. The simulation framework places no a priori restrictions on the manufacturing process; the order of dependencies may describe a continuum from perfectly linear (each subsequent step in the process relies on all steps that come before it) to totally unordered (individual steps have no reliance on the completion of any previous steps). For each step in a given process, there is at least one station type described in the configuration capable of performing the related work, and there must be at least one instance of that station type in the factory. Further, factories may have more than one station type capable of performing a given step; station types capable of performing multiple steps; and layouts that have multiple copies of a single station type.

Station types are described as a list of one or more process steps performed by the station and required input parts. Individual station instances x are described by their station type, and: location within the factory; size of the station; idle and active energy use $E_{\text{idle},x}$ and $E_{\text{active},x}$; active and idle operating costs $C_{op_{\text{active}},x}$ and $C_{op_{\text{idle}},x}$, and capital cost $C_{\text{cap},x}$; process duration; and station failure rate. Individual station instances describe these metrics separately in order to encapsulate unit-to-unit variations. Stations also describe the approach and departure vectors that AGVs must take to and from the station, as well as a region in front of the station where AGVs should queue when waiting to enter the station.

A key feature of the simulation is the use of AGVs for transporting in-process vehicles between assembly stations within the factory. The framework makes the implicit assumption that AGVs are capable of moving throughout the factory floor without traveling on any predefined paths. In other words, the AGVs have total autonomy and authority to move between stations, routing around stations that are failed and pathways that are blocked, negotiating arbitrary factory layouts, and avoiding collisions.

At each simulation time step, the path that an AGV takes is the minimum path length between the AGV's current position and target station, taking into account the fixed positions of stations on the factory floor. The solution is deterministic for a given time step and factory state. If the factory state changes between time steps and the target station is no longer available (e.g., the station fails or becomes busy), the transport will attempt to find a different, working station, either one of the same type or one of a different type that also satisfies the process dependency criteria; failing that, the AGV will queue at the nearest failed station satisfying the dependency criteria. If a collision will occur during the next update between an AGV and any other dynamic object (i.e., another AGV or a human worker), a collision resolution algorithm is used to negotiate a new path solution.

Given a factory configuration, the simulation models the time evolution of the factory to fulfill the requested orders using the specified manufacturing dependencies. The simulation starts when the AGVs enter the factory floor and collect any base components (e.g., a painted car frame). AGVs proceed between stations, completing the required steps for each vehicle. Once a vehicle is completed, the AGV deposits it at a special warehousing station and then returns to the factory entrance to begin a new vehicle or, if all orders are fulfilled, it returns to the AGV home location. During the simulation, the timing of discrete events, such as an equipment failure, and the durations of specific processes are modeled as random variables with distribution parameters defined in the factory configuration, and Monte Carlo methods are used to compute factory performance metrics. By default, the simulation models process durations (e.g., time on station) as normally distributed variables with mean process time μ_t and standard deviation σ_t. Failure occurrence times (e.g., station malfunctions) are modeled using a Weibull distribution with a mean time between failure λ^{-1} and shape parameter κ.

The simulation models three basic performance criteria of the configured factory: energy cost, monetary cost, and total process time. The software computes the mean active time of each station, $\bar{t}_{\text{active},x}$, and the mean total manufacturing run time, $\bar{T}_{\text{process}}$. Then the energy cost is computed as

$$E_{\text{process}} = \sum_x E_{\text{active},x} \cdot t_{\text{active},x} + E_{\text{idle},x} \cdot \left(\bar{T}_{\text{process}} - \bar{t}_{\text{active},x}\right), \tag{1}$$

and the monetary cost is the sum of the capital and operating costs, computed as

$$C_{\text{process}} = \sum_x C_{\text{cap},x} + C_{op_{\text{active}},x} \cdot t_{\text{active},x} + C_{op_{\text{idle}},x} \cdot \left(\bar{T}_{\text{process}} - \bar{t}_{\text{active},x}\right). \tag{2}$$

Additionally, the standard deviations of energy, cost, and time are reported for the set of Monte Carlo runs, and each individual run's performance is provided for the configured factory.

To evaluate factory configuration performance during the optimization, we created a simple manufacturing process description for a single product (a vehicle). The process describes 13 steps and station types that are required to complete the product. Steps and their corresponding station types were labeled to indicate their function, such as "paint shop" or "engine assembly," but these labels are only used to distinguish station types and do not correspond, even in relative terms, to the actual performance characteristics of a real factory. We also modeled each station instance of a given type to be identical (no unit-to-unit or age-related variations), only differing in the placement within the factory.

Two manufacturing process descriptions were used in this optimization. The first process description is a baseline factory where the process dependencies are fully constrained. The second process description used is a combination of in-order step sequences out-of-order step sequences. The resulting process is a diverging–converging graph, where the process always begins and ends with the same steps but is indeterminate in the middle. This "pseudo-ordered" process is intended to be representative of a future factory's flexible manufacturing environment and is entirely arbitrary in terms of the ordering of dependencies.

As with the manufacturing process descriptions station performance metrics, such as process duration and failure rate characteristics, are simplified. The values of these performance metrics were chosen per station type such that we exercised a range of mean processing times, process time variations, and failure rates. This allowed the performance of a specific factory configuration to be discussed with respect to the sensitivity to a general performance class of equipment, such as “long processing time with low time variability and low failure rate.”

For both the baseline process description and the pseudo-ordered process, there are several other fixed quantities used. The number of AGVs available in both factory types was limited to four, and all AGVs share a common set of performance criteria: movement speed and failure rate. In the case of the baseline factory, we coded the AGVs to act like those used by Tesla, essentially restricted by the manufacturing process linearity. In the pseudo-ordered factory, the nature of the process description allowed the AGVs to roam more freely, as described above. Additionally, the number and behavior of maintenance personnel available for fixing broken AGVs and stations were fixed for both factory types. Finally, the number of Monte Carlo runs and the order size (quantity of vehicles) for both factories were both fixed to the same values to allow for valid comparisons.

Optimization

For this study, we assumed that a factory’s configuration had a significant performance impact on a factory with a flexible manufacturing process consisting of a partially unordered assembly process and AGVs. Further, we hypothesized that using genetic algorithms, we could optimize this configuration to create a factory with one or more improvements in three critical performance metrics versus a traditional transfer line (linear) manufacturing process: energy, cost, and output rate.

We began by computing the performance of a highly simplified example baseline factory using our simulation. The factory consisted of 13 stations, configured as the traditional transfer line, as shown by a screenshot of the simulation software in Fig. 1. The simulation is set to produce an order of 40 automobiles. Using the baseline performance, we set minimum performance thresholds for the genetically derived individuals. We then proceeded with the optimization.

Fig. 1 A simulation screenshot of our baseline factory layout. This layout models the linear transfer line used in automobile manufacturing. This layout was used to seed the optimization

We used GTMOEA to run our optimization, configured per Rohling's findings in Rohling (2004), and initialized our gene pool with a population of 500 individuals; the baseline layout was used as a seed solution, and 499 other randomly generated layouts were used as the starting population. Each individual represents a unique description of a factory and was described through an XML instance. We computed fitness scores using a Pareto ranking algorithm from their objective scores: mean process time, mean total energy, capital cost, and the standard deviations of process time and total energy. We modified the fitness scores using several scaling algorithms: SPEA2 density, transforms, niching, and hypercube distance. We tuned the thresholds used for these algorithms for each objective between episodes as we approached our optimal solutions. Individuals were selected using the roulette wheel method, a procedure that assigns a proportionate weight to each individual based on its fitness score. Newly created individuals were put through a crossover mating method followed by five different mutation operators, each with unity probability of applying to the individual. The mutation operators we used included a uniform distribution and several normal distributions with varying standard deviations. Each normal distribution had a 2 % chance of modifying a particular parameter, while the uniform had a 1 % chance.

The individual pseudo-ordered factory configurations were created by the genetic algorithm to comply with the vision of a future factory: multiple station instances in an arbitrary configuration along with a flexible manufacturing process and AGVs. As such, our search space for the pseudo-linear factory was limited to selecting the quantity of each station type and the location of station instances. GTMOEA was constrained to selecting up to three instances of each station type, and station placement was restricted to be within the factory boundaries. Not all members of the search space are valid, requiring that all configurations be vetted through an intermediate code prior to evaluation to check for: at least one of each station type; stations do not overlap; and ingress and egress vectors are not blocked. Evaluation of invalid individuals did not occur, and they were removed from the mating pool immediately. In this optimization, the number of AGVs and order size remained fixed across all trials. An example, valid pseudo-ordered factory configuration output produced by the genetic algorithm, is shown in Fig. 2.

The optimization was iterative and split up between "episodes," each of which contained multiple generations of individuals. Between episodes, resulting Pareto optimal individuals were inspected by hand and those with exceptionally good performance on a single dimension and exceptionally poor performance on all other dimensions were pruned from the elite mating pool. Also, performance thresholds, crossover variables, mutation rates, and search space parameter ranges were tuned between episodes. Each episode was seeded with the Pareto optimal individuals from the previous episode, and then the optimization resumed.

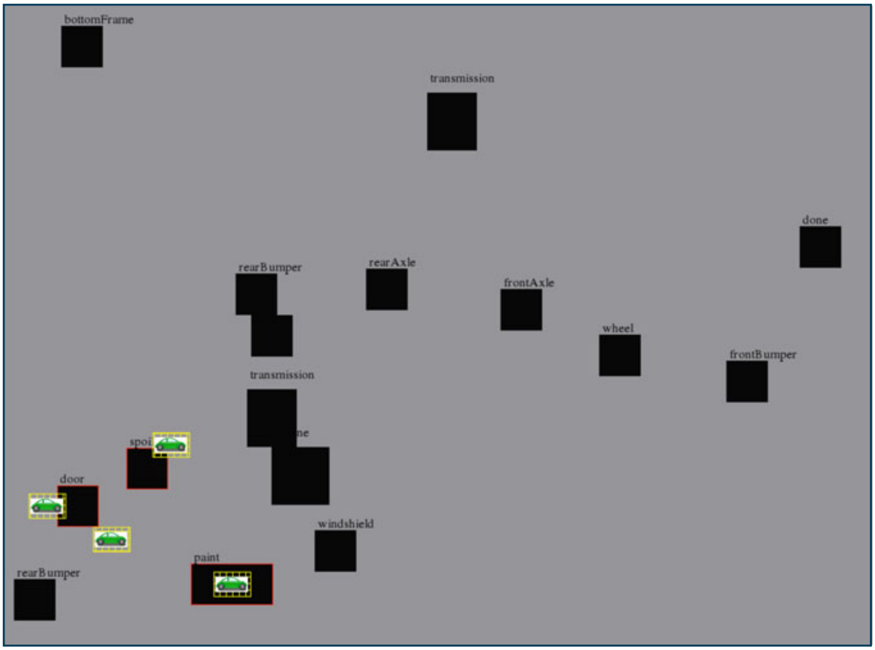

Fig. 2 A simulation screenshot of a non-linear factory layout produced by GTMOEA and run through our simulation software. Note that while some stations are placed close together, the simulation has verified that the layout is valid with no overlaps or missing station types

Analysis

The baseline factory performance was computed prior to the start of optimization. We used this performance to show performance improvements as percentages. Limitations on flexibility and adaptability with respect to our defined factory performance parameters were the main targets for improvement using GTMOEA.

In total, 332,824 individual factory configurations were evaluated over the span of four months. The final Pareto front shows the performance range of the possible factory configurations created by the genetic algorithm. It consists of only 124 individuals found to be dominant. The performance of the baseline factory was, in general, dominated by the flexible factory individuals in terms of mean total energy use and mean processing time, as shown in Figs. 3 and 4, owing to flexibility of the optimized factories.

Only when including capital cost does the baseline factory reside on the Pareto front, as shown in Fig. 3, as its implicit assumption of "one of each station type" is necessarily the minimum capital cost of a viable configuration. Because it lies on the Pareto front in our solution, we know that GTMOEA found no configurations that used exactly one of each station type with lower energy and time than the baseline, indicating that some of the utility of flexibility may only be realized for a pseudo-linear process when multiple station instances are present.

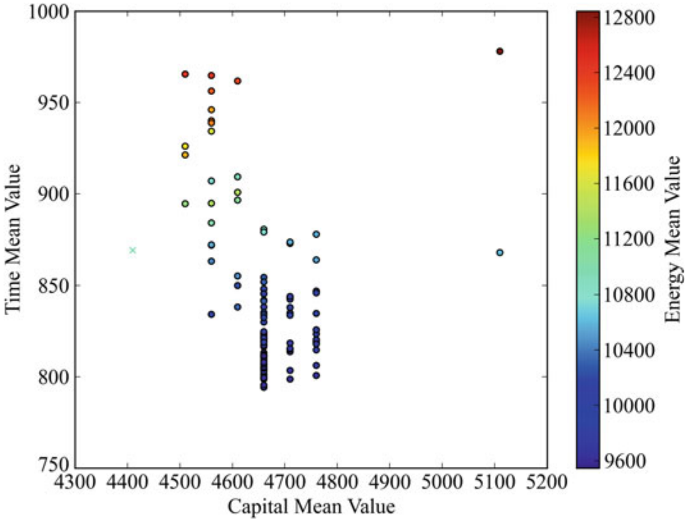

Fig. 3 Pareto front, time versus capital cost. The linear factory has the lowest capital cost on the Pareto front and is denoted by an "*x*". Objectives inherent, but not shown, include standard deviations of process time and total energy

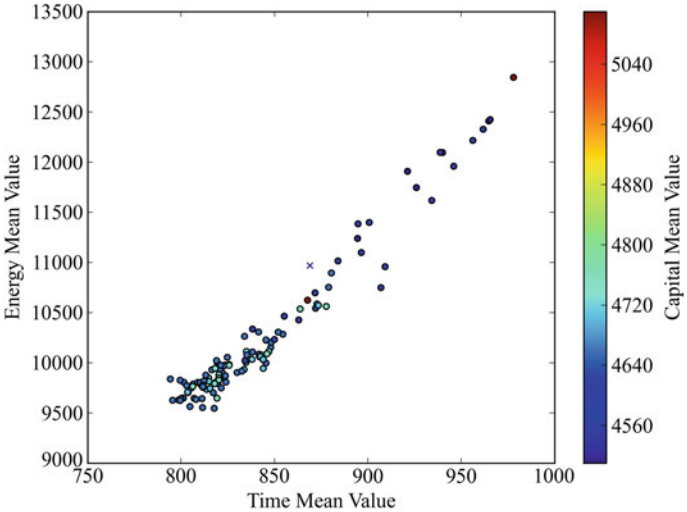

Fig. 4 Pareto front, energy versus time. Note the high correlation between energy and processing time. The linear factory, denoted by an "*x*", falls toward the back end of the Pareto front in terms of time and energy, but maintains a low capital cost. Objectives inherent but not shown include standard deviations of process time and total energy

Indeed, this observation is supported when looking at the composition of individuals on the Pareto front. Because the optimization was fixed to utilizing only four AGVs, Pareto individuals had, in most cases, two or less of each type of station, despite the number of cars being produced. Only one Pareto-optimal individual was found with three copies of a given station type, and this station had a high failure rate and long processing time. Further, only rarely (<5 %) did the optimization find configurations to be Pareto optimal when they contained multiple copies of stations types with short mean processing times, low process time variability, and low failure rates. In fact, only station types defined to have both a long processing time and a high failure rate were consistently selected by the genetic algorithm for multiple instances, and only when the capital and energy cost functions were relatively low.

With respect to location of stations in Pareto individuals, no discernible patterns exist, nor based on fixed characteristics (e.g., process definition dependency ordering, station characteristics, etc.), optimization input variables.

The Pareto individuals provide that, depending on the specific goals of a factory layout optimization, the mean total energy of the given factory can be reduced with respect to the baseline by up to 12.9 %, and the mean processing time can be reduced by up to 8.6 % without dramatic increases in capital cost or a loss of manufacturing flexibility.

Conclusions

By modeling an automotive factory simulation as a pseudo-ordered process, we were able to use multi-objective evolutionary algorithms to optimize the layout of the factory. We have achieved solutions that are able to reduce both energy usage and processing time through the use of AGVs. The results have also verified that the transfer line, which has been utilized for the past century, is still a Pareto optimal solution for its low capital cost. Having achieved successful optimization results with our simple factory, we believe that with further work, we will be able to run the genetic optimization on a more detailed simulation, utilizing a larger factory, a higher number of stations and AGVs, and delivering a more realistic number of automobiles.

Additionally, we believe that genetic optimization can play a key role in optimizing the use of other performance-relevant factory technologies, such as just-in-time manufacturing techniques. By increasing our simulation fidelity to incorporate tracking of the all real-time factory assets that support the enterprise, as in Bennett (2013), we can use genetic optimization to ensure a more robust logistical performance, which is a very attractive solution for manufacturers.

References

Azadivar F, Wang J (2000) Facility layout optimization using simulation and genetic algorithms. Int J Prod Res 38(17):4369–4383

Bennett G (2013) The future of manufacturing utilizing tagging technology. In: Dynamics in logistics. Springer, Berlin, pp 3–11

Camuffo A, Volpato G (1996) Dynamic capabilities and manufacturing automation: organizational learning in the Italian automobile industry. Ind Corp Change 5(3):813–838

Clarkson E, Hurt J, Zutty J, Skeels C, Parise B, Rohling G (2013) Supporting robust system analysis with the test matrix tool framework. In: Proceedings of the 2013 ACM SIGSIM conference on principles of advanced discrete simulation, pp 23–34

Drira A, Pierreval H, Hajri-Gabouj S (2007) Facility layout problems: a survey. Ann Rev Control 31(2):255–267

Hamamoto S, Yih Y, Salvendy G (1999) Development and validation of genetic algorithm-based facility layout-a case study in the pharmaceutical industry. Int J Prod Res 37:749–768

Mawdesley MJ, Al-Jibouri SH, Yang H (2002) Genetic algorithms for construction site layout in project planning. J Construct Eng and Manage 128(5):418–426

Rohling G (2004) Multiple objective evolutionary algorithms for independent, computationally expensive objective evaluations. Doctoral dissertation, Georgia Institute of Technology

Smith JS (2003) Survey on the use of simulation for manufacturing system design and operation. J Manuf Syst 22(2):157–171

Zhang J (1997) Genetic algorithm based simulation optimization of flexible manufacturing systems. PhD dissertation, Kansas State University

Managing the Life Cycle of IT-Based Inter-firm Resources in Production and Logistics Networks

Jens Pöppelbuß, Michael Teucke, Dirk Werthmann and Michael Freitag

Abstract This paper applies the concept of inter-firm resources to inter-organizational information systems that are shared between enterprises within production and logistics networks. The paper focuses on challenges during collaborative initiation, development, implementation, operation, and maintenance as well as termination of such shared information systems. The availability of instruments for improving all these life cycle phases of shared information systems is discussed based on the implementation of an EPCIS-based data exchange infrastructure within an automotive production network.

Keywords Inter-firm resources · Inter-organizational information systems · IT systems · Life cycle management · Supply chain management

Introduction

Production and logistics companies form networks in order to increase their own competitiveness in the global market and create more value for their customers (Simatupang et al. 2004). However, companies in such networks, and consequently the networks as a whole, have to meet increasingly more ambitious goals:

J. Pöppelbuß (✉)
Industrial Services Group, University of Bremen, Wilhelm-Herbst-Street 5,
28359 Bremen, Germany
e-mail: jepo@is.uni-bremen.de

M. Teucke · D. Werthmann · M. Freitag
BIBA—Bremer Institut für Produktion und Logistik GmbH, University of Bremen,
Hochschulring 20, 28359 Bremen, Germany
e-mail: tck@biba.uni-bremen.de

D. Werthmann
e-mail: wdi@biba.uni-bremen.de

M. Freitag
e-mail: fre@biba.uni-bremen.de

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short delivery times, high delivery reliability, and a growing range of individualized and varied products. A critical success factor for improved cooperation within these networks is the efficient exchange of information throughout the network (Tan 2001). Many different types of information can be beneficial for improved cooperation, like transactional and operational information, (e.g., orders, invoices, and product or service master data) or tactically and strategically relevant information (e.g., financial data, demand forecasts, customer information) (Ali et al. 2008; Klein and Rai 2009). Additionally, by realizing an information exchange almost in real time, disturbances along the supply chain can be reduced (McFarlane and Sheffi 2003).

Contemporary information technology (IT) offers opportunities for collaborating with network partners faster, more flexible, and at lower costs (Davis et al. 2011). However, a joint IT infrastructure needs to be put and kept in place for storing, processing, and distributing information throughout the network in an efficient manner (Attaran and Attaran 2002). This requires the participating network partners to agree on common standards, transmission protocols, interfaces, and data structures. They have to invest in corresponding, often network-specific, inter-firm resources, (e.g., by programming specific interfaces for specific peer-to-peer connections). Moreover, such inter-firm resources must be managed along their whole life cycle from initiation to termination.

The German automotive industry may serve as an example to illustrate this problem area. The German automotive industry has been facing challenges related to the implementation and management of inter-organizational IT infrastructures for many years. For instance, the German research project "RFID-based Automotive Network—RAN (Lepratti et al. 2014)," funded by the Federal Ministry of Economics and Technology, developed common standards for IT infrastructures for generating event data, a structure of the event data, and an inter-organizational information system (IOS) for exchanging data between network partners (Toth and Liebler 2012). The automotive industry, due to its size, automation, and interconnectivity of its complex collaborative production and logistics processes, strongly depends on timely exchange of accurate and relevant process related information, e.g., about the location and status of objects within production networks. Data exchanged by a so-called InfoBroker network can be used for planning and controlling material flows in production and distribution processes of the automotive industry.

The InfoBroker is an inter-firm resource that needs to be managed along its complete life cycle. In the following, we draw from Alter's (2002) work system method to describe the life cycle phases of such inter-firm resources. For the different life cycle phases, we identify challenges that have to be met in each phase. We also use the InfoBroker network developed within the RAN project to illustrate existing instruments, as well as still existing deficits of collaborative planning, building, operation, and termination of IOS. Finally, we provide an outlook on further research, which is needed to support a life-cycle-oriented management of IOS in production and logistics networks.

The remainder of this paper is structured as follows: The second chapter introduces a life cycle model of IOS. The third chapter presents challenges encountered during the life cycle and illustrates how we coped with these challenges during the RAN project, in which the InfoBroker was developed. The paper concludes with a brief summary and directions for further research.

A Life-Cycle Model for Shared Information Systems

Adopting the terminology of the relational view (Dyer and Singh 1998), IOS represent inter-firm resources, as they are used cooperatively by the different network partners. Each partner invests in and owns some components (e.g., software, hardware) of the overall IOS. IOS comprise components that are not solely located within a single organization, but span organizational boundaries. They must be maintained and operated as long as the networked organizations are cooperating. They may also be subject to termination when networks dissolve or new technological options call for a complete redesign.

IOS in production and logistics networks can be understood as work systems (Alter 2008). "A work system is a system in which human participants and/or machines perform work (processes and activities) using information, technology, and other resources to produce specific products and/or services for specific internal or external customers." (Alter 2008, p. 451) The term work system is generic, as it can encompass information systems, projects, value chains, supply chains, and others (Alter 2002). Hence, IOS represent a specific category of work systems.

Work systems "exist in a particular form during a particular time interval" (Alter 2002, p. 10). Alter describes in his work system life cycle (WSLC) model how the form and state of such a work system evolve through iterations combining planned and unplanned change. Planned change involves the deliberate allocation of resources (e.g., human, financial, and technical resources) to a project with the goal to change the work system's form. Unplanned change happens through minor adaptations apart from such planned projects. The WSLC model assumes, as shown in Fig. 1, that the life cycle of a work system consists of one or more iterations of four the phases, which are the following (Alter 2001):

- *Initiation*: The participating organizations of the network jointly decide that they intend to share information and to have an IOS. In this phase, they clarify the reasons and their objectives for having a planned project to build up or change the IOS. They identify the people and processes that will be affected and allocate time and resources necessary for the project. Unless initial investigations indicate differently, this phase concludes "with a verbal or written agreement about the proposed system's general function and scope, plus a shared understanding that it is economically justified and technically and organizationally feasible" (Alter 2001, p. 15).
- *Development*: The participating organizations design, create, or obtain the IOS or its components, respectively. This phase includes deciding how the IOS will operate and which data will be exchanged. This phase may involve the

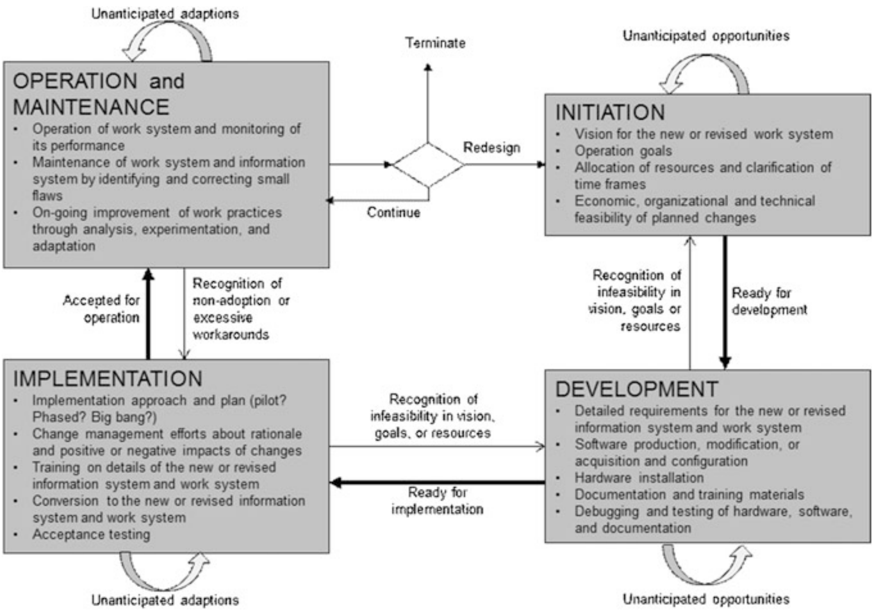

Fig. 1 Work system's life cycle (WSLC) phases and their relations (Alter 2002)

installation of commercial off-the-shelf software or the development of new applications or adapters. The completion of this phase does not mean that the IOS works properly. It just means that the computerized parts of the IOS operate correctly according to technical requirements and that they are ready-to-use at the different organizations within the network.

- *Implementation*: The participating organizations make the IOS operational. Here, implementation does not refer to the process of acquiring, designing, and programming software (which is part of the previous phase), but to the process of making changes to the network and the IOS come alive in the participating organizations. Plans are necessary for changing old ways of doing to the new target state. Business processes in the participating organizations need to be changed and process participants need to be trained accordingly.
- *Operation and Maintenance*: The participating organizations keep the IOS alive and effective. Accordingly, they devote resources to the ongoing monitoring, operations, and maintenance (reflected through minor changes that do not require major projects). The organizations need to ensure that the shared information system provides the benefits and that incremental changes as desired by participants are taken into account. This phase continues until the shared information system is terminated, (e.g., due to a reconfiguration of the supply chain) or another major change is required, (e.g., due to a change from EDI-based to XML-based data exchange), leading to a new iteration.

These four phases apply whenever a project creates or significantly changes the work system, e.g., the shared information system. The fact that the life cycle of a shared information system might involve multiple iterations implies that the system of organizations (i.e., the network) can go through a series of iterations that were not predictable when the organizations first decided to cooperate. “Each iteration typically ends when a period of continuous change (maintenance and incremental improvements) gives way to a discontinuous change in which major parts of the system are re-thought, modified, and possibly merged with other systems” (Alter 2001, p. 10). Having run through these four phases, the decision about the future of an IOS has three general options: (1) operation and maintenance continues including incremental changes, (2) it is redesigned significantly (starting a new iteration), and (3) it gets terminated.

It can be expected that the termination of an IOS or even the termination of the cooperation between organizations as a whole also requires major changes to the affected work systems, leading to further iterations of the aforementioned phases. These possibly affect overlapping but deviating (sets of) systems or subsystems, e.g., in cases where production and logistics networks are reconfigured and the previous IOS needs to be phased out and finally closed down in a structured manner and where each of the previously cooperating organizations must define and implement new work systems themselves (Rajlich and Bennett 2000).

Challenges and Methods Along the Life Cycle

Models for production and logistics network operation often assume that relevant information is available when needed and at fairly low costs. The costs of information systems, compared to their capacity (e.g., the costs per stored data byte) have decreased. However, the costs for common and collaborative design and use of data systems to enable collaboration of different partners in a network remain significant (Whelan and McGrath 2002; Bhimani and Ncube 2006).

The life-cycle-oriented management of information systems within production and logistics networks has to cope with the challenges that come up during initiation, development, implementation, and operation until termination of the IOS. In Table 1, typical challenges of all life cycle phases of an IOS are presented. These challenges have been deduced from the descriptions of the WSLC phases as summarized in the previous section and in Fig. 1.

The RAN project may serve as an example to illustrate which of these challenges have already been addressed in practical applications. The RAN project developed and prototypically implemented the architecture of the so-called InfoBroker, which is an adoption according to the needs of the automotive industry of the Electronic Product Code (EPC) global-network data exchange standard (Werthmann et al. 2013).

Table 1 Challenges during the life cycle of shared information systems

Life cycle phase	Challenges
Initiation	Network partners have to agree on a common vision and goals Necessary resources have to be available at every partner Affected stakeholders have to be involved Contact persons at each company are needed Necessary hardware components need to be available Costs and benefits of the system have to be shared fairly between the partners
Development	Involved companies have to agree on common requirements Necessary interfaces to existing IT systems have to be designed Necessary hardware and software components have to pass test runs Comprehensible and complete manuals have to be composed
Implementation	Implementation steps have to be coordinated between the partners Affected employees have to be trained Conversion to the new systems has to be prepared properly
Operation and Maintenance	Ongoing maintenance has to be executed Data safety and security of data from partners have to be guaranteed Operation has to stick to the agreements from the initiation phase

By developing such a prototypical IOS, the RAN project had to cope with these challenges. In order to allow new partners to join the network as well as to adopt and implement the information exchange standards, the project has developed an "integration concept" describing necessary steps a company joining the network has to follow (RFID-Based Automotive Network 2013b). The integration concept includes methods chosen by the RAN project in order to cope with the mentioned challenges.

For passing the *initiation* phase of a RAN-based shared information system, the partners can choose a so-called control scenario for improving a selected process within the automotive production network. The control scenario provides a description of a reference process, describing the main process steps for such a scenario, the main actors, and the instant of time and the location as well as the general content of the scenario. In addition, it describes advantages of the selected scenario. The specific control scenario cross references to additional documentation where the affected processes and underlying RFID technology are described in more detail. The process documentation describes the most efficient way for using RFID and the InfoBroker technology within each standard process designed within the RAN project. The hardware documentation describes the characteristics of RFID hardware being able to fulfill the requirements of the chosen scenario and may be used to create the data to be exchanged by the InfoBroker network. Suggestions for proper RFID reader installation and for mounting the RFID tags are provided as well. To assess the profitability and resource efficiency of the RAN approach, methods for measuring the costs and benefits have been adopted (Reinhart et al. 2011). These methods can be applied multiple times during the life cycle for assessing the performance of the whole system or parts of it. Based on the results of the assessments, management decisions can be taken about the further development of the shared information system during each life cycle phase.

For the *development* phase, requirements can be derived from the RAN guideline, which describes the developed control scenarios. Standards for the communication interfaces were also developed during the RAN project and can be used to set up the InfoBroker environment. Moreover, standards about the data structure on RFID tags and within the InfoBroker network were also defined. The entire guideline written during the project can be used as a basis for detailed guidelines of the concrete implementation of a shared information system.

For the *implementation* phase, there were no specific guidelines developed as part of the RAN project. Some explanations are available in the RAN integration concept, but they are not specific to shared information systems as they are based on a common procedure model by Tamm and Tribowski (2010). The *operation and maintenance* phase of the system has been given only cursory treatment in the RAN integration concept.

The availability of instruments within the RAN network's integration concept to cope with the above identified challenges is summarized in Table 2.

Table 2 Availability of instruments in RAN integration concept for coping with challenges of shared information systems

Life cycle phase	Challenges	Instruments recommended by RAN project
Initiation	Agreement on common vision and goals Availability of necessary resources Involvement of stakeholders Contact persons at each company Availability of hardware Sharing of system costs and benefits between partners	RAN control scenarios No instruments available RAN control scenarios RAN control scenarios RFID hardware descriptions RAN economic feasibility study
Development	Agreement on common requirements Design of interfaces to existing IT systems Test runs of hardware/software components Composition of system manuals	RAN data and data structures RAN hardware descriptions RAN InfoBroker concept RAN RFID equipment, installation and operation No instruments available
Implementation	Coordination of implementation steps Training of employees Preparation of conversion to new systems	RAN integration concept No instruments available RAN integration concept, RAN InfoBroker concept
Operation and Maintenance	Execution of ongoing maintenance Guarantee of data safety for partners Check system conformity to agreements	No instruments available RAN InfoBroker concept No instruments available

The most controversial aspects within the RAN project were data ownership and cost allocation within the InfoBroker network. Anxiety over the data exchange was not concerned about data safety, but about disadvantages for the provider inherent in providing data to partners within the production network. For example, logistics service providers were afraid that purchase departments of car manufacturers may exert pressure on them when the latter learn about increased process efficiency from the provided data. Having a look at the cost allocation within scenarios using the InfoBroker network some partners see huge benefits when receiving data from network partners. In a lot of scenarios, the partners responsible for providing the needed data, however, do not have benefits that generate a positive return on investment in a proper period of time.

Concerning the mentioned challenges of a life-cycle-oriented management of shared information systems in production networks, the following conclusions can be drawn in assessment of the RAN integration concept: The concept has been developed with the problem of several different network partners in mind. It covers different life cycle phases, however, with emphasis on early life cycle phases, analysis, conception, and realization (implementation). It takes into account network dynamics by providing a concept for setting up new networks as well as for new companies joining an already established network. Dedicated methods for running such networks are lacking, only methods for disjoining or terminating are available. The concept also provides several different perspectives on the networked information system problem, covering technical problems (data and data structures and RFID hardware), organizational problems (providing a control scenario and process repository), and integrating both in a perspective on the Info-Broker architecture. In addition, it covers economic problems with its profitability perspective. Collaboration aspects are integrated into some of these perspectives, in particular, in the control scenario work package. Profitability aspects, however, are covered only from the perspective of an individual enterprise, lacking, for instance, methods for allocation (distribution) of costs and benefits between different partners in the network situated at different points of the value creation chain. The main obstacle for a quick implementation of the InfoBroker in production networks is the uncertainty about disadvantages based on the exchanged data and the cost and benefits allocation resulting from the InfoBroker implementation.

Conclusion and Outlook

IOS are a specific type of inter-firm resources which have to be managed over their whole life cycle, covering the phases of initiation, development, implementation, and operation and maintenance and, possibly also, termination in the end. As the RAN project demonstrates, existing approaches that can be used to address the different problems within the different life cycle phases do not cover sufficiently all concerns of potential network participants about negative consequences of sharing data. Moreover, later phases of the life cycle, like network redesign or termination,

Table 3 Research agenda for life cycle phases

Life cycle phase	Directions for design-oriented research
Initiation	Methods and instruments to enable common, but temporarily and spatially distributed planning and engineering of shared information systems Methods and instruments for mitigating potential negative impacts by the data provided to partners within the networks
Development	Methods and instruments that support a wider application of e-business standards and shared technical platforms
Implementation	Methods and instruments for cross-organizational change management
Operation and maintenance	Methods and instruments balancing of costs and benefits of shared information systems related to their ongoing operation and maintenance

as well as aspects of collaboration between different organizations, for instance the allocation of costs and benefits, are not addressed in a sufficient way either. To deal with these challenges, only the general literature about change management, like by Lientz and Rea (2004), is available. Based on the mentioned aspects, a research agenda for addressing these challenges is formulated in Table 3.

For further exploration of the life-cycle-oriented management of IOS and the use of methods to cope with the respective challenges, an examination of additional case studies would be appropriate. The authors expect that this exploration would result in a more comprehensive list of methods applied in practice for coping with specific challenges in each phase. Based on such a list, a refinement of the research agenda would be possible.

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References

Ali M, Kurnia S, Johnston R (2008) A dyadic model of interorganizational systems (IOS) adoption maturity. In: Proceedings of the Hawaii international conference on systems sciences. Waikoloa, Hawaii, USA. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4438712. Accessed 19 Nov 2013

Alter S (2001) Which life cycle—work system, information system, or software? Commun AIS 7 (17):1–52

Alter S (2002) The Work system method for understanding information systems and information systems research. Comput Inf Sci 9(6). http://eduportal.dmst.aueb.gr/html/det/The_work_system_method_for_understanding_IS__7072.pdf. Accessed 19 Nov 2013

Alter S (2008) Defining information systems as work systems: implications for the IS field. Eur J Inf Syst 17(5):448–469. http://www.palgrave-journals.com/doifinder/10.1057/ejis.2008.37. Accessed 14 Nov 2013

Attaran M, Attaran S (2002) Collaborative computing technology: the hot new managing tool. J Manage Develop 21(8):598–609

Bhimani A, Ncube M (2006) Virtual integration costs and the limits of supply chain scalability. J Acc Pub Pol 25(4):390–408. http://linkinghub.elsevier.com/retrieve/pii/ S0278425406000494. Accessed 12 Nov 2013

Davis M, Spohrer J, Maglio P (2011) Guest editorial: how technology is changing the design and delivery of services. Oper Manage Res http://www.springerlink.com/index/2373262133674710.pdf. Accessed 19 Nov 2013

Dyer J, Singh H (1998) The relational view: Cooperative strategy and sources of interorganizational competitive advantage. Acad Manage Rev http://amr.aom.org/content/ 23/4/660.short. Accessed 19 Nov 2013

Klein R, Rai A (2009) Inter-firm strategic information flows in logistics supply chain relationships. MIS Q. http://dl.acm.org/citation.cfm?id=2017442. Accessed 19 Nov 2013

Lepratti R, Lamparter S, Schröder R (eds) (2014) Transparenz in globalen Lieferketten der Automobilindustrie. Ansätze zur Logistik- und Produktionsoptimierung. Publicis Publishing, Erlangen (in print)

Lientz BP, Rea KP (2004) Breakthrough IT change management. How to get enduring change results. Elsevier Butterworth-Heinemann, Amsterdam

McFarlane D, Sheffi Y (2003) The Impact of automatic identification on supply chain operations. Int J Logistics Manage 14(1):1–17

Rajlich V, Bennett K (2000) A staged model for the software life cycle. Computer 33(7). http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=869374. Accessed 19 Nov 2013

Reinhart G, Irrenhauser T, Reinhardt S, Reisen K, Schellman H (2011) Wirtschaftlicher und ressourcen-effizienter durch RFID? ZWF 106(4):225–230

RFID-based Automotive Network RAN (2013b) RAN Integration Concept

Simatupang TM, Wright AC, Sridharan R (2004) Applying the theory of constraints to supply chain collaboration. Supply Chain Manage An Int J 9(1):57–70

Tamm G, Tribowski C (2010) RFID. In: Günther O, Karl W, Lienhart R, Zeppenfeld K (eds) Informatik im Fokus. Springer, Heidelberg

Tan KC (2001) A framework of supply chain management literature. Eur J Purchasing Supply Manage 7(1):39–48

Toth M, Liebler K (2012) Real-Time Logistics and Virtual Experiment Fields. In: Windt K (ed) Robust manufacturing control. Springer, Heidelberg, pp 327–340

Werthmann D, Brandwein D, Ruthenbeck C, Scholz-Reiter B (2013) Standardized information exchange in automotive distribution processes. In: Bakhtadze N, Chernyshov K, Dolgui A, Lototsky V: Manuf Model Manage Control 7(1):670–675

Whelan E, McGrath F (2002) A study of the total life cycle costs of an E-Commerce investment. A research in progress. Eval Program Plan 25(2):191–196

Autonomous Control Strategy for High Precision Marking of Installation Drill Holes Using a Mobile Robot

Jürgen Pannek, Tom Naundorf and Matthias Gerdts

Abstract Modern production lines typically consist of several components, which have to be installed with high precision in order to work together harmoniously. Upon installation of this equipment, a vast number of drill holes need to be marked. This stage of the setup process of a factory is performed manually at present and henceforth it is both time-consuming and error-prone. Within this work, we present a method to accomplish this task autonomously by means of possibly multiple mobile robots. To this end, we propose a hierarchical event based control strategy for the mixed-integer optimal control problem and provide insight into real-time capable solution methods. Moreover, an experimental setup utilizing a Leica AT901-LR laser tracker and a KUKA youBot is studied. This case study shows that the process can be performed autonomously satisfying the desired marking precision and yet be completed within a shorter time frame thus reducing the costs.

Keywords Autonomous control · Feedback design · Event base control

Introduction

Digital factory has been an upcoming topic for several years and intends to merge industry and Information Technology (IT). The general idea is to use virtual planning tools to accompany the design and construction of buildings and

J. Pannek (✉)
Faculty of Production Engineering, University of Bremen, 28359 Bremen, Germany
e-mail: pannek@uni-bremen.de

T. Naundorf · M. Gerdts
Faculty of Aerospace Engineering, University of the Federal Armed Forces, 85577 Munich, Germany
e-mail: tomnaundorf@bundeswehr.de

M. Gerdts
e-mail: matthias.gerdts@unibw.de

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production facilities such that criteria like process flow, internal and external logistics, working conditions, and transformation ability are improved (Bracht et al. 2011). Before any machinery is installed, respective installation locations and fixing spots need to be marked. At present, this stage is performed by hand. Due to the typically vast number of marking points, the procedure requires a lot of competent personnel and is time-consuming as well as monotonous. Especially the latter property may lead to erroneous markings, which have to be identified and corrected at later stages of the construction.

To reduce the costs of the described stage, we propose the usage of several mobile robots. Each of these robots is connected to a stationary laser tracker and forms an event-based or hybrid control system, see, e.g., Tabuada (2009). The event-based property is due to the problem structure: First, the robot has to be moved to a neighborhood of the target, which allows for performing the marking task. In the second step, the manipulator of the robot has to be controlled such that the desired target is marked with predefined accuracy. Regarding the installation of production lines, the maximal deviation has to be smaller than 1 mm for fixing spots within a range of 100 m and more. To complete the marking task, we formulate an assignment problem between marking spots and robot–laser pairs. Due to its mixed-integer nature, this control problem is challenging and computing times cannot be neglected, cf. Floudas (1995). By introducing a hierarchy of three layers consisting of assignment, external and internal loops, we can circumvent the real-time issue. In particular, once a target is assigned to a robot, the robot has to complete this marking problem before asking for a new assignment. Between two such events, the assignment problem can be solved or updated using model predictive control like methods, see, e.g., cf. Grüne and Pannek (2011) or Kirches (2010), and is real-time feasible.

The paper is structured as follows. First, we provide details on the marking process and the proposed control structure. Thereafter, we discuss the design of the controls, which offer degrees of freedom within our structure, i.e., the assignment and the external feedback layer. Using an experimental feasibility study, we show that the proposed feedback fulfills the precision requirements. Last, we conclude our work and show possible improvements of the control strategy.

Modeling the Marking Process

As described earlier, marking drill holes for a production line is typically scheduled toward the end of the design process of a factory hall. In particular, the coordinates of the drill holes are known beforehand for a given reference frame defining a coordinate system within the factory hall. A simple example may be to center the origin at a corner of the hall and choose one of the walls as the principal axis. Then a second principal axis can be defined to form a Cartesian coordinate system. Such a coordinate system is implicitly given by the technical drawings, which are used to optimally position the elements of the production line.

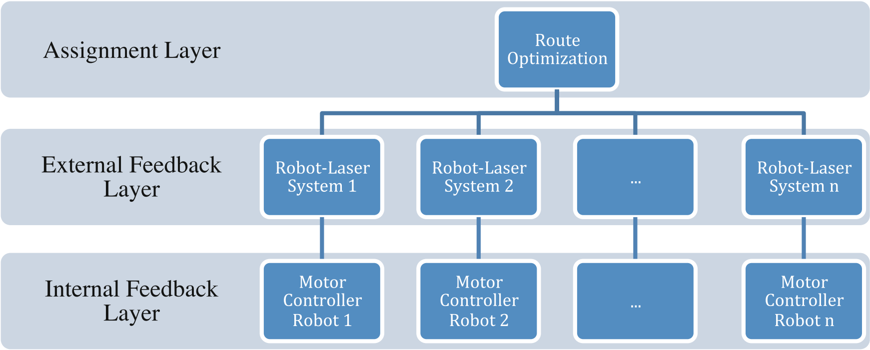
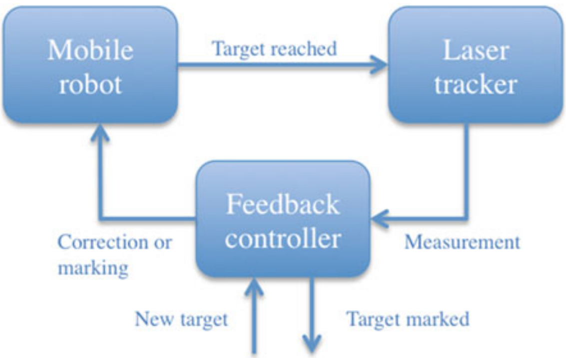


Fig. 1 Hierarchy of the discrete event feedback showing the central optimization combined with feedbacks utilizing external and internal sensors

For the autonomous marking process, we define possibly many base points within the given Cartesian coordinates. These base points are used to position laser tracking systems, which serve as homing devices for the mobile robots. In particular, each laser tracker introduces an additional coordinate system. The latter results from the original Cartesian coordinates by one translation and one rotation.

Each robot consists of a mobile base, one manipulator, and two reflector semi spheres used for tracking the base and the arm. The components of the robot comprise separate local position controllers, and, for security reasons, these mechanisms should not be circumvented. Unfortunately, the robot-based sensors are not accurate enough for our control task. For this reason, we assign a tracker to each robot that combined to form a control system. Within each control system, the position control of the robot exhibits a discrete nature, i.e., a new position should only be assigned once the last position has been reached. Here, we propose the hierarchical discrete event feedback sketched in Figs. 1 and 2 to solve the marking problem.

Fig. 2 Feedback loop within the external feedback layer



The idea of the hierarchical approach is to separate the assignment from the control task. At the top level a central optimal control problem is solved iteratively which

- minimizes the total time of the marking process,
- considers the dynamics of the robots moving within the factory hall,
- avoids collision of the robots, and
- guarantees clear line of sight between each robot–tracker pair.

As a result, each robot–laser pair is assigned a marking task that can be performed independently, i.e., no communication between the robot–laser pairs is necessary.

On the external feedback layer the control loop is designed in the two-step discrete event manner. The steps separate the movement of the robot base and manipulator. Upon completion of each movement, an event is triggered which causes the laser tracker to measure the actual state of the robot. If the position is within a predefined neighborhood of the target, the feedback can switch between base and manipulator or notify the assignment layer that a marking task is completed.

Last, on the internal feedback layer, there are black box control loops incorporating the rotation sensor of the wheels of the base and the joints of the arm. These local feedbacks exhibit several shortcomings, in particular in the context of highly accurate positioning. In the following description of the experimental setup, we discuss the occurring difficulties and their possible treatment within the external feedback layer.

Control Design on the Assignment and External Feedback Layer

As described earlier, the external feedback is event based and consists of two discrete stages corresponding to the robot actuators, see Fig. 2 for an illustration. In the first event cycle, the feedback controller is given a new target that it converts to its local coordinates. Then, a position correction command containing a pair of coordinates is sent to the robot. Using internal sensors the robot steers to the designated target. Once the movement is complete, an event is triggered and the laser tracker provides an accurate measurement of the position of the robot. The feedback controller then determines whether a correction movement is necessary. In this case, the procedure is repeated using a correction of the position of the robot. If a predefined neighborhood of the marking point is reached, the controller switches to the second event cycle. Now, correction commands are used in a similar loop to position the manipulator such that the target can be marked with sufficiently low deviation. Once the marking is completed, the assignment layer is notified and a new target is passed to the controller.

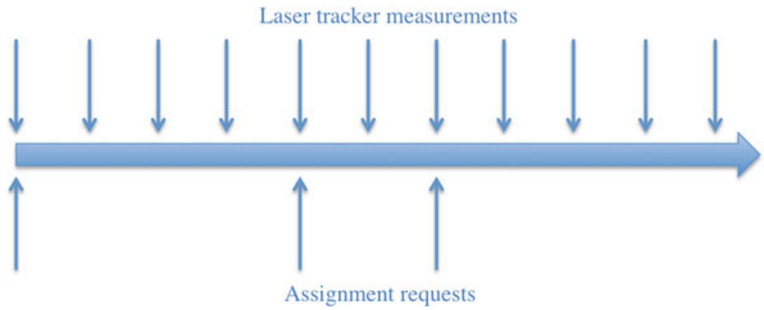


Fig. 3 Sketch of a time frame for several robot–laser subsystems transmitting respective measurement data and requesting new targets

Within the assignment layer, the previously described optimal control problem is solved repeatedly using the latest measurements of all robot–laser subsystems. These measurements are used as initial values of the subsystem dynamics and current as well as past target points are excluded from the problem. Then, at every computation instant, an optimal collision-free assignment for the next marking point is computed for each subsystem. Since the required transition times of the subsystems are unknown, these are problems with free terminal time. Typically, such a problem is hard to solve since the assignment is an integer decision while the robot dynamics are continuous in time, i.e., the problem is a mixed-integer one, see, e.g., Floudas (1995) for solution techniques. However, solutions are only required at time instances where one of the subsystems has completed a marking and requests new target information, cf. Fig. 3. Since the respective time intervals between two subsequent instances are typically large, the problem may be solved in real-time.

The availability of intermediate measurement data by the robot–laser subsystems additionally allows for a receding horizon control like approach. In particular, the measurements can be used to keep the optimal solution of the mixed-integer problem up to date. Indeed, the optimal solution typically changes slightly if the time instances of the measurements are close to one another. Yet, large changes may occur if the time interval between measurements increases. Since large changes require disproportionately long computing times, intermediate updates offer a computationally cheap alternative, cf., e.g., Grüne and Pannek (2011) or Kirches (2010). Additionally, mathematical insight into optimization methods and duals of optimization variables reveals techniques such as real-time iterations, sensitivity or hierarchical updates, cf. Diehl et al. (2005), Pannek and Gerdts (2012), and Bock et al. (2007). In contrast to the recomputation methods described before, these methods utilize the time between two assignments instead of the time between two measurements, and prepare a solution, which is parameterized in the initial value. Once the latest measurement from the robot–laser subsystems is available, the solution can be computed instantly.

While the optimal new target should be assigned to a subsystem, we like to stress that optimality is not required. Indeed, delays due to repositioning on the lower control levels may render a computed solution to be nonoptimal. Feasibility is not an issue for this control task since collisions can always be avoided. Hence, the degree of optimality of such an approach may be measured a posteriori using techniques from Grüne and Pannek (2009).

Note that the assignment layer may also be designed in a distributed control manner utilizing primal or dual data exchange, see, e.g., Pannek (2013), Rawlings and Mayne (2009), or Rantzer (2009). In this case, the collision avoidance problem has to be tackled locally and it is not clear what kind of stability and (sub)optimality can be achieved for our application.

Experimental Setup and Results

In our experiments, we mimic the full range marking process on an experimental scale with the goal of a feasibility analysis of the approach. Therefore, only one robot–laser system is studied and a simple instruction program simulates the assignment.

The mobile robot is a one-arm version of the KUKA youBot, cf. KUKA Industries GmbH (2012) for details. It consists of two actuators, the base and the manipulator. Features of the base are a fully fledged Linux computer and so-called omni wheels, which allow the robot to move in any direction in the plain and rotate on the spot, see Fig. 4 for an illustration.

Note that these moving abilities render the dynamic to be holonomic, see, e.g., Goldstein et al. (2002). We like to stress that this property is not essential for marking problem, yet it simplifies the optimal control problem to be solved on the assignment layer, cf. Reeds and Shepp (1990). The manipulator is mounted on top of the base and possesses five degrees of freedom, which enables the arm to reach the ground, see Fig. 5 for an illustration.

Both base and manipulator feature several rotary encoders such that the rotational position of each omni wheel and each joint can be determined. Additionally, two semi sphere reflectors are mounted on the youBot allowing the laser tracker to measure the exact position of the youBot.

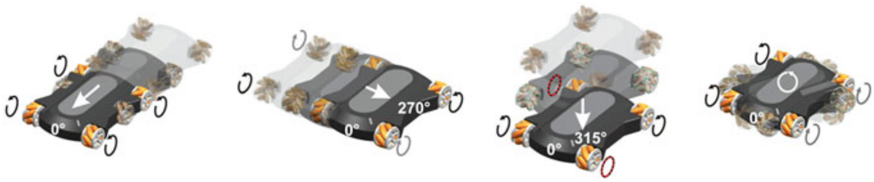


Fig. 4 Translational and rotational abilities of the robot base (©KUKA Laboratories GmbH 2012, pp.17–18)

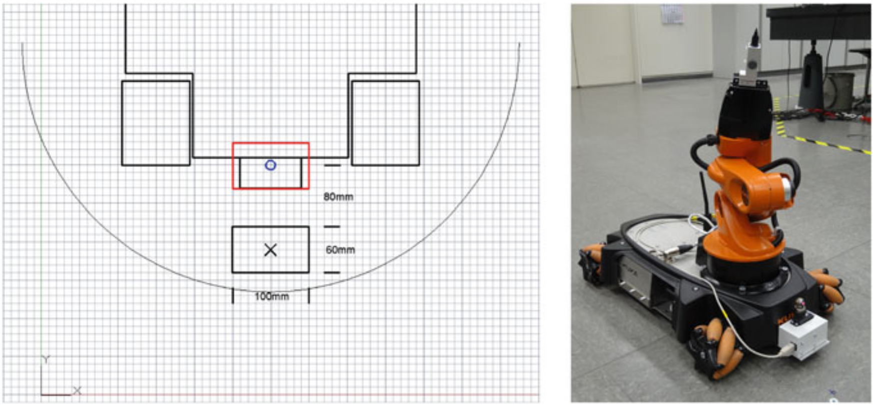


Fig. 5 Schematic of the operating range of the youBot manipulator (*left*) and illustration of the location semi sphere reflectors (*right*). The *red square* and the *blue circle* (*left*) represent the allowable positioning neighborhood of the reflector semi sphere and the position of the reflector semi sphere. The second reflector is mounted on the manipulator (*right*). The target area (*left*) for the marking task is given by the 100 mm × 60 mm square in front of the youBot

Table 1 Stochastic properties of base and manipulator

	Forward	Sideward	Joint 1	Joint 2	Joint 3	Joint 4
Zero offset			1.3°	0.5°	−1.4°	4.5°
Expectancy ratio	0.994094	0.960034	0.986901	0.977830	0.992445	0.931255
Variance	0.000644	0.000890	0.000008	0.000036	0.008501	0.000090

In order to obtain a provisional linear approximation of the movement of both base and arm of the youBot, in (Naundorf 2013) a number of measurement experiments were performed to identify the respective constants, cf. Table 1 and Fig. 6.

Considering the arm, we found that, despite the internal slip of 0.5° per joint, the expectance ratios between set and actual distances as well as the respective variances are sufficiently accurate to perform the marking task with high precision. The variances of the base, however, are too large to position the robot at a certain neighborhood of a target. The main reason for this deficiency is slip at the omni wheels, which is due to their construction and cannot be avoided. Therefore, the external measurements and the external feedback are necessary to guarantee an accurate positioning of the base.

Within our experiments, we used a Leica AT901-LR laser tracker to externally measure the position of the youBot base or arm. The tracker provides two options which are useful for our control task: For one, the absolute interferometer allows dynamically following and measuring the distance to an object. And secondly, the

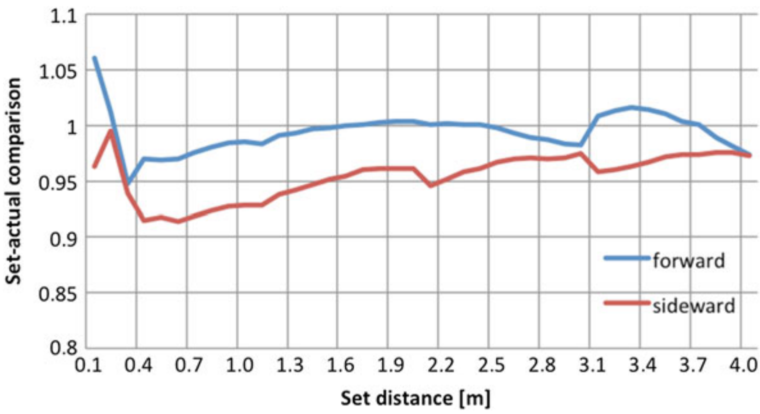


Fig. 6 Set-actual comparison for forward and sideward movement of the youBot base using the quotient of set to actual distance

power-lock functionality allows detecting reflectors within a neighborhood of the current focus. This property enables us to switch between reflectors mounted on the arm and the base. Here, we use a rotatable semi sphere reflector mounted at the front of the base, which is controlled such that its focus is always directed toward the tracker. To measure the arm, a reflector is integrated in the terminal link of the arm. Similar to the base reflector, we control the joint A5, cf. Fig. 5, to point the reflector toward the tracker. Utilizing the power-lock functionality a switch between both reflectors can be performed. To this end, the untracked reflector is moved to a neighborhood of the focus of the tracker and then the line of sight for the tracked one is broken. The Leica AT901-LR works within a range of 160 m with accuracy of 15 µm + 6 µm/m, which is more than sufficient for our positioning accuracy of 1 mm.

During our experiments, we encountered several deficiencies of the youBot such as misalignment of the base due to slip, incorrect internal parameter resetting, and ineffective movements of both base and arm. The external feedback was modified to identify and correct these issues using basic geometric movements or switching to relative coordinates. Due to the compensation mechanisms, the marking process is slowed down significantly, but still faster than a manual approach. Additionally, we found that the described control loop setup is able to achieve the goal of marking an arbitrary series of drill holes on the ground with sufficient accuracy within the range of the tracker, cf. Fig. 7 for an exemplary marking of a calibrated point.

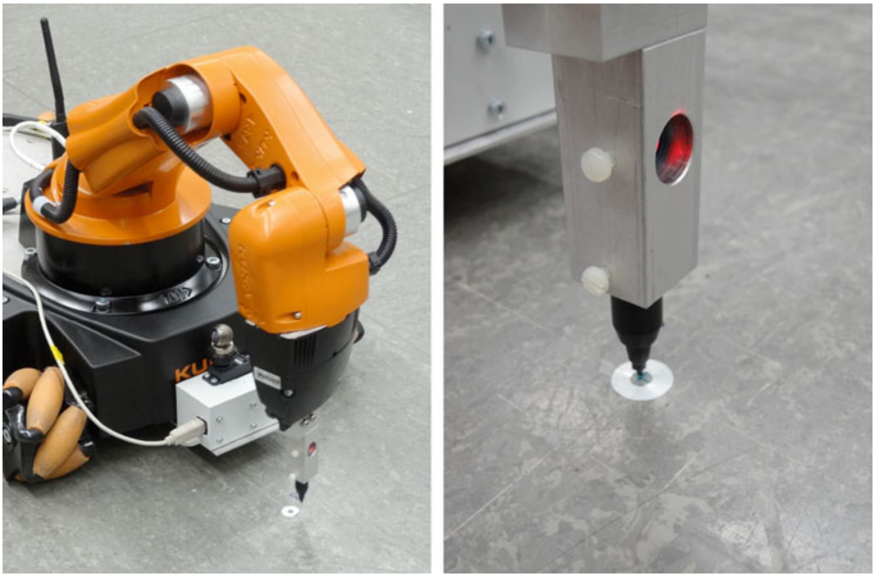


Fig. 7 youBot marking a calibrated point

Conclusion

We have shown that the described hierarchical control design is able to compute an optimal routing plan for the drill hole marking problem for installing automation equipment. Within our experiments we found that the combination of a KUKA youbot and a Leica AT901-LR laser tracker allows us to design a feedback, which has shown the desired accuracy of the marking process during experiments.

The discrete nature of the robot–laser system is one of the key issues to be treated in future research. As a consequence, the time-consuming error identification and compensation methods within the external feedback may be removed. Additionally, we plan to integrate the external feedback layer into the assignment layer by means of a cooperative dynamic game approach. The advantage of such a structure is that target may be switched on the fly, thus reducing the total time requirements of the marking process.

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References

Bock HG, Diehl M, Kostina EA, Schlöder JP (2007) Constrained optimal feedback control of systems governed by large differential algebraic equations. In: Biegler L, Ghattas O, Heikenschloss M, Keyes D, Bloemen Waanders B (eds) Real-Time PDE-constrained optimization, pp 3–22

Bracht U, Geckler D, Wenzel S (2011) Digitale Fabrik. VDI Buch, Springer, Berlin. doi:10.1007/978-3-540-88973-1

Diehl M, Bock HG, Schlöder JP (2005) A real-time iteration scheme for nonlinear optimization in optimal feedback control. SIAM Jour Contr 43(5):1714–1736. doi:10.1137/S0363012902400713

Floudas CA (1995) Nonlinear and mixed-integer optimization: fundamentals and applications. Oxford University Press, Oxford

Grüne L, Pannek J (2009) Practical NMPC suboptimality estimates along trajectories. Sys Contr Lett 58:161–168. doi:10.1016/j.sysconle.2008.10.012

Grüne L, Pannek J (2011) Nonlinear model predictive control: theory and algorithms. Springer, Berlin. doi:10.1007/978-0-85729-501-9

Goldstein H, Poole Jr CP, Safko JL (2002) Classical mechanics, 3rd edn. Addison Wesley, Boston

Kirches C (2010) Fast Numerical methods for mixed-integer nonlinear model predictive control. Vieweg Teubner, Berlin

KUKA Laboratories GmbH (2012) Operating and assembly instructions

Locomotec (2012) KUKA youbot User Manual. http://www.youbot-store.com/media/pdf/kuka-youbot_usermanual.pdf. Accessed 19 Nov 2012

Naundorf T (2013) Entwicklung von Regelstrategien zur hochpräzisen Positionierung eines KUKA youBot Roboters. Master thesis, Universität der Bundeswehr München

Rantzer A (2009) Dynamic dual decomposition for distributed control. In: Proceedings of ACC'09, pp 884–888. doi:10.1109/ACC.2009.5160224

Rawlings JB, Mayne DQ (2009) Model predictive control: theory and design. Nob Hill Publishing, Madison

Reeds JA, Shepp LA (1990) Optimal paths for a car that goes both forwards and backwards. Pac J Math 145(2):367–393

Pannek J (2013) Parallelizing a state exchange strategy for noncooperative distributed NMPC. Sys Contr Lett 62:29–36. doi:10.1016/j.sysconle.2012.10.015

Pannek J, Gerdts M (2012) Robust stability and performance bounds for MPC with abstract updates. In: Proceedings of IFAC NMPC12, pp 311–316. doi:10.3182/20120823-5-NL-3013.00020

Tabuada P (2009) Verification and control of hybrid systems: a symbolic approach. Springer, Berlin, doi:10.1007/978-1-4419-0224-5

The Impact of Shortest-Path Searches on Dynamic Autonomous Transport Scheduling

Max Gath, Otthein Herzog and Maximilian Vaske

Abstract The requirements of transport processes have become increasingly complex due to shorter transit times, the individual qualities of shipments, and higher amounts of small sized orders. Especially in courier and express services providing same day deliveries, the high degree of dynamics even increases this complexity. To ensure reliable and flexible planning and control of transport processes, we present a reactive and proactive agent-based system to support the dispatching of logistic transport service providers. Beside the application in simulated real-world processes of our industrial partners, this paper focuses on the impact and relevance of shortest-path queries in the system. We compare the application of state-of-the-art algorithms and investigate the effects of high speed shortest-path computations in agent-based negotiations. The results prove that efficient shortest-path algorithms are an essential key component in agent-based control of dynamic transport processes.

Keywords Shortest-path algorithms · Planning and scheduling · Autonomous logistic processes · Multiagent systems

M. Gath (✉) · O. Herzog · M. Vaske
Institute for Artificial Intelligence, TZI—Center for Computing
and Communication Technologies, Universität Bremen, Bremen, Germany
e-mail: mgath@tzi.de

O. Herzog
e-mail: herzog@tzi.de

M. Vaske
e-mail: zottel@tzi.de

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Introduction

The growing cost pressure in logistics to offer competitive prices, while increasing the quality of services requires logistic service providers to setup more efficient processes. Especially in courier and express services, the optimization of planning and control processes is a complex problem. In courier and express services small- and medium-sized shipments have to be transported within guaranteed time windows and probably within a few hours. Regarding the dispatching process, the general problem can be mapped to the well-known vehicle routing problem (VRP) (Parragh et al. 2008a) or pickup and delivery problem (PDP) (Parragh et al. 2008b). However, the complexity of process planning is even increased by changing amounts and individual qualities of shipments like weight, volume, priority, and value. Handling this complexity in real situations is further aggravated by the high degree of dynamics that results from unexpected events such as rapidly changing order situations and delays. Moreover, the exact amount and properties of shipments are not known in advance. Actual capacities are only revealed while serving tasks. Picked-up shipments decrease the vehicles' capacities during ongoing tours. To react to changing traffic conditions and delays at incoming goods departments, it is essential to adapt tours and timetables while considering actual capacities.

Transport Processes of Courier and Express Services

We started with a detailed documentation and an analysis of the relevant processes of our industrial partners and revealed the interdependencies between processes and actors by modeling the business processes with the well-established *Business Process Modeling Notation* (BPMN). In order to cover the general planning and control, the collected information has been enriched by interviews with other transport service providers and logistics experts. While the dispatching processes of several forwarding agencies are varying in detail, e.g., by applying different software systems, the general procedure is not varying substantially. First, an information system collects all incoming orders and assigns these orders to predefined tours by a static mapping, e.g., of postal codes to tours. In general, the first assignment neither considers the amount of effectively received orders nor the properties of shipments or available vehicles, but is an essential preprocessing step. Second, this allocation is optimized by the dispatcher. Time critical orders are processed with higher priority and orders of overloaded tours are identified and reassigned to tours with available capacities. After this rough planning a fine-grained planning process is started by each contracted freight carrier. In this step, the freight carrier schedules its trucks and assigns the orders to one of its vehicles. Next, the freight operator determines the route by applying its expertise and additional knowledge, e.g., about preferred time slots of incoming goods departments. Damaged or time critical orders which cannot be processed within guaranteed time windows are reported to the forwarding agency. Thus, external transport providers may be instructed to transport these time critical goods. In conclusion, the general planning and control processes in groupage traffic reduce the problem complexity by splitting up the overall problem (the assignment of all orders to vehicles while considering relevant constraints) into smaller problems with less complexity. After the preprocessing, each contracted transport company is solving the reduced problem to assign a subset of orders to a subset of vehicles. However, this implies that possible dependencies and optimization potentials between orders of different transport companies are not detected and consequently neglected. Next, we identified the data, which can serve as a basis for the decisions in autonomous processes and analyzed their format, amount, quality, feasibility, relevance, and the point of operation where the data is available. Consequently, processing only data, which is available in current processes, allows for the integration of autonomous logistics processes without any new hardware investments. For instance, software systems should not consider the exact volume, as there is no reliable information available in current information systems, because the volume of heterogeneous goods cannot determine automatically so far. With the data provided by our industrial partners we aggregated several performance indicators to quantitatively describe the current stages of processes and to identify the optimization potential in the business processes, which is related to dispatching. In conclusion, the general problem of our industrial partners refers to the VRP (Golden et al. 2008) which is concerned with determining tours with minimum costs for a fleet of vehicles to satisfy customer requests at different destinations while the start and end point of the tour is the depot.

Related Work

In forwarding agencies, information technologies support dispatchers in their decision making who still create tours manually on the basis of individual long-term experiences. Indeed, there are several professional transport management systems (TMS) for planning and controlling transport processes like PTV, 4Flow, or EURO-LOG.[1] Moreover, in the past decades, numerous efficient heuristics and metaheuristics have been developed for the transportation domain such as ant systems, tabu search, simulated annealing, and genetic algorithms (Parragh et al. 2008a, b; Golden et al. 2008; Gendreau and Bräysy 2005). However, the dynamics in logistics and individual requirements of the application domain are often neglected. Central planning and control in dynamic and complex logistic processes is increasingly difficult due to the requirements of flexibility and adaptability to changing environments. The goal is to optimize the planning and control processes

[1]See: http://www.ptvgroup.com; http://www.4flow.de; http://www.eurolog.com.

by providing operational plans, tours, and routes automatically while considering all relevant data to enable optimal decision making at any point of the operations.

In autonomous logistic processes, the decision making is shifted from central, hierarchical planning, and control systems to decentralized, heterarchical systems (Scholz-Reiter et al. 2004). Intelligent software agents represent logistic entities, e.g., containers or vehicles. Thus, they are able to plan and schedule their way throughout the logistic network autonomously (Schuldt 2011). The agents act on behalf of the represented objects and try to reach the objectives assigned to them by their owners. Consequently, relevant information is directly linked to products. For instance, an agent representing a shipment is aware of its individual weight, volume, and its designated place and time of arrival. As a result, the material flow is directly connected to the information flow, which allows agents to receive and process relevant data immediately. By considering real-time information about the status of the physical world, the quality of the agents' decision-making processes is improved. The agents apply and share this knowledge by communication and negotiation mechanisms with other agents, in order to optimize the efficiency of processes and the resource utilization. Semantic technologies such as domain-specific ontologies, communication protocols, and speech acts are applied to ensure the unambiguous exchange of information. By delegating planning and control processes to decentralized entities, the overall problem is split into smaller problem instances that can be solved optimally. The advantages of applying multiagent systems are high flexibility, adaptability, scalability, and robustness of decentralized systems through problem decomposition and the proactive, reactive, and adaptive behavior of intelligent agents (Wooldridge 2013). Therefore, agent systems are especially applied to open, unpredictable, dynamic, and complex environments. There are many examples of multiagent applications within logistic processes for resource allocation, scheduling, optimization, and controlling. Agent-based commercial systems are used within the planning and control processes of containerized freight (Dorer and Calisti 2005). In-house logistic material handling systems have been implemented with self-controlled and self-configured components (Lewandowski et al. 2013). Agent-based systems have optimized planning and control processes within dynamic environments (Fischer et al. 1995; Harjes and Scholz-Reiter 2013). Other ranges of application have been provided for industrial logistic processes (Skobelev 2011).

Agent-Based Dispatching in Dynamic Transport Processes

In our developed system, agents represent transport vehicles and orders. The agents differ in their individual properties, e.g., represented vehicles vary in their capacities, work schedules, and speed limits. Similarly, each *order agent* carries the unique characteristics of its represented shipment such as the pickup and delivery location, weight, value, time windows, and premium service constraints. The goal of *order agents* is to find a proper transport service provider for transporting the shipment from the depot to the destination (or vice versa) within given time windows. *Vehicle agents* negotiate and communicate with *order agents* to maximize the number of carried shipments while satisfying all relevant constraints and premium service priorities.

The system starts with the rough planning step by applying a k-means algorithm (Mac Queen 1967). In contrast to a static mapping from postal codes to tours, the algorithm assigns only effectively arrived orders to available vehicles by grouping orders in nearby districts. Consequently, the flexibility of the rough planning step is increased because the system is able to react to daily as well as seasonal fluctuations. After the rough planning step, each *vehicle agent* starts a detailed planning process. On the one hand, the *vehicle agent* considers the represented truck's capacity, the driving times dependent on the type of the road and the respective speed limits, as well as the individual capacities of the shipments such as the weight, priority, time windows, handling times, and the pickup or delivery location. On the other hand, the agent optimizes the objective functions to reduce cost and determine efficient solutions. For instance, the vehicle identifies the shortest-path for visiting all stops. As a result, the agent solves a selective traveling salesman problem (TSP), which is NP hard (Christofides 1976). The design of two different TSP solver is described by Edelkamp et al. (2013) and by Edelkamp and Gath (2013). The input of the solvers is the distance matrix including all the cities, which have to be visited, and the current position of the vehicle. Thus, several shortest-path searches are applied for the computation of this distance matrix. Especially, in dynamic environments with changing traffic conditions and in scenarios in which orders have to be scheduled during operations, it is infeasible to precalculate all the distances offline. This may only be an adequate solution for static problems when all service requests are known in advance. Section "Shortest-Path Algorithms" describes state-of-the-art and often applied shortest-path algorithms which have been implemented within the decision-making processes of the agents. After the detailed planning step of each *vehicle agent*, several orders may not be serviced by a vehicle. Thus, the responsible agent acts in the same way like agents representing dynamically incoming orders: The agent sends a transport request to available *vehicle agents* and starts a new negotiation. The *vehicle agents* compute proposals by determining their additional cost for transporting the shipment. In order to schedule new orders also while transporting other shipments, the agent considers all relevant changes of the environment and its internal state, e.g., already loaded shipments and the current position of the vehicle. The computed cost is sent back to the *order agent* that chooses the transport provider with the least cost. If it is not possible to satisfy the orders' requirements, a *refuse message* is sent by the *vehicle agent*. To transport a premium service instead of conventional orders, or another premium service with less cost, already accepted orders (that have not been boarded yet) may not be included in the new plan and have to be rescheduled. Affected *order agents* negotiate with other transport service providers again. The agent models consider concurrency aspects within negotiations, the dynamics of the environment, as well as the interdependencies between planning and the execution of an existing plan. Details of the proactive and reactive agent design are provided by Gath et al. (2013a, b).

Shortest-Path Algorithms

In this section, we present three state-of-the-art algorithms, which were implemented within the decision-making processes of the agents. Section "Dijkstra-Shortest-Path" describes the well-known Dijkstra algorithm (Dijkstra 1959). Section "A* Algorithm" continues with the A* algorithm. Section "Hub-Labeling on Contraction Hierarchies" provides a high speed algorithm optimized for road networks which is based on hub-labeling (Abraham et al. 2012) and contraction hierarchies (CH) (Geisberger et al. 2012). All algorithms are complete and optimal.

Dijkstra-Shortest-Path

Let N denote the set of nodes, E a set of edges and dist: $E \rightarrow \mathbb{R}$ a distance function of an edge. The Dijkstra shortest-path algorithm (Dijkstra 1959) is probably the best known and most frequently applied algorithm for the computation of a shortest-path P with the minimum distance $\min_P \sum_{e \in P} \text{dist}(e)$ between two nodes $s, t \in N$. Nodes are labeled as visited, reachable, or unvisited and contain a reference to a predecessor node and a distance to s. At first all nodes are unvisited with an infinite distance. While reachable nodes exist and target t has not visited the algorithm which performs the following steps: First, it chooses the reachable nearest node c. Node c is labeled as visited and all unvisited nodes n connected to an outgoing edge are evaluated next. Let d_n denote the distance from s to n. If n is reachable and d_n is smaller than its currently saved distance, mark n as reachable with distance d_n and predecessor c. After termination, if there exists a path from s to t, the distance of t denotes the shortest distance from s to t.

A Algorithm*

The A* algorithm is similar to the Dijkstra algorithm, but applies an additional heuristic which underestimates the real cost from a processed node to the target to push the search in the right direction and avoid the expansion of nodes which are not part of the shortest-path. For instance, on road networks the Euclidian air distances may be used as a valid heuristic. We implemented a memory efficient version of the A* algorithm which is based on radix heaps. As a result, each node can be processed in constant time and space. Details about this algorithm are provided by Greulich (2013).

Hub-Labeling on Contraction Hierarchies

Since 2011, hub-labeling algorithms (HL) (Abraham et al. 2011) in combination with CH (Geisberger et al. 2012) have become the most efficient approach for shortest-path queries. For instance, shortest-path queries on the whole transport network of West-Europe are processed in less than a millisecond (Abraham et al. 2011, p. 239; 2012, p. 34). First, the CH and hub-labels are computed for each node offline. The general idea of distance labeling algorithms is that the distance between two nodes is only determined by the comparison of their assigned labels. Thus, search queries on the generated labels are efficiently performed online. Hub-labels contain a list with references to several other nodes (the hubs). At the labeling processes, the *cover property* has to be fulfilled: "for any two vertices s and t, there exists a vertex on the shortest s–t path that belongs to both labels (of s and t)" (Abraham et al. 2011, p. 230). Consequently, the cover property ensures that all shortest-paths in a graph may be determined by the labels of the source and target nodes. Especially if the labeling algorithm is applied on nodes saved in CH, this allows memory efficient label representations. In order to build a CH, a preprocessing step is started which extends the original graph g to a larger graph g'. The resulting graph g' contains direct shortcuts between nodes which are represented by paths in g. The algorithm iterates over every node and calculates shortcuts and assigns a distinct level in the CH to the node. For each node a priority value is calculated. The most important value is the *edge difference* between the current graph and the graph resulting from processing that node. The node with the lowest priority is processed next. The performance of the algorithm depends on the sequence of nodes added to the CH (Geisberger et al. 2012). Due to the fact that the sequence relies on the priority of the nodes and the priority changes by the extension of the CH, the priorities are updated continuously after adding a new node to the CH. As the computation of the priorities is cost intensive, it is estimated. The better the approximated values are, the less shortcuts are determined and the more efficient is the memory consumption and the search on the CH. As a result, the priority ordering accelerates the shortest-path searches on the CH because it is goal directed and the shortcuts decrease the number of nodes, which are processes during the search. There are also approaches, which can be applied on time-dependent graphs (Batz et al. 2008) or on dynamically changing graphs (Geisberger et al. 2012).

Evaluation

To describe the system's performance quantitatively and show its applicability, we conclude the results of the case study described by Gath et al. (2013b). For the evaluation, we applied the agent-based event-driven simulation platform PlaSMA.[2] PlaSMA allows the integration of real-word infrastructures imported from OpenStreeMap[3] and supports the continuous simulation of uninterrupted time intervals. Moreover, it includes a geographic information system (GIS) to determine the coordinates of addresses. It is designed for the modeling, simulation, evaluation, and optimization of planning and control processes in logistics. We simulated real-world scenarios based on process data and orders provided by our industrial partners and modeled the road network of their whole business area. In our first investigation, we simulated all orders effectively transported by our industrial partner within two representative weeks. The complete road network infrastructure contains 156,722 traffic junctions and 365,609 roads. It includes all relevant highways, motorways, and inner city roads based on the OpenStreetMap database. Beside its type, also additional information about the distance and the speed limit are included in this infrastructure model. The maximum speed of vehicles is 80 km/h. To cover real-world conditions, a vehicle's speed is reduced to 80 % of the speed limit of the road section. As customers sometimes refuse to accept the delivery of a shipment during operations this is analogously simulated dynamically. The details of the experimental setup are described by Gath et al. (2013b).

Figure 1 shows the amount of shipments which are successfully processed and which are changed between agents in continuous negotiations to optimize the allocation. Note that a shipment may be changed for multiple times if the representing *order agent* finds another vehicle that transports the shipment with less cost.

Within the simulation 1,347,092, TSPs are solved within the decision-making processes of the agents. In relation to the total number of shipments, the high number of changes indicates that the initial allocation is continuously optimized by agent-based negotiations. Thus, the agent system allows for an efficient grouping of packages at pickup and delivery locations. Loads at the same location are transported by a single vehicle, because vehicles generate no additional cost for transporting further shipments from or to an already visited location. In contrast to current processes, the number of shipments transported by external transport providers is thereby reduced by more than 80 %. As a result, the dispatching system reduces the daily costs significantly by increasing the capacity utilization of the own vehicle fleet and by reducing the required number of external transport providers. In addition, the results reveal that a huge number of TSPs have to be solved within the decision-making processes of the agents. For each TSP a distance matrix is computed, which includes information that is only available during daytime operations such as the current position of the vehicle and the locations of new incoming orders. Pre- or offline

[2] http://plasma.informatik.uni-bremen.de.

[3] http://www.openstreetmap.org.

Fig. 1 Shipments which are successfully processed and changed between agents

computation of distance matrices is not feasible because this could result in a table with |N| × |N| entries. This obviously exceeds the memory requirements.

Figure 2 shows the physical time required for the simulation of a scenario as well as the average number of node expansions required in a single search with different shortest-path algorithms. As the hub-labeling not explicitly expand nodes, we compare the average number of nodes represented by a label. Within the search, this list of nodes has to be processed to identify the shortest way. Note, that all algorithms are well-established shortest-path searches. Likewise to the above-investigated case study, in this scenario we simulated real-world processes with orders provided by our industrial partner. The underlying transport infrastructure contains 85,633 nodes and 196,647 edges. All experiments were performed on a laptop computer with an Intel quad-core i72620-M CPU/2.7 GHz and 16 GB RAM. Memory requirements are not exceeded. Figure 2 clearly indicates that the average number of nodes, which is processed in a single search, is strongly related to the time performance of the overall approach. Although the A* search significantly reduces the number of node expansions, the performance is not increased in the same way. This is due to the time consumption and afford of the heuristic, which is applied at each node expansion to determine the Euclidian distance on the sphere surface of the earth as lower bound cost. Thus, in larger graphs the gap between the number of node expansions and improved time performance of the A* algorithm is decreasing. The results prove a significant impact of the shortest-path.

Algorithm to the computation time of the agent-based dispatching approach even on small infrastructures investigated in this experiment. As the applied TSP solvers

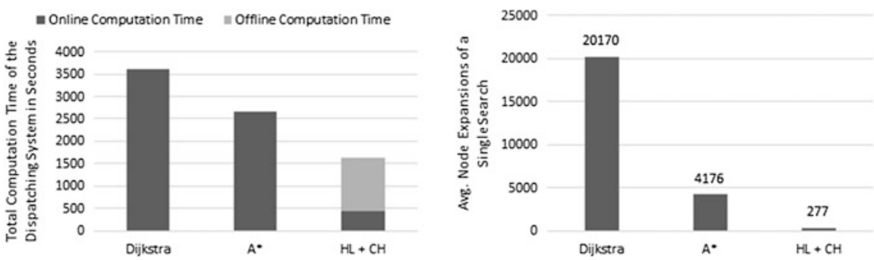

Fig. 2 Comparison of the scenario's computation time and the number of node expansions

are state-of-the-art (Edelkamp and Gath 2013; Edelkamp et al. 2013), this show that the application of the well-established Dijkstra and A* algorithm is the most time-expensive operation of the agent-based dispatching system. In general, this is remarkable because the Shortest-Path Problem is in *P*, while the TSP is an NP-hard problem but easier to handle in real-world application. Moreover, other possible bottlenecks of the system such as the performance of the applied agent management system are not relevant. Thus, it is even infeasible in industrial applications with real-time computational requirements, to apply Dijkstra or A* algorithms in agent-based dispatching systems, but necessary to switch to recently developed high performance algorithms for shortest-path computations.

Conclusion

In this chapter, we presented an agent-based approach for dynamic planning and scheduling in transport logistics. The focus is on shortest-path queries, which provide the basis for the agent's decision-making processes. We presented three well-established implementations of shortest-path searches and compared their impact to the run-time performance of the dispatching system. On one hand, the results show that the developed system optimizes the planning and control processes by our industrial partners. The agent-based dispatching system provides high quality tours, and the system significantly decreases daily costs by reducing the required number of external transport providers. On the other hand, the results prove that standard search algorithms preclude the system's industrial application. In conclusion, an efficient high speed shortest-path algorithm, such as hub-labeling on CH, is a key component and essential for the industrial application of agent-based dispatching systems. Future research will focus on even larger graphs, further speed-up techniques, dynamically changing infrastructures, and the integration of the agent-based dispatching system in Industry 4.0 applications.

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References

Abraham I, Delling D, Goldberg AV, Werneck RF (2011) A hub-based labeling algorithm for shortest paths in road networks. In: Experimental algorithms. 10th international symposium SEA 2011. Lecture notes in computer science, vol 6630. Springer, Berlin, pp 230–241

Abraham I, Delling D, Goldberg AV, Werneck RF (2012) Hierarchical hub labelings for shortest paths. In: Algorithms—ESA 2012. 20th Annual European symposium, Ljubljana, September 2012. Lecture notes in computer science, vol 7501. Springer, Berlin, pp 24–35

Batz GV, Delling D, Sanders P, Vetter C (2008) Time-dependent contraction hierarchies. In: Proceedings of the 11th workshop on algorithm engineering and experiments, New York
Christofides N (1976) Worst-case analysis of a new heuristic for the travelling salesman problem. In: Technical Report 388, Graduate School of Industrial Administration, Carnegie-Mellon University
Dijkstra EW (1959) A note on two problems in connexion with graphs. Num Math 1:269–271
Dorer K, Calisti M (2005) An adaptive solution to dynamic transport optimization. In: Proceedings of the 4th international conference on autonomous agents and multiagent systems, ACM Press, pp 45–51
Edelkamp S, Gath M (2013) Optimal decision making in agent-based autonomous groupage traffic. In: Proceedings of the 5th international conference on agents and artificial intelligence, vol 1, pp 248–254
Edelkamp S, Gath M, Cazenave T, Teytaud F (2013) Algorithm and knowledge engineering for the TSPTW problem. In: IEEE symposium on computer intelligence in scheduling, Singapore
Fischer K, Müller JP, Pischel M (1995) Cooperative transportation scheduling: an application domain for dai. J Appl Artif Intell 10:1–33
Gath M, Herzog O, Edelkamp S (2013a) Agent-based dispatching in groupage traffic. In: IEEE symposium on computer intelligence in production and logistics systems, Singapore
Gath M, Herzog O, Edelkamp S (2013b) Agent-based planning and control for groupage traffic. In: Proceedings of the 10th international conference and expo of emerging technologies (to appear)
Geisberger R, Sanders P, Schultes D, Vetter C (2012) Exact routing in large road networks using contraction hierarchies. Transp Sci 46:388–404
Gendreau M, Bräysy O (2005) Vehicle routing problem with time windows, part I: route construction and local search algorithms. Transp Sci 39:104–118
Golden B, Raghavan S, Wasil E (eds) (2008) The vehicle routing problem: latest advances and new challenges. Springer, New York
Greulich C (2013) Enhanced shortest path computation for multiagent-based intermodal transport planning in dynamic environments, In: Proceedings of the 5th international conference on agents and artificial intelligence, vol 2, pp 324–329
Harjes F, Scholz-Reiter B (2013) Agent-based disposition in event logistics. Res Logistics Prod 2:137–150
Lewandowski M, Werthmann D, Gath M, Lawo M (2013) Agent-based control for material handling systems in in-house logistics. In: European conference on smart objects, systems and technologies
Mac Queen J (1967) Some methods for classification and analysis of multivariate observations. In: Proceedings of the 5th Berkeley symposium on mathematical statistics and probability, vol 1, pp 281–297
Parragh SN, Doerner KF, Hartl RF (2008a) A survey on pickup and delivery problems, part I: transportation between customers and depot. J für Betriebswirtschaft 58(1):21–51
Parragh SN, Doerner KF, Hartl RF (2008b) A survey on pickup and delivery problems part II: transport between pickup and delivery locations. J für Betriebswirtschaft 58(2):81–117
Scholz-Reiter B, Windt K, Freitag M (2004) Autonomous logistic processes: new demands and first approaches. In: Proceedings of the 37th CIRP international seminar on manufacturing systems, pp 357–362
Schuldt A (2011) Multiagent coordination enabling autonomous logistics. Springer, Berlin
Skobelev P (2011) Multi-agent systems for real time resource allocation, scheduling, optimization and controlling: industrial applications. In: Mařík V, Vrba P, Leitão P (eds) Holonic and multi-agent systems for manufacturing. Springer, Berlin, pp 1–14
Wooldridge M (2013) Intelligent agents. In: Weiss G (ed) Multiagent systems. A modern approach to distributed artificial intelligence. MIT Press, Cambridge, pp 3–50

A Mathematical Dynamic Fuzzy Logic to Estimate the Average Throughput Time for a New Automated Full-Case Picking System

Mohammed Ruzayqat, Valentine Obi and Bernd Noche

Abstract This chapter presents a new automated full-case Order Picking (OP) system. A dynamic fuzzy logic will be used to determine the average expected throughput time of the system and to find the mathematical equations, which describe the system. This system has been developed as a new technique that minimizes OP time and other non-value adding tasks and maximizes performance. This new system will improve productivity, accuracy, and speed of order delivery in comparison with conventional automated full-case picking systems.

Keywords Full-case · Order picking · Automated · Indexing conveyor · Dynamic fuzzy logic

Introduction

The Order Picking (OP) is one of most important logistic warehouse's processes. One of the reasons for the high level of importance placed on OP operations is their direct connection to customer's satisfaction, and that is what makes OP one of the most controlled logistic processes. The picking process cost can be over 65 % of the warehouse's operating costs. In fact, the retrieval cost exceeds the storage cost of any given item (Coyle et al. 1996). The efficiency of the OP system depends on many factors including the product demand, the warehouse layout, the location of

M. Ruzayqat (✉) · V. Obi · B. Noche
Transport Systems and Logistics, Duisburg-Essen University, Duisburg, Germany
e-mail: mohammed.ruzayqat@uni-due.de

V. Obi
e-mail: valentine.obi@stud.uni-due.de

B. Noche
e-mail: bernd.noche@uni-due.de

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the items, the picking method in combination with the routing methods, the experience of the employees, and the extent of automation (Gattorna 2003). Minimizing the order retrieval time is therefore a need for any OP system. The travel time to retrieve an order is a direct expense, but it does not add value. It should be noted that in many OP situations, minimizing travel time is chosen as an objective for improvement. It is usually realistic to assume that the travel is an increasing function of the travel distance in case of manual pick OP systems (Hall 1993; Petersen II 1999).

Automated Cell Storage and Retrieval System (ACS/RS) is a new full-case OP system, which is developed for the handling of products in plastic crates, totes, boxes, or bins. This system is ideal for applications with large daily case picking volumes, and the typical application areas can be found in the distribution area of the factories (retailers, dairies, bakeries, meat processing plants etc.), and in e-commerce at distribution centers and cross-docking facilities. ACS/RS presents a new design idea of improving the warehousing performance measures in terms of utilizing the scarce storage space for specific purposes, and designing an OP operation in order to increase productivity, reduce cycle time, and increase accuracy under the concept of automated storage and retrieval system design problem, focusing more on the operations throughput and utilization of the storage area. The proposed design storage system will be described in detail supported by new functions and operations principles. A model case will be modeled and constructed to assist in measuring the effectiveness of the proposed total system performance measures. Future research can compare it with existing practices.

"Fuzzy logic starts with and builds on a set of user supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the way systems behave in the real world. Additional benefits of fuzzy logic include its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity" (Srivastava et al. 2013).

Problem Statement

The idea of this system is based on the vertical indexing conveyor principle to build the storage racks in this model (cells). Many cells are fixed on one conveyor, and many conveyors are built together to form the whole ACS/RS as in Fig. 1.

The ASRCS deals mainly with large volumes of product handled in plastic crates or trays. It has the ability to handle a variety of standard crates. As a full-case crate picking system, ACS/RS is typically applied to commodities such as food, beverage, dairy, flowers, sausage, and bread picking process. In this system crates are stored in cells, which have the same design of the vertical elevator systems. In other words, vertical elevator will be used as a vertical flow rack. Storage and retrieval processes are executed from the bottom side of the elevators, and the horizontal

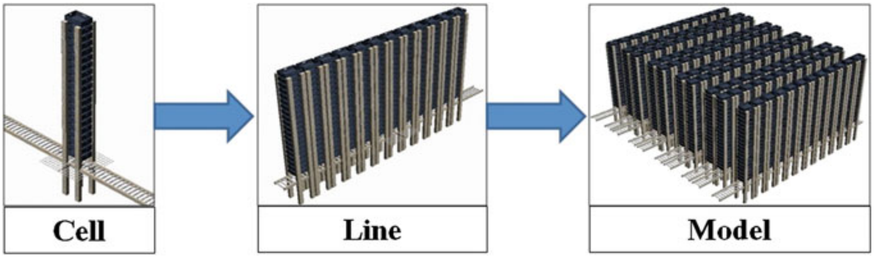

Fig. 1 Three-dimensional (3D) phases to form the 3D layout of the model

movements are undertaken by conveyors installed in the bottom side of the elevators and this conveyor passes through all elevators in the row and the storage strategy will be as Last In First Out (LIFO) strategy. Crates will be picked, transported, and palletized automatically without manual labor.

A mathematical model is needed to describe and find the minimum average throughput time of this system. The throughput of the system can be easily calculated by determining the throughput of one cell per line, and multiplying the obtained value by the number of lines in the model for estimating the throughput of the whole system. In accordance with the speed of the cells and conveyors movements, the required time will be calculated for the SKU input and output processes (storage in cell and retrieval from the cell), and which will be the same for every cell in system, because the cells and the conveyors have a fixed speed for all locations in the system.

Model Parameters

In order to achieve the goals, the layout of the model case is formed by using ten vertical indexing conveyors to form one storage line in the model case, and then ten lines to form the whole model, where every two lines are combined together to form one aisle with a free area (maintenance hallway) for maintenance work as in Fig. 2.

In this model, the storage units or the Stock Keeping Units (SKUs) are plastic crates (each crate has a length of 0.6 m, a width of 0.4 m and a height of 0.28 m), and many crates are stored in one cell. The dimensions of a storage position within the cell are 0.65 m long, 0.45 m wide, and 0.33 m high, and the dimensions of the cell boundary are 0.7 m long, 0.6 m wide, and the cell height depends on the cell capacity. The maintenance hallway width is 0.7 m. The vertical speed up and down of the cell is 0.33 m/s, and the horizontal speed of the main conveyor is 0.5 m/s, while the distributing and collecting conveyor speed is 2.5 m/s.

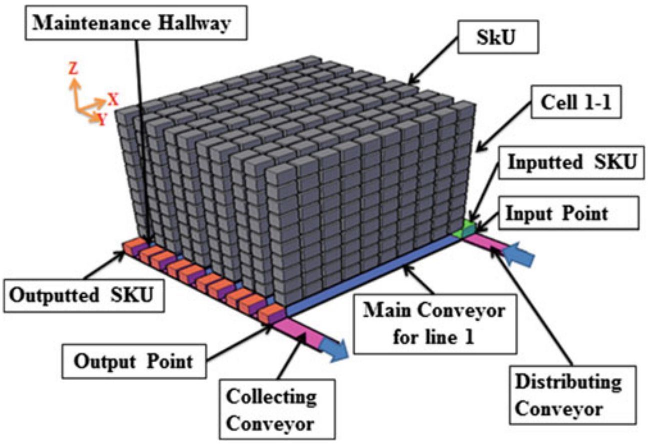

Fig. 2 3D layout of the automated cell storage and retrieval model

Methodology

A dynamic fuzzy logic is used to determine the minimum average throughput time of the model. Assuming that, the capacities of the cells are the same, these cells are full, and all SKUs should be retrieved. In our case to estimate the minimum, average output time can be done by using this logic:

- Select the middle cell in the model.
- Count the movement steps along the SKU path from the first storage position in the middle cell until the output point.
- Make a table of these steps for a number of SKUs.
- Find a mathematical equation to represent these cases for every number of SKUs.
- Convert the movement steps to time-steps by dividing the distance of these steps by their speeds at every time along the SKU path from the first storage position in the middle cell until the output point.
- Aggregate the time-steps for every SKU, and divide them by the number of SKUs to find the average output time for these SKUs.

From the layout of our model there is no middle cell directly, but there are two cells for which the average time is the average output time of the model per line. These two cells will be the cell number 6 on the conveyor number 6 (cell66) and the cell number 5 on the conveyor number 5 (cell55) as in the Fig. 3.

To execute the procedures in the methodology section some assumptions are assumed as follows:

- Box_i is the box of number i in the cell, and we start to count from the first storage position in the cell from the bottom side, (where i = 1, 2, 3, …).

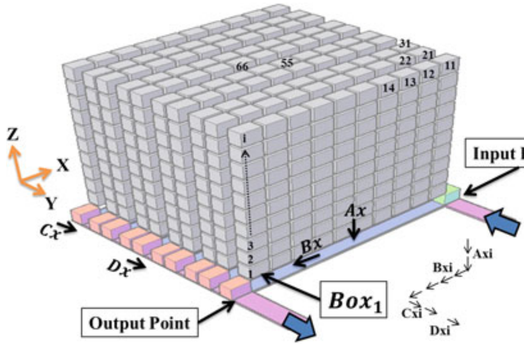

Fig. 3 3D layout of the model case

- AX is the time needed for one unit to finish a vertical travel in the cell.
- BX is the time needed for one unit to finish a horizontal travel on the main conveyor.
- CX is the time needed for one unit to finish a horizontal travel on the collecting conveyor equivalent to the storage line width (cell width).
- DX is the time needed for one unit to finish a horizontal travel on the collecting conveyor equivalent to the maintenance lane width.
- EX is the time needed for one unit to wait within the cell because of the conflict with the previous box.

By using the first three steps in the methodology for cell66 (see Figs. 4 and 5). Then summations of these movement steps are collected in Table 1.

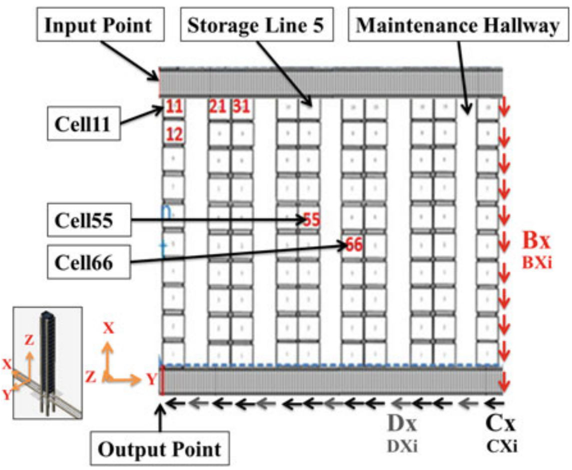

Fig. 4 The top view of the model case

Events / Box Nr.	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END																			
2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END																	
3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END															
4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END													
5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END											
6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END									
7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END							
8	A8	E7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END					
9	A9	E8	A8	E7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END			
10	A10	E9	A9	E8	A8	E7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	C1	D1	C2	C3	D2	C4	C5	D3	C6	END	

Fig. 5 Time table of the output steps for the first 10 boxes from cell66

Table 1 Summations of movement steps for the first 10 boxes from cell66

Box no.	AX	BX	CX	DX	EX
1	1	5	6	3	0
2	2	5	6	3	1
3	3	5	6	3	2
4	4	5	6	3	3
5	5	5	6	3	4
6	6	5	6	3	5
7	7	5	6	3	6
8	8	5	6	3	7
9	9	5	6	3	8
10	10	5	6	3	9

Calculations

By using the last three steps in the methodology we can find that, the total movement steps for Box_i when $i = 1, 2, \ldots, 10$. As in Eqs. (1), (2), and (3):

$$\text{Box}_1 = 1 \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + 0 \times \text{EX} \tag{1}$$

$$\text{Box}_2 = 2 \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + 1 \times \text{EX} \tag{2}$$

$$\text{Box}_{10} = 10 \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + 9 \times \text{EX} \tag{3}$$

Similarly, we can find the final equation for every box number i as in Eq. (4).

$$\text{Box}_i = i \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + (i - 1) \times \text{EX} \tag{4}$$

And to find the average movement steps Ave(MS) for every box number i the Eq. (5) can be used.

$$\text{Ave}(\text{MS}) = \frac{\text{Box}_i}{i} = \frac{i \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + (i - 1) \times \text{EX}}{i} \quad (5)$$

Then to covert the movement steps to time-steps for every SKU, the equations from (6)–(10) can be used as follows:

$$\text{AX} = \frac{H_{\text{cell}}}{V_{\text{v}}} = \frac{0.33}{0.33} = 1\,\text{s} \quad (6)$$

where H_{cell} is the height of the storage position in the cell and V_{v} is the vertical speed of the chain system (cell speed).

$$\text{BX} = \frac{L_{\text{cell}}}{V_{\text{h}}} = \frac{0.7}{0.5} = 1.4\,\text{s} \quad (7)$$

where L_{cell} is the length of the cell and V_{h} is the conveyor speed.

$$\text{CX} = \frac{W_{\text{cell}}}{CC_{\text{v}}} = \frac{0.6}{2.5} = 0.24\,\text{s} \quad (8)$$

where W_{cell} is the width of the cell and CC_{v} is the collective conveyor speed.

$$\text{DX} = \frac{W_{\text{f}}}{CC_{\text{v}}} = \frac{0.7}{2.5} = 0.28\,\text{s} \quad (9)$$

where W_{f} is the width of the maintenance hallway.

$$\text{EX} = \frac{L_{\text{crate}} + T}{V_{\text{h}}} = \frac{0.6 + 0.1}{0.5} = 1.4\,\text{s} \quad (10)$$

where L_{crate} is the length of the crate and T is the tolerance between two crates on the conveyors.

The expected output time for Box_i when i = 1, 2, 3, … according to the model assumptions as follows:

$$\begin{aligned} \text{Box}_i &= i \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + (\text{i} - 1) \times \text{EX} \\ &= i \times 1\,\text{s} + 5 \times 1.4\,\text{s} + 6 \times 0.24\,\text{s} + 3 \times 0.28\,\text{s} + (\text{i} - 1) \times 1.4 \\ &= (2.4i + 7.88)\,\text{s} \end{aligned}$$

Then the average output time for every retrieved box from one cell when the number of retrieved SKUs equal i ($\text{Ave}(\text{OT}_i)$) can be found as follows:

$$\text{Ave}(\text{OT}_i) = \frac{\text{Box}_i}{i} = \frac{(2.4 \times i) + 7.88\,\text{s}}{i} = 2.4 + \frac{7.88\,\text{s}}{i} \quad (11)$$

And from this result we can find the time difference between the two outputted SKUs from the same cell as follows:

$$\Delta \text{Box}_i = \text{Box}_i - \text{Box}_i - 1 = 2.4 \times i + 7.88 - 2.4 \times (i - 1) + 7.88 = 2.4\,\text{s}$$

The total required time for a horizontal and vertical travel of crate = 1.4 + 1 = 2.4 s. It means that when the number of output unit increases by 1, the total output time decreases instantly by 2.4 s. And as the same the $\text{Ave}(\text{OT}_i)$ when i = 2, 3, and 10 can be calculated as follows:

$$\text{Ave}(\text{OT}_2) = \frac{\text{Box}_2}{2} = \frac{2 \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + 1 \times \text{EX}}{2} = \frac{12.68\,\text{s}}{2} = 6.34\,\text{s}$$
$$\text{Ave}(\text{OT}_3) = \frac{\text{Box}_3}{3} = \frac{3 \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + 2 \times \text{EX}}{3} = \frac{15.08\,\text{s}}{3} = 5.026\,\text{s}$$
$$\text{Ave}(\text{OT}_{10}) = \frac{\text{Box}_{10}}{10} = \frac{10 \times \text{AX} + 5 \times \text{BX} + 6 \times \text{CX} + 3 \times \text{DX} + 9 \times \text{EX}}{10} = \frac{31.08\,\text{s}}{10} = 3.11\,\text{s}$$

And by using Eq. (11) the minimum throughput time can be calculated as follows:

$$\text{Ave}(\text{OT}_i) = \frac{\text{Box}_i}{i} = \frac{(2.4 \times i) + 7.88\,\text{s}}{i} = 2.4 + \frac{7.88\,\text{s}}{i} \tag{11}$$

$$\text{Min. Throughput time} = \lim_{i \to \infty} 2.4 + \frac{7.88}{i} = 2.4\,\text{s} \tag{12}$$

It means where the amount of output order is very big, the average output time will be close to 2.4 s. Similarly to cell66, the movement steps from cell55 are collected and analyzed as in Fig. 6, and Table 2.

The same concept is used in the calculations for the cell55.

Event / Box Nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END																		
2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END																
3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END														
4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END												
5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END										
6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END								
7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END						
8	A8	E7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END				
9	A9	E8	A8	E7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END		
10	A10	E9	A9	E8	A8	E7	A7	E6	A6	E5	A5	E4	A4	E3	A3	E2	A2	E1	A1	B1	B2	B3	B4	B5	B6	C1	C2	D1	C3	C4	D2	C5	END

Fig. 6 Time table of the output steps for the first 10 boxes from cell55

Table 2 Summations of movement steps for the first 10 boxes cell55

Box no.	AX	BX	CX	DX	EX
1	1	6	5	2	0
2	2	6	5	2	1
3	3	6	5	2	2
4	4	6	5	2	3
5	5	6	5	2	4
6	6	6	5	2	5
7	7	6	5	2	6
8	8	6	5	2	7
9	9	6	5	2	8
10	10	6	5	2	9

$$\text{Ave}(\text{OT}_i) = \frac{\text{Box}_i}{i} = \frac{(2.4 \times i) + 8.76\,\text{s}}{i} = 2.4 + \frac{8.76\,\text{s}}{i} \tag{13}$$

$$\text{Min. Throughput time} = \lim_{i \to \infty} 2.4 + \frac{8.76}{i} = 2.4\,\text{s} \tag{14}$$

Then the average of these two cells is taken to estimate the real average throughput time and the minimum throughput time of the model per line as follows:

$$\text{Ave}(\text{OT}_i) = \frac{\text{Box}_i}{i} = \frac{(2.4 \times i) + 8.32\,\text{s}}{i} = 2.4\,\text{s} + \frac{8.32\,\text{s}}{i} \tag{15}$$

$$\text{Min. Throughput time} = \lim_{i \to \infty} 2.4 + \frac{8.32}{i} = 2.4\,\text{s} \tag{16}$$

Conclusion

The new state-of-the-art of ACS/RS is completely automated and the labor cost is quite small. Lifts are used for the dual purposes of storage and retrieval in the system. The expected average output time of one unit is 10.72 s, while when the amount of the order is very huge, the average output time will be 2.4 s. The system minimizes the throughput time and is in conformation to the developmental trend of OP, which entails high quantity and low variety. Feasibility study of the system can be investigated in future research. The ability to access all items at one time, which are needed to fulfill the order, and the high ability to increase the throughput of the system without increasing the investment cost are the biggest advantages of this system.

References

Coyle J, Bardi E, Langley C (1996) The management of business logistics, 6th edn. West Publishing Company, New York

Gattorna J (ed) (2003) Gower handbook of supply chain management. Gower Publishing Ltd, Aldershot

Hall RW (1993) Distance approximations for routing manual pickers in a warehouse. IIE Trans 25:76–87

Petersen CG II (1999) The impact of routing and storage policies on warehouse efficiency. Int J Oper Prod Manag 19:1053–1064

Srivastava VK, Goel RK, Bharti PK (2013) Application of fuzzy logic in decision making and grid technology. Int J Eng 2:761–765

Pilot Prototype of Autonomous Pallets and Employing Little's Law for Routing

Afshin Mehrsai, Hamid-Reza Karimi, Klaus-Dieter Thoben and Bernd Scholz-Reiter

Abstract Application of autonomous control for shop-floor scheduling by considering real-time control of material flows is advantageous to those assembly lines with dynamic and uncertain circumstances. Among several potential processors with computing and communication capabilities—for representing autonomous material carriers—wireless sensor nodes seem as promising objects to be applied in practice. For realizing autonomy in making scheduling and routing-control decisions some methodologies need to be embedded in the nodes. Among several experimented methodologies, e.g., artificial intelligence, genetic algorithm, etc., in the context of a doctoral research, in this current special case of assembly scenario, the queuing theory and its simple equations seem quite suitable. For instance, employment of Little's law for calculating and analysis of simple queuing structures is a favorable method for autonomous pallets in real shop-floors. Concerning the simplicity and inexpensive computing loads of such a rule, it suits the best to the low capacity wireless sensors in developing pilot prototypes of autonomous carriers. Little's law can be used to estimate the current waiting times of alternative stations and try to find a non-decreasing order of operations to improve the performance record (e.g., makespan) of the entire assembly system. To develop a pilot prototype, some wireless sensors—representing pallets in practice—are connected to a simulated assembly scenario via the TCP/IP protocol to evaluate the feasibility of realizing autonomous pallets in the practice of shop-floor control. Nevertheless, wireless nodes are distributed objects, so the use of data sharing for transferring low data between each other and respectively low energy consumption is necessary.

A. Mehrsai (✉) · K.-D. Thoben · B. Scholz-Reiter
Department of Planning and Control of Production Systems, University of Bremen,
c/o BIBA, Hochschulring 20, 28359 Bremen, Germany
e-mail: meh@biba.uni-bremen.de

H.-R. Karimi
Department of Engineering, Faculty of Engineering and Science, University of Agder,
4898 Grimstad, Norway
e-mail: hamid.r.karimi@uia.no

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Keywords Autonomous pallets · Shop-floor real-time scheduling and control · Prototype with simulation · Queuing theory · Wireless sensor nodes

Introduction

The exploration of those objects with autonomous control in production and logistics activities has been an interesting topic for scholars in the recent decade. It is also known that planning, scheduling, and control span have three major levels in organization and material flow planning as: strategic, tactical, and operational in logistics and production environment (Bilgen and Günther 2010). Regarding the complexity of material flow scheduling and control in the operational level, autonomous control can be potentially examined for employment in this microlevel of decision making with local perceptions and problem-solving approaches. Among several manufacturing problems, shop-floor (assembly lines) scheduling is a well known one for academics and practitioners. Indeed, the flow control of materials through stations based on a given (conventional) schedule is not always a competent solution; this is particularly true, when the operation circumstance is turbulent and dynamic and affected by uncertain factors. On this basis, the employment of autonomous carriers for moving (semi-)finished materials from a station to another one within a (close to) real-time control manner is a proficient research for practitioners. Introducing the concept of autonomous pallets in simulation experiments by Mehrsai et al. (2013) shed the light to further developments in bringing this concept closer to practice. In other words, there is not a wide range of potential objects in a production logistics environment with lasting capability for a long time in the system than can be suitable for undertaking the passion of autonomous control in practice. By looking into the details of likely candidates with this capability, products themselves and material carriers (e.g., container, pallet, jig, fixture, etc.) can undertake the merit of self-organization. While self-organized products may be more beneficial to products' users, material carriers engaged in production logistic activities are more applicable for manufacturers. Therefore, the idea of making a pilot prototype for autonomous pallets, which can run throughout a production line and autonomously control the flow of materials is desired and followed in this paper.

For this purpose, a comprehensive research was necessary to investigate alternative technologies and methodologies for supporting the occurrence of this favorite desire. In terms of technology, the state-of-the-art in ICT gradually facilitated the realization of autonomous agents in research labs with some experimental implementations. Radio frequency identification (RFID) and wireless sensor nodes (WSNs) are two exemplary technologies using mobile techniques for data storage as well as processing, respectively. These are competent candidates for pilot prototypes; however, RFID is not suitable for those missions with necessary distributed computing. Thus, WSNs are considered for representing autonomous pallets in this chapter. Accordingly, among several methodologies for inspiring the intelligence and computing capabilities to autonomous objects in shop-floors, e.g., artificial intelligence, Little's law in queuing theory seems very appropriate. Because this theorem needs low computing capacity and its algorithm is very simple, which make it suitable for WSNs. Indeed, the main contribution of this paper refers to the application of Little's law in WSNs for locally modeling and analyzing queuing systems by distributed pallets in an assembly system. The introduction to WSNs and the explanation of equations are just briefly mentioned.

The rest of the paper covers a short explanation about WSNs. Following that a description of the pilot prototype for autonomous pallets with the connection to a simulated assembly scenario is given. The queuing theory with the focus on Little's law is purposefully explained in the next section. The developed algorithms for real-time connection to the simulation scenario and the implementation of Little's law in WSNs are described later. Afterwards, the developed assembly scenario is elaborated in detail. Thereafter, the results out of the real prototype are illustrated and compared with other alternative methods, reported in previous academic papers. Finally, the summary and future of the work are described.

WSNs for Mobile Autonomous Objects

One of the most abundantly used technologies to carry the mission of data storage (for external processing) is RFID, which is currently very much applied in industrial applications, e.g., for tracking materials and identification purposes. The advantages like cheap price, relatively reasonable storage capacity, tags with flexibility forms, and adjustable applications make the RFID technology quite suitable for intelligent products toward the autonomy concept. This issue is recently addressed in autonomous product studies by CRC 637 research cluster at the University of Bremen, see www.sfb637.uni-bremen.de. However, RFID tags as pure data collection memories are clustered in the category of passive computing objects with no self-computing capability. This fact makes the variety of RFID as impractical means to be used by autonomous controlled objects for self-organization. On the contrary, WSNs are another means of ICT, investigated by CRC 637 research cluster for autonomous controlled objects, see Fig. 1. If the logistics objects can be generally classified into single items (e.g., products), packages and material carriers (e.g., pallets), and transportation means (e.g., container, forklift trucks), RFID and barcodes can be used for the single items, WSNs for packages and carriers, and GPS/cellular networks for transportation means (Son 2011).

In the recent years, employments of WSNs are increasing in many aspects of modern lifestyles. Those applications have motivated the researchers around the world to attempt to this field for investigating the quality of service (QoS) and performance of networks for more efficiency improvement. Usually, WSNs are supposed to be used in harsh environments; consequently, the performance metric evaluation of real situations is difficult. These WSNs have some capabilities, which

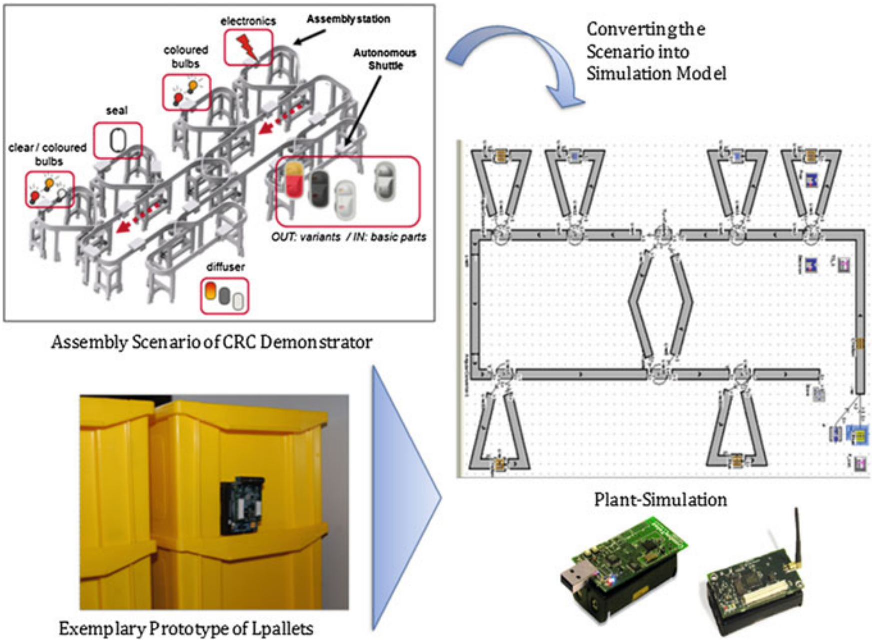

Fig. 1 Integration of WSNs representing autonomous pallets in the rare light assembly scenario of CRC 637, using simulation, WSNs, and TCP/IP protocol

made them suitable to be employed by the project of intelligent containers in the same research cluster mentioned above. Among some competencies of WSNs, their capabilities in collecting and processing data, interacting with their environments via sensors, communicating with each other, and monitoring other objects, to be directly used in logistics operations, all have underlined this state-of-the-art ICT. For more information about the WSN (Telos) see Polastre et al. (2005), Ruiz-Garcia et al. (2009).

An important issue on the application of WSNs in real-time autonomous pallets is to determine the approximate physical location of objects at any given time and local calculation. The knowledge of the location of the nodes presents the opportunity of providing location-dependent services. Also the information embedded in the packet sent from each node in WSNs contains the location of the corresponding node and the computing task. Therefore, the number of nodes and their consumption power has effects on computing power and memory size, which should be considered in real applications (Farahani 2008). Accordingly, data sharing between the nodes is another important issue in saving energy and computing expenses, since every node observes its location and may share its perception with other nodes to reduce complexity. Thus, data sharing supports the desire of computing simplicity as a decisive factor in energy saving. WSNs, representing autonomous pallets in an assembly system, must monitor local key performance indicators

(KPIs) and transmit them to the other active and (/or in sleep mode) nodes to keep continuity of data sharing, while keeping autonomy of nodes. All this needs to be more elaborated in further works.

Prototype of Autonomous Pallets with WSNs

For developing a prototype of autonomous pallets it was decided to employ wireless nodes with limited computation as well as communication capabilities (with WLAN technology). This importance took place by means of connecting real WSNs directly to an already developed simulated assembly scenario in a discrete-event manner. In doing so, the simulated model in Plant-Simulation package is integrated to some WSNs, each of which represents an autonomous pallet in the assembly scenario. This integration is done, thanks to the TCP/IP (a communication protocol) socket with the purpose of real-time synchronizing and experimenting on the performance of real WSNs in rendering control decisions in assembly line environments, see Fig. 1. In addition, Fig. 2 displays the monitoring package of the connected WSNs to each other and to the simulation for data sharing as well as connecting to the TCP/IP socket. There is one node among all which does the mission of data transfer from and to TCP/IP socket and all others share own data with that node. This monitoring package developed by Son, to centrally observe the

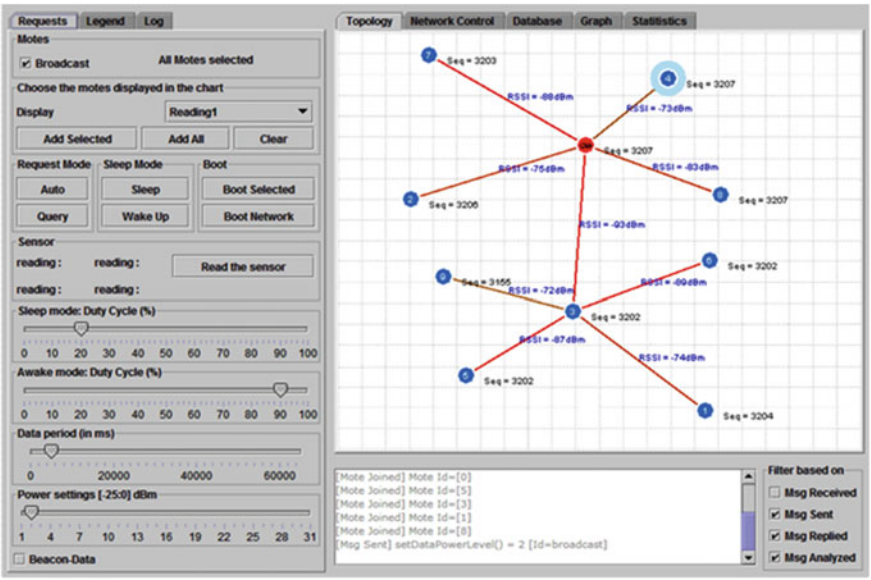

Fig. 2 A Java-based control system for monitoring the performance of connecting WSN by means of TCP/IP (Son 2011)

performance of distributed WSNs in terms of power supply, strength of data transfer, proper communication, and so forth, within an open environment, see Son et al. (2010), Son (2011). The details of the applied communication protocols between WSNs are not covered in this paper. But, the developed algorithm for connecting WSNs to the simulation-scenario and the methodology for autonomous pallets, using Little's law, should be explained in detail. Next section, concisely deals with the queuing theory pertinent to Little's law for modeling and analyzing the assembly system as a queuing system and later it defines the algorithms.

Little's Law in Queuing Theory

Queuing theory is a branch of probability theory that emerged almost one century ago, also known as traffic theory, congestion theory, theory of mass service, and theory of stochastic service systems (Cooper 1981). It is an analysis mathematical tool for studying the relationships between congestion and delay by defining derivation of characteristic quantities such as throughput time (TPT) and waiting time, in those of systems with some jobs to be processed, served, and buffered, e.g., communication systems, banking systems, and production systems. A queuing system can be recognized by three important characteristics as: the input process, the service mechanism, and the queue discipline. Basically, queuing systems are based on stochastic processes like the Markov process (Ouazene et al. 2013).

Applied notations

Notation	Description
ρ_i	Load at station i
λ_i	Total arrival rate at station i
ε_i	Service rate of a single server at station i
μ_i	Total service rate of all servers in station i
L_{qi}	Mean queue length of station i
W_i	Mean waiting time for station i
V_i	Mean system time
MPS	Master production schedule
WS	Work station
WN	Wireless node

The Markov chain is a special case of the Markov process with discrete state space and time. A well-known example for the Markov process is the special process of birth and death (BD) (Gross et al. 2008). Within BD process, transitions occur only to direct neighbors. $\{A_t\}$ counts all the arrivals and $\{D_t\}$ counts all the departures up to the time instance t. Thus, $\{N_t\} = \{A_t\} - \{D_t\}$ is a homogeneous stationary BD process with transition probabilities of $pij(h)$. For more illustration, the state transition diagram of one dimensional BD process is depicted in Fig. 3.

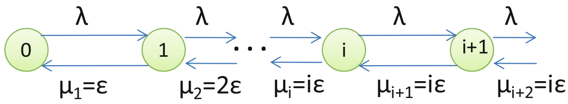

Fig. 3 Finite state process as special case of a BD process

However, the state transition diagram can be depicted when the system is in the discrete-time domain. For instance, M/M/i describes a station with i servers with Markovian arrival $\lambda = \lambda_i; \forall i \in I$ as well as service process. Then in this case from the $i + 1$ state, the queue is built up and then this equation holds true $\mu_i = \mu_{i+1} = \mu_{i+2} = \ldots$. Here, the notations like λ is the arrival rate that follows the Poisson distribution, $\mu = n\varepsilon$ stands for the general service rate of a station, ε is the service rate of one server in the station, and $\beta = \frac{1}{\varepsilon}$ denotes the mean service time for one server $n = 1$.

Generally, there are some KPIs for evaluating the performance of queuing systems, e.g., arrival rate, waiting time, and service rate (Ravindran 2008; Dombacher 2009). Among several evaluation disciplines, Little's Law (1) is a general key for modeling and analyzing queuing systems, since this is a general law and it is not specified for any particular arrival or service distributions, queuing discipline, or number of servers. With respect to the space limit just necessary equations are described. In addition, when the system is in a steady state situation the following equations can be used (i.e., in case of a single server in each station).

$$L_q = \lambda W_q \tag{1}$$

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu-\lambda)} \tag{2}$$

$$V = \frac{1}{\mu-\lambda} \tag{3}$$

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} \tag{4}$$

$$\lambda_i = \rho_i \varepsilon_i \tag{5}$$

Methodology and Synchronization

The procedure of connecting WSNs to the simulation scenario can be shortly described by the algorithm shown in Fig. 4a. Concerning the limited memory and computing capacity, at this level of prototype-development just a simple algorithm inspired by Little's law is employed. Each node, representing an autonomous pallet, collects information about waiting time at every station and builds a list of waiting

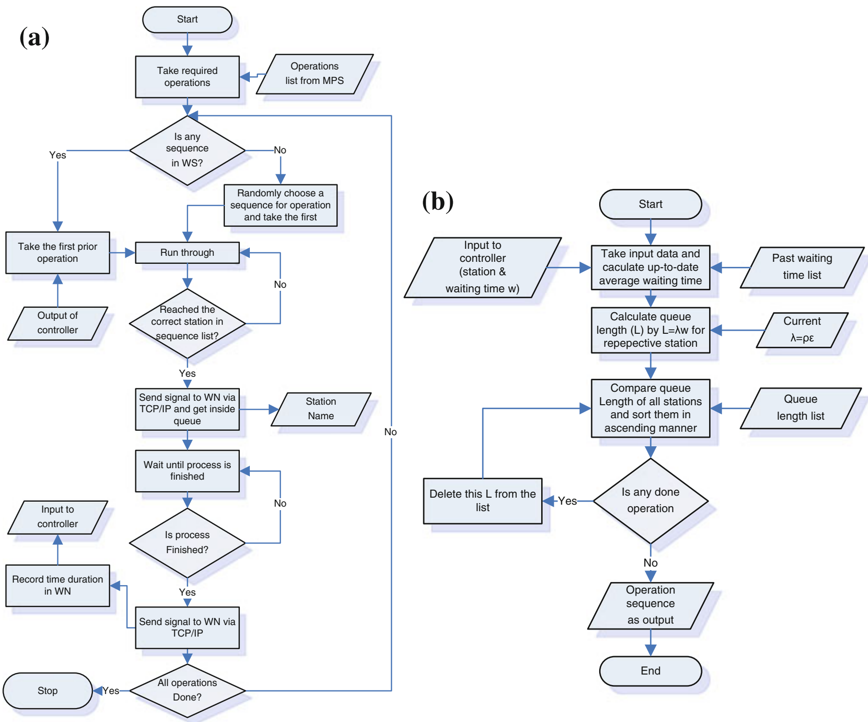

Fig. 4 **a** Processes of connecting WN as autonomous pallets to the assembly scenario. **b** Chart of Little's law controller inside WNs for choosing the next operation in real-time sequencing

times in each visiting event from every station. This leads to a matrix of waiting times collected in different events. In this regard, each autonomous pallet derives the length of queues for every station according to the moving average value of the experienced waiting times (in several round trips) for each station and the current service rate of each station by using (5) and (6).

$$L_i = \lambda_i W_i \tag{6}$$

where ρ_i is the current record of utilization for station i, and ε_i is the service rate of station i, which is considered constant over the simulation horizon. Eventually, according to the real-time values about the utilization of each station every WN approximates the queue length for the respective station. Upon that a priority list (sequencing) for operations can be configured. However, this sequence list is dynamic and after completion of each operation it is recalculated according to the current situation of the system (utilizations and waiting times). Figure 4b defines the procedure of calculating and controlling the operations' sequences inside WNs. This algorithm must be run in front of each single station to update the sequence of the remaining operations and choose the best station for that moment.

Assembly Scenario

Generally, five (5) working stations are assumed for the assembly line that build, together with one (un)load station, a closed-loop network of stations, see Fig. 5. Three (3) final product types are imagined to be assembled and delivered from this system. The number of operations O_{jm} of a job (a semi-finished product) j is equal to the machines' number m, so that each operation is assigned to a specific machine and they visit each machine only once. Thus, there are five (5) operations to be done for each job. Although, the incoming jobs have freedom in selecting the operations' number (sequence) from 1 to 4, and there is a fixed constraint in the last operation. It means the last operation must be machine number 5 or 1, because of the design-restrictions in the assembly system. Moreover, if the last operation is number 1, then the previous operation of that must be done on the machine 5. For the assembly network and the possible permutations for jobs' sequences see Fig. 5. Indeed, with regard to the probability fact of $P(A \cup B) = P(A) + P(B) - P(A \cap B)$, the mentioned constraint in the operations' sequences results in $(4! \times 1! + 3! \times 2! - 3!) = 30$ possibilities for allocating jobs' operations to the m machines. However, if this restriction did not exist the number of permutations with respect to the combination $\binom{S+K-1}{S-1}$, where S defines the number of station and K denotes product types, would result in $7!/(4! \times (7-4)!) = 35$ permutations. Furthermore, the distributed structure of this problem in terms of machines and pallets, besides the stochastic nature of all processes make this allocation problem a case of a complex real-time scheduling over the simulation time horizon.

Each single supply of semi-finished products arrives spontaneously with a stochastic manner to the un-/load station. In practice, the semi-finished products (replenished externally) are moved through the stations by means of pallets and they have to be promptly released to the system with real-time dispatching decisions. Generally, this assembly scenario follows the Conwip material flow control

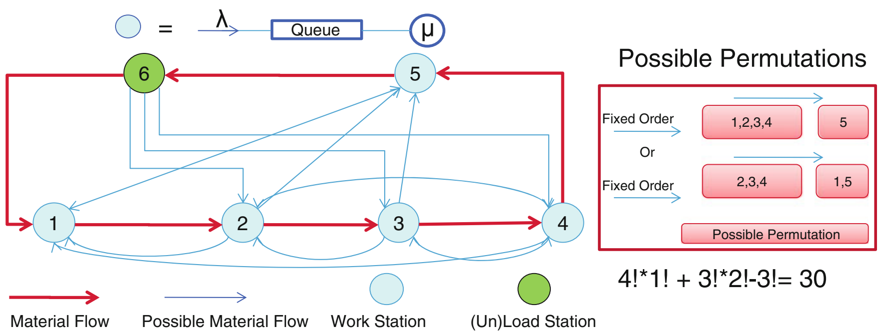

Fig. 5 Simulated assembly scenario on the *left* and the permutations for each job's order (sequence) on the *right*

by means of pallets, i.e., a pallet carries one job (semi-finished product) throughout the network and unloads at the unload station and takes another available job from that station in the next round, see Mehrsai and Scholz-Reiter (2011). Here, different alternative scenarios based on material replenishment and processing times are examined. Variable (stochastic) and constant intervals in the replenishments—between supplies of semi-finished products to the entrance (un/load station)—as well as the unbalanced processing times are the considered alternatives (scenarios). The scenarios are defined with the intention of evaluating the performances of autonomous pallets under different circumstances. Furthermore, the working time, the waiting time, and the blocked time of each station as well as the average flow time (AFT) of finished products and the makespan (completion time of last product) of all orders (150 each type) are the criteria to be compared. Here, the blocked time is the time that a product is asking for operation on a machine, while the machine is busy. In contrary, the waiting time is the time that a machine is waiting for a product to be processed. Table 1 shows the conditions of the three alternative scenarios.

Results of Synchronizing the Prototype and Simulation

Table 2 depicts some numerical data derived from Little's law for the aforementioned hybrid flow-open shop scheduling problem. Besides, these are compared against similar performances out of a conventional dispatching rule: first-in-first-out (FIFO) as well as an intelligent control system—for each autonomous pallet—out of radial basis function neural network (RBFN), see Mehrsai et al. (2013). The superiority of Little's law in simply estimating the direct waiting times, and correspondingly the order of operations can be recognized. The performance records for each station encompass the utilization percentage (working, waiting, and blocking), AFT of every pallet in one round of the assembly network, and the makespan of all jobs.

The results out of Little's law are quite comparable with RBFN and even show a slightly better performance. This can be explained by the simple procedure of this strategy and the direct calculation of waiting times instead of learning and inferring them in case of RBFN. It can be judged that, because of the simplicity of the scenario in this specific case, the straightforward strategy requires no complex and long-term learning procedure; it presents in turn better outputs. Note that application of Little's law with its simple structure is applicable to particular problems with exclusive simple structures, whereas learning pallets with RBFN can be universally used in complex systems with intelligence for rendering decisions.

Table 1 Examined scenarios with the three alternatives

Scenario	Process time of each station					Supply inter-arrival time for a type					Setup time				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	Neg. Exp with ß = 10 min, for all					Neg. Exp with ß = 50 min, for all					5 min, for all				
2	Neg. Exp with ß=10 min, for all					Constant 50 min					5 min, for all				
3	ß1 = 8	ß1 = 8	ß1 = 8	ß1 = 10	ß1 = 8	Constant 45 min					5 min, for all				

Table 2 Examined scenarios with the three alternatives, using Little's law, compared against using FIFO and RBFN, see Mehrsai et al. (2013)

Station	1	2	3	4	5
Scenario 1 with Little's law					
Working (%)	52.36	59.23	58.08	56.15	55.33
Waiting (%)	25.17	19.48	20.10	21.25	22.46
Blocked (%)	22.47	21.30	21.82	22.60	22.21
AFT	2.91 h		Makespan		5 day + 7 h + 33 min
Scenario 1 with RBFN					
Working (%)	60.97	54.82	58.41	55.73	53.45
Waiting (%)	19.36	25.77	21.67	23.91	26.7
Blocked (%)	19.67	19.42	19.92	20.36	19.86
AFT	3.06 h		Makespan		5 day + 12 h + 37 min
Scenario 1 with FIFO					
Working (%)	53.66	52.83	54.95	54.49	59.85
Waiting (%)	24.84	25.67	23.55	24.01	18.64
Blocked (%)	21.5	21.5	21.5	21.5	21.5
AFT	3.04 h		Makespan		5 day + 15 h + 39 min
Scenario 2 with Little's law					
Working (%)	54.84	61.09	54.61	57.86	57.58
Waiting (%)	24.22	17.71	25.55	21.00	20.96
Blocked (%)	20.94	21.20	19.83	21.13	21.46
AFT	2.94 h		Makespan		5 day + 8 h + 08 min
Scenario 2 with RBFN					
Working (%)	57.28	57.66	61.7	57.5	57.72
Waiting (%)	21.13	22.63	15.61	21.17	20.24
Blocked (%)	21.59	19.71	22.69	21.33	22.04
AFT	3.18 h		Makespan		5 day + 8 h + 33 min
Scenario 2 with FIFO					
Working (%)	55.54	54.29	57.54	54.14	50.5
Waiting (%)	16.99	18.24	14.99	18.39	22.03
Blocked (%)	27.47	27.47	27.47	27.47	27.47
AFT	3.49 h		Makespan		5 day + 16 h + 31 min
Scenario 3 with Little's law					
Working (%)	50.45	49.16	53.25	64.95	49.52
Waiting (%)	25.29	28.15	23.63	11.15	26.71
Blocked (%)	24.27	22.69	23.12	23.91	23.76
AFT	2.87 h		Makespan		4 day + 20 h + 25 min

Summary and Future Work

This paper aimed at explaining the initial attempts for a pilot prototype representing the idea of autonomous pallets, utilized for real-time material flow control in shop-floors. This importance took place by employing WSNs and Little's law out of queuing theory for making sequencing decisions by every single autonomous pallet. It is demonstrated that queuing theory has the capability of modeling assembly lines even in network forms, e.g., Little's law can easily be employed by pallets for estimating queuing characteristics in assembly networks. This leads to autonomous pallets for the task of stations' monitoring as well as arranging the operations in a decentralized and real-time control manner. Therefore, to reflect the prototype feasibility of autonomous pallets, queuing theory can be competently used for approximating the general expected records of each queue. Every pallet is able to watch the service rate of each station and then based on the observed load of the station, the arrival rate for that can be estimated. Later, by having the arrival rate and the average experienced waiting time for the station—saved in the memory of WN—the estimated waiting time in that station can easily be calculated by Little's law. Furthermore, the sensitivity analysis is another capability of queuing theory in modeling complex interactive systems including servers, buffers, and customers, see Gross et al. (2008). Generally, sensitivity analysis can be explained as the study of potential changes happening to any system with uncertain variables and their effects on the conclusion and output of the system. Or, in general, it can analyze the uncertainty influences on the queuing systems' behaviors. Moreover, unlike RFID, because of the data processing capability WSNs were chosen to be employed in developing autonomous pallets.

References

Bilgen B, Günther HO (2010) Integrated production and distribution planning in the fast moving consumer goods industry: a block planning application. OR Spectr 32(4):927–955

Cooper RB (1981) Introduction to queueing theory, 2nd edn. North Holland, New York

Dombacher C (2009) Stationary queueing models with aspects of customer impatience and retrial behaviour. Telecom 131. http://www.telecomm.at/documents/Stationary_QM.pdf. Accessed 01 Nov 2013

Farahani S (2008) ZigBee wireless networks and transceivers. Elsevier, Amsterdam

Gross D, Shortle JF, Thompson JM, Harris CM (2008) Fundamentals of queueing theory. Wiley, New York

Mehrsai A, Scholz-Reiter B (2011) Towards learning pallets applied in pull control job-open shop problem. In: IEEE international symposium on assembly and manufacturing (ISAM), pp 1–6

Mehrsai A, Karimi HR, Thoben K-D, Scholz-Reiter B (2013) Application of learning pallets for real-time scheduling by the use of radial basis function network. Neurocomputing 101:82–93

Ouazene Y, Chehade H, Yalaoui A, Yalaoui F (2013) Equivalent machine method for approximate evaluation of buffered unreliable production lines. In: IEEE workshop on computational intelligence in production and logistics systems (CIPLS), pp 33–39

Polastre J, Szewczyk R, Culler D (2005) Telos: enabling ultra-low power wireless research. In: Fourth international symposium on information processing in sensor networks, pp 364–369

Ravindran A (2008) Operations research and management science handbook. CRC

Ruiz-Garcia L, Lunadei L, Barreiro P, Robla I (2009) A review of wireless sensor technologies and applications in agriculture and food industry: state of the art and current trends. Sensors 9(6):4728–4750

Son VQ (2011) Modeling and implementation of wireless sensor networks for logistics applications. Dissertation, University of Bremen

Son VQ, Wenning B, Görg C, Timm-Giel A (2010) WiSeCoMaSys: a tool for data collection and management of wireless sensor networks. In: International conference on advanced technologies for communications (ATC), pp 33–38

Toward a Comprehensive Approach to the Transformation of Logistic Models

Hans-Jörg Kreowski, Marco Franke, Karl Hribernik, Sabine Kuske, Klaus-Dieter Thoben and Caro von Totth

Abstract In this paper, we propose a framework for modeling of logistic systems with an emphasis on model transformation. Due to the complexity of logistic systems, their models are bound to consist of many heterogeneous components on various descriptive levels from the requirement definition to the platform-specific implementation. To cover these phenomena in a comprehensive way, our approach provides two main concepts: First, we introduce logistic models that may be the combination of a variety of component models, which in turn may be of different types, i.e., they may be specified by means of different modeling methods. Second, we offer model transformations that allow to translate logistic models of one type into logistic models of another type whenever needed (for example, to bridge the gap between visual platform-independent models and textual platform-specific models or to facilitate the interaction of component models of different types).

Keywords Interoperability · Model transformation · Heterogeneous modeling

H.-J. Kreowski (✉) · S. Kuske · C. von Totth
Universität Bremen, Linzer Strasse 9a, 28359 Bremen, Germany
e-mail: kreo@informatik.uni-bremen.de

S. Kuske
e-mail: kuske@informatik.uni-bremen.de

C. von Totth
e-mail: caro@informatik.uni-bremen.de

M. Franke · K. Hribernik · K.-D. Thoben
BIBA—Bremer Institut für Produktion und Logistik, Hochschulring 20, 28359 Bremen, Germany
e-mail: fma@biba.uni-bremen.de

K. Hribernik
e-mail: hri@biba.uni-bremen.de

K.-D. Thoben
e-mail: tho@biba.uni-bremen.de

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Introduction

Today's logistic systems are often characterized by a widespread network of various processes and further components, like data bases and programming platforms, a dynamic structuring where subcomponents may be added, removed, or adapted to new requirements, many involved players with different interests, and fast changing customer requests, markets, and technologies. These phenomena result in quite heterogeneous logistic systems consisting of processes and further components that run on different platforms and are developed by means of various planning and modeling methods. For detailed information see Barnhart and Laporte (2006), Laguna and Marklund (2004), Recker (2006).

The increasing complexity, heterogeneity, and dynamism of current and future logistics systems mean that modeling and the transformation of models is highly relevant to the field of logistics. For example, the rapid cycles of contractual relationships in today's supply networks mean that logistics stakeholders frequently need to change their processes. This increasingly entails the integration of processes previously outside the scope of logistics providers, such as manufacturing processes. Furthermore, the integration of these processes into close, multi-stakeholder collaborations throughout supply networks means that multiple process models, often of different types, need to be integrated, simulated, and verified prior to and during contracts.

The IT systems employed by logistics providers also need to be able to handle this increasing complexity, heterogeneity, and dynamism. Currently, logistics providers often meet these demands with quick, in-house development of proprietary systems with little or no support for standard interfaces or data exchange formats. Current advances in cloud computing allow logistics stakeholders to completely outsource IT resources and use individual software modules as "cloud services" on demand on a pay-per-use basis. The resulting IT landscape is highly complex and distributed and spans multiple stakeholders across supply and retail chains. While standard interfaces and data exchange formats exist in the sector, their uptake by industry is not widespread. Correct, verifiable, and robust transformations between different data formats and interfaces, which themselves can be seen as models, are thus critical for the operation of today's logistics systems.

The demand for individualized products and services leads to an atomization of manufacturing and logistic operations. The result is the increasing need for logistics stakeholders to deal with high volumes of "batch size one" orders. Demands with regard to the quality, speed, and traceability of logistic operations are also rising. Recent technical and organizational developments in logistics have been made to meet these demands. The integration of auto-ID technologies such as RFID into logistic processes strives to manage individual items throughout supply and retail chains. With the Internet of Things, traceability can be extended to include information about the environment and condition of goods using sensors and embedded systems. Research into the autonomous control of individual logistics entities has been explored, for example, in the Collaborative Research Centre 637. "Autonomous

Cooperating Logistic Processes—A Paradigm Shift and its Limitations" (Hülsmann and Windt 2007; Hülsmann et al. 2011). Here, logistic objects with the capability to take decisions on their own are assumed to interact with each other in non-deterministic systems. The aim is to achieve increased robustness and positive emergence of the overall system due to the distributed and flexible handling of dynamics and complexity. Conventional methods of modeling are limited in their applicability to these types of highly complex and dynamic logistic systems. While a modeling methodology for autonomous control in logistics has been developed (Scholz-Reiter et al. 2011b), numerous challenges remain unaddressed (Scholz-Reiter et al. 2011a).

Cyber-physical systems (CPS) are the current culmination of these developments. A corresponding definition and detailed information are given in NSF National Science Foundation (2008) or Broy (2010). Their application is expected to revolutionize manufacturing and logistic processes—hence the title "Industrie 4.0" of the relevant high-tech strategy announced by the German government, which anticipates a fourth Industrial Revolution. CPS are themselves highly complex and dynamic "systems of systems" consisting of numerous computational and mechatronic devices. CPS components and their interactions are, however, currently represented by many different models spanning multiple domains so that suitable transformation approaches are required to achieve adequate views upon the systems and their components in design, engineering, and operation.

These trends lead to an increasing number of autonomous and heterogeneous systems in the application field of logistics. This evolution will increase the challenges in the interoperability of logistic processes regarding both the modeling and implementation of the underlying IT landscape. To enable the interoperability of logistic processes in the future, this paper presents an approach to how information can be exchanged between different modeling methods in design phase and between different IT systems in operation time. For this purpose, the notion of heterogeneous logistic model is given in section "Heterogeneous Logistic Models". Subsequently, a general and formal specification of transformation processes between different types of logistic models is given and illustrated with an example in section "Model Transformation Units". The example translates a specific type of business process model into Petri nets, in particular. Finally, the impact of such kind of representation forms and given transformation possibilities is described in the conclusion. The proposed modeling framework adapts earlier work in Kreowski et al. (2010, 2012), Kreowski and Kuske (2013) to the needs of logistics.

Heterogeneous Logistic Models

Models of logistic systems—in particular, large, distributed systems that support the cooperation of many parties—consist of many components that may be designed heterogeneously by means of different modeling methods. The components themselves may be structured in the same way. Without loss of generality, the components may be ordered such that n components can be numbered from 1 to n and a model becomes a tuple of components. If a component is not structured itself, it can be specified as an entity or process of a modeling method or modeling language like *BPMN*, *UML* or Petri nets, or it is an elementary data object like a number, a symbol, a finite set, a string, a file or a document. Summarizing, we propose the following notion of (heterogeneous) logistic models.

Definition 1 Let $\mathcal{L}$ be a collection of modeling methods and modeling languages and let D be a set of data domains. Then a **logistic model** *mod* **of type** T is

1. $mod \in L$ for some $L \in \mathcal{L}$ with $type(mod) = L$,
2. $mod \in D$ for some $D \in \mathcal{D}$ with $type(mod) = D$,
3. a tuple $(mod_1, \ldots, mod_k)$ for some $k \in \mathbb{N}$ and a model mod_i of type T_i for $i = 1, \ldots, k$ with $type(mod) = T_1 \times \cdots \times T_k$.

The set of all models of type T is denoted by $\mathcal{M}(T)$.

To avoid distinction between these cases, in the following we consider all models as tuples. This is possible because there is no need to distinguish between a model *mod* and the 1-tuple (*mod*).

The underlying modeling framework is generic in that the modeling languages and the domains can be chosen according to the intended application and the taste of the designers. The following example may illustrate the principle.

Example 1 $\mathcal{L}$ may contain the modeling language *Business Process Model and Notation BPMN*, the *Unified Modeling Language UML*, the modeling methods of Petri nets, and of event-driven process chains. D may contain the integers, a set *ID* of identifiers, and the truth values $BOOL = \{true, false\}$. Then a sample model is the simple production process *producer* depicted in Fig. 1. It is of type $BPMN_{light}$ which is *BPMN* without pools and swim lanes (OMG 2013).

It can produce two products *A* and *B*, each of which can be sent whenever there is a respective order. The process *producer* is part of a supply chain with a trading

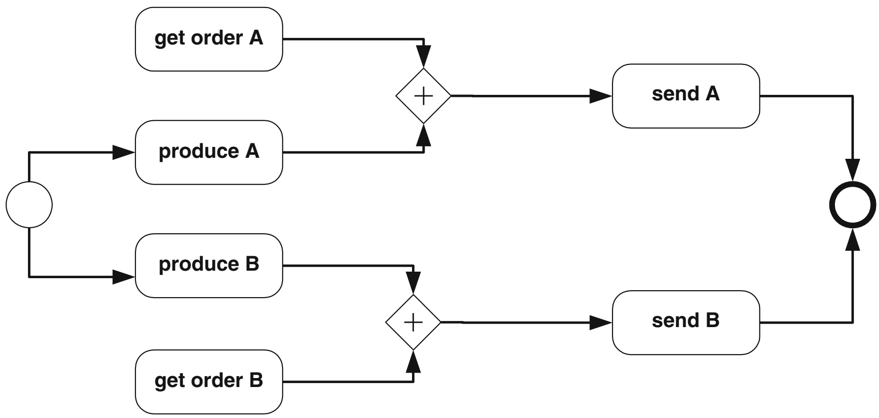

Fig. 1 The *producer* process in $BPMN_{light}$

process *trader* that puts orders of *A* and *B* to the *producer* and receives the sent products from there. In turn, it gets orders from a consumer process *consumer* that also receives the products sent by the *trader*. The start event triggers the activities *get order A* and *get order B* only if there are such orders in the environment, i.e., put by the *consumer*. Finally, *consumer* can put orders to *trader* and receive the products from there. The processes *trader* and *consumer* may also be modeled in $BPMN_{light}$ as given in Figs. 2 and 3 respectively.

If we consider the two sets of activities $InOut = \{get\ order\ A, get\ order\ B, send\ A, send\ B\}$ and $OutIn = \{put\ order\ A, put\ order\ B, receive\ A, receive\ B\}$, then the communication between *producer* and *trader* on one hand and between *trader* and *consumer* on the other hand can be expressed by the pairs (*put order A,get order A*), (*put order B,get order B*), (*send A,receive A*), (*send B,receive B*). The set *connect* of these four pairs is a model of the set type with elements of the type $InOut \times OutIn$. The combination

$$supply_0 = (producer,\ connect,\ trader,\ connect,\ consumer)$$

models the whole supply chain as a quintuple of type $BPMN_{connect} = BPMN_{light} \times C \times BPMN_{light} \times C \times BPMN_{light}$ where C is the type of *connect*.

To complete the section of logistic models, one further aspect is important. As long as one considers free tupling, the components are unrelated with each other so that the tuple and its separate components provide the same information. But in many practical cases the components are related—and should be related—in some way. For example, the $supply_0$-tuple only makes sense if the first set of connectors connects activities of *producer* and *trader* while the second set connects activities of *trader* and *consumer*. Therefore, we allow adding conditions to the declaration of model types restricting the class of models. To formulate the conditions, called

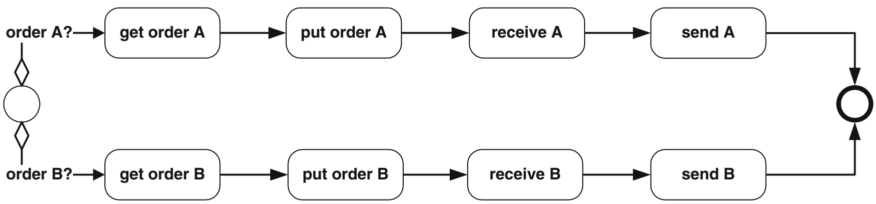

Fig. 2 The *trader* process in $BPMN_{light}$

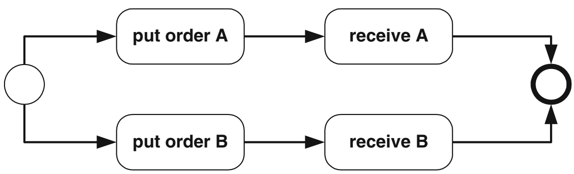

Fig. 3 The consumer process in $BPMN_{light}$

constraints in the following, one may assume a proper logic like the propositional calculus or first order logic. More practically speaking, constraints may be written like Boolean expressions in programming languages.

Definition 2 Let $T = T_1 \times \cdots \times T_k$ be a type with types T_i for $i = 1, \ldots, k$. Let x be some syntactic entity that describes a property that may hold for models of type T or not. Then x is called a **constraint** and T $\underline{with}$ x a **constraint type**. The set of all models of type T for which x holds is denoted by $\mathcal{M}(T\ \underline{with}\ x)$.

It should be noted that constraints can be combined by Boolean operators like *and* and *or* with the obvious meaning that *and* yields the intersection and *or* the union respectively. If we assume the constraint *true* that always holds, then the type T and the constraint type T $\underline{with}$ *true* specify the same set of models. Hence, there is no need to distinguish between types and constraint types. In the following, the term type includes constraint types.

Model Transformation Units

As discussed in the Introduction, there are various good reasons, if not necessities, to transform logistic models. First of all, visual models must be transformed into programs to be integrated into a running logistic system. Moreover, one may want to check required properties using some model checker. But the input models of the respective tool may be of a different type than the models at hand. Model transformation can solve the problem. In this section, we introduce the notion of model transformation units that allow transforming logistic models as introduced in the previous section. As a logistic model is a tuple of component models, the components can be transformed componentwise and simultaneously by means of actions. An action specifies for each component how it is processed using operations that are available for the models of the respective types. If the component models are numbers, strings, or sets, then one can use arithmetic, word-processing, or set-theoretic operations respectively. If the component models are modeled according to a logistic modeling language or method, then suitable operations must be chosen for the construction, reconstruction, and deconstruction of the models. If, finally, the component models are tuples again, then the component operation can be recursively chosen as an action.

As actions keep the type of models, their application can be iterated. In this way, a set of actions defines a complex model transformation. But, usually, transformation processes are not just arbitrary sequences of action applications starting and ending on arbitrary models. Therefore, we assume in addition that initial and terminal models can be specified and that the order of action application can be restricted by means of a control condition.

There is one further aspect to be considered. While actions preserve the type of the processed model, model transformations are meant to transform input models into output models which have different types usually. For example, a visual model of $BPMN_{light}$ may be transformed into a Petri net or a *JAVA* program so that not only the models change, but also their types. To cover this aspect, input, output, and working types can be chosen separately due to the intended model transformation. Then the input models are adapted by an initialization to models of the working type on which the actions run. Finally, the resulting working models are projected to the output type by a terminalization. Given an input model, some components of the working type can be components of the input models, while others may be auxiliary or needed as output components. They are chosen as fixed constant initial models. Given a resulting working model, some of its components are taken as the output model. This leads to the following definition:

Definition 3 Let $\mathcal{L}$ be a collection of modeling methods and modeling languages and $\mathcal{D}$ be a set of data domains. Let, for each $X \in \mathcal{L} \cup \mathcal{D}$, OP_X be a set of unary operations on the models of type X. Then a **model transformation unit** is a system $mtu = (ITD, OTD, WT, A, C)$ where

- $WT = T_1 \times \cdots \times T_k$ is the **working type**,
- A is a set of **actions** on WT,
- C is a **control condition**,
- ITD is the **input type declaration** consisting of an **input type** $IT = I_1 \times \ldots. \times I_m$ $\underline{with}$ x and an **initialization** *initial*,
- OTD is the **output type declaration** consisting of an **output type** $OT = O_1 \times \ldots. \times O_n$ $\underline{with}$ y and a **terminalization** *terminal*.

subject to the following conditions:

1. each action has the form $a = (op_1, \ldots., op_k)$ $\underline{with}$ z where $op_i \in OP_{T_i}$ for $i = 1, \ldots.,$ k *and* z is a constraint,
2. *initial* associates each working type component T_i with some input type component I_j or with a fixed model of type T_i,
3. *terminal* associates each output type component O_j with some working type component T_i.

To enhance the flexibility of actions, we assume that the set of operations OP_T for each type T contains the void operation "-", which refers to the identity. Consequently, an action keeps a component of a model invariant if the respective component of the action is void.

The following example may illustrate the features of model transformation units.

Example 2 We would like to transform a $BPMN_{light}$ model like *producer* into a Petri net, the type of which is denoted by *PN*, to enable us—for example—to employ a model checker for Petri nets (see Aalst and Stahl 2011; Hee et al. 2013 for further relations between business process models and Petri nets). Therefore, the input type is $BPMN_{light}$ and the output type is *PN*. As working type, we take the product $BPMN_{light} \times PN$. The initialization assigns $BPMN_{light}$ to itself and *PN* to the empty Petri net $\varnothing$. Therefore, the initial working models are pairs of $BPMN_{light}$ models and $\varnothing$ like (*producer*, $\varnothing$). The terminalization assigns the only output type

PN to the *PN*-component of the working type. Consequently, the Petri net of any resulting working model is considered as output model. To specify the dynamic part, we need operations and actions. The basic idea is to replace each flow object *f* of the initial $BPMN_{light}$ model by a place *pf*, a transition *tf* and a flow relation from *tf* to *pf* as well as each sequence flow from a flow object *f* to a flow object *f′* by a flow relation between *pf* and *tf′*. In the case of the end event, the transition must be doubled with a flow to the end place each and the two sequence flows into the end event must be redirected to the now different end transitions. To achieve this, we need an operation *mark* on $BPMN_{light}$ models that mark flow objects and sequence flows as *done* provided that they are not yet marked and operations *add*(*f*) and *add* ($f \rightarrow f'$) on Petri nets where *add*(*f*) adds $tf \rightarrow pf$ to a given Petri net and $add(f \rightarrow f')$ adds an edge from the place *pf* to the transition *tf′* provided that both exist. This allows us to combine these operations to the actions *act*(*f*) = (*mark*(*f*), *add*(*f*)) and $act(f \rightarrow f') = (mark(f \rightarrow f'), add(f \rightarrow f'))$ for some identifiers $f, f' \in ID$. It should be noted that the actions can only be applied if the parameters are flow objects and sequence flows of the input process and that none of them can be applied twice so that the length of every sequence of action applications is bounded by the number of flow objects and sequence flows. Moreover, no action can be applied if all elements of the input process are marked by *done*. If we require as control condition that *act*(*f*) and *act*(*f′*) be applied before $act(f \rightarrow f')$ and that actions be applied as long as possible, then each sequence flow becomes reflected in the flow relation of the corresponding Petri net and all elements of the input process are carried over to the Petri net part. For example, the input model *producer* is transformed into the following Petri net, which is shown in Fig. 4.

A schematic representation of the sample model transformation unit may look as follows.

$BPMN_{light}$ -to-*PN*
input: $BPMN_{light}$
working: $BPMN_{light} \times PN$
initial: $BPMN_{light} \rightarrowtail BPMN_{light}$ & $PN \rightarrowtail \emptyset$
actions: act(f) = (mark(f), add(f))
act(f ➔ f') = (mark(f ➔ f'), add(f ➔ f') for f, f'∈ ID
control: act(f) > act (f ➔ f') & act (f') > act(f ➔ f') & as long as possible output: *PN*
terminal: $PN \rightarrowtail PN$

As the sample model transformation unit transforms $BPMN_{light}$ processes into Petri nets, a model transformation unit relates input models to output models in general. A given input model induces an initial working model due to the input type declaration. The working model is transformed by a sequence of action applications which is regulated by the control condition. In particular, the control condition specifies when the action application can terminate. Then the reached working model induces an output model due to the output type declaration.

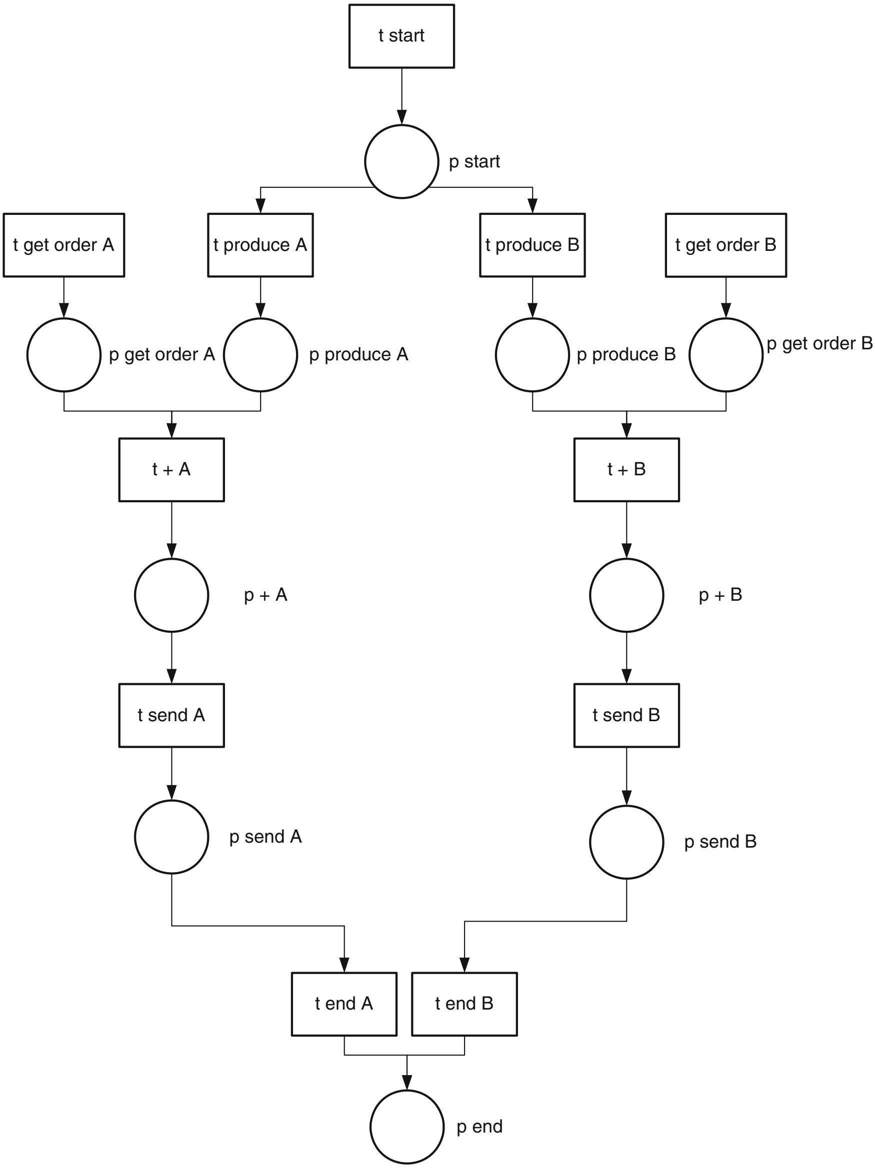

Fig. 4 The $BPMN_{light}$ process *producer* transformed into a Petri net

Definition 4 Let $mtu = (ITD, OTD, WT, A, C)$ be a model transformation unit. Then *mtu* specifies the **semantic relation** $SEM(mtu) \subseteq \mathcal{M}(IT) \times \mathcal{M}(OT)$ between input and output models, where an input model $in \in \mathcal{M}(IT)$ is transformed into an output model $out \in \mathcal{M}(OT)$, i.e. $(in, out) \in SEM(mtu)$, in the following three steps:

1. Let $IT = I_1 \times \cdots \times I_m$ with x and $WT = T_1 \times \cdots \times T_k$. Then $in = (in_1, \ldots, in_m)$ gives rise to a working model $mod(in) = (mod_1, \ldots, mod_k)$ with $mod_i = in_j$ if *initial* associates T_i with I_j, and $mod_i = init_j$ if *initial* associates T_i with the fixed model $init_j$.
2. Let $\Rightarrow_A \subseteq \mathcal{M}(WT) \times \mathcal{L}(WT)$ denote the application of actions in A to working models, $\Rightarrow_A^* \subseteq \mathcal{L}(WT) \times \mathcal{M}(WT)$ the reflexive and transitive closure of $\Rightarrow_A$, i.e., the arbitrary iterations of action applications, and $\Rightarrow_{A, C}^* \subseteq \mathcal{M}(WT) \times \mathcal{M}(WT)$ the iterated action applications that obey the control condition C. Then $mod(in)$ is transformed using $\Rightarrow_{A, C}^*$. A working model $mod' \in \mathcal{M}(WT)$ is considered as a result if $mod \Rightarrow_{A, C}^* mod'$.
3. Let $mod' = (mod'_1, \ldots, mod'_k)$ be a result and $OT = O_1 \times \cdots \times O_n$ with y. Then the output $out = (out_1, \ldots, out_n)$ is given by $out_j = mod'_i$ if *terminal* associates O_j with T_i provided that *out* satisfies the constraint y.

A further example may help to see the meaning and significance of the introduced concepts.

Example 3 The supply chain $supply_0$ in Example 1 is a heterogeneous model with five components of two different types. It may be preferable to have a homogeneous model of some suitable type, say *BPMN*, because there may be a simulator available for *BPMN* processes or an automatic transformation of *BPMN* processes into *JAVA* programs. A model transformation unit can bridge the gap between $supply_0$ and *BPMN*.

$BPMN_{\text{connect}}$-to-*BPMN*
input: $BPMN_{\text{connect}}$
working: $BPMN_{\text{connect}} \times BPMN$
initial: $BPMN_{\text{connect}} \rightarrowtail BPMN_{\text{connect}}$ and $BPMN \rightarrowtail \varnothing$
actions: *(-,add(p)) & (-,add(c))*
control: (-,*add*(*p1*)); (-,*add*(*p2*)); (-,*add*(*p3*)); (-,*add*(*c1*)); (-,*add*(*c2*))
output: *BPMN*
terminal: $BPMN \rightarrowtail BPMN$

where $\varnothing$ denotes an empty pool, the operation *add*(*p*) for a $BPMN_{light}$ process p adds p as a new swim lane to the given pool, the operation *add*(*c*) for a binary relation $c \subseteq ID \times ID$ adds the elements of c as message flows provided that c relates flow objects of two swim lanes of the given pool, and where $(p_1, c_1, p_2, c_2, p_3)$ identifies the input model. Moreover, the control condition requires that the five actions are applied one after the other denoted by means of the sequencing operator ";". Semantically, the model transformation unit takes a $BPMN_{connect}$ model, combines it with the empty pool in the first step, applies the five actions, and projects the result to the second component. Note that the first component is not changed and that the model constraints make sure that the two connectors c_1 and c_2 relate activities of the respective swim lanes. Applied to $supply_0$, the transformation yields the *BPMN* process $supply_1$, which is shown in Fig. 5, where dashed arrows

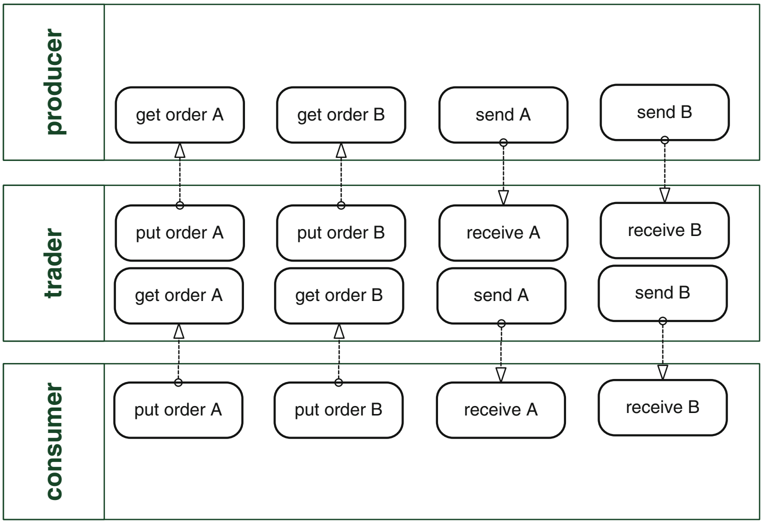

Fig. 5 *BPMN* model of the supply chain (confer example 1 for the complete subprocesses)

denote the message flows and those activities of the three swim lane processes that are involved in the communication are given explicitly.

Conclusion

In this paper, we have sketched fundamental concepts constituting a framework for the modeling of logistic systems: logistic models that can be heterogeneously composed of component models and specified by means of different modeling languages as well as model transformations that bridge the gap between different descriptive levels and support the interaction of models of different types. To shed more light on the significance and usefulness of the approach, further topics must be studied:

1. Further case studies, which are more realistic than our small toy supply chain, are needed. In particular, the use of further modeling languages and methods and their coexistence within modeling of one model should be demonstrated.
2. We have pointed out that model transformation is necessary if one wants to employ a tool for testing, simulation, visualization, or verification that requires input models of another type than the models at hand. It would be of interest to show explicit cases where such transformations are advantageous.
3. The actions of model transformation units combine operations on the component models depending on their types. If the types refer to truth values, numbers, sequences, or sets, then one can use the usual Boolean, arithmetic, word-processing, or set-theoretic operations respectively. If a component is a tuple again, then it can be operated by actions again. But if it is specified by

means of a modeling language, then it may be necessary to enrich the language by new operations like the marking of activities and sequence flows in the $BPMN_{light}$ examples and the building operations in the *BPMN* and Petri net examples.

4. The introduced modeling of logistic systems has not only a formal syntax, but also a precise formal semantics. Potentially, this permits to prove interesting properties like termination, functionality, and correctness of model transformations, which cannot be addressed properly without formal semantics.

References

Barnhart C, Laporte G (2006) Handbooks in operations research and management science: transportation. Elsevier Science and Technology, Amsterdam

Broy M (2010) Cyber-physical systems: innovation durch softwareintensive eingebettete Systeme. Springer, Berlin

Hee K, Sidorova N, Werf J (2013) Business process modeling using petri nets. In: Jensen K, van der Aalst WMP, Balbo G, Koutny M, Wolf K (eds) Transactions on petri nets and other models of concurrency lecture, Notes in Computer Science 7480:116–161

Hülsmann M, Windt K (2007) Understanding of autonomous cooperation and control in logistics —the impact of autonomy on management, information, communication and material flow. Springer, Berlin

Hülsmann M, Scholz-Reiter B, Windt K (2011) Autonomous cooperation and control in logistics. Springer, Berlin

Kreowski H-J, Kuske S (2013) Graph tuple transformation. Electronic Communications of the EASST 62, 23 pages

Kreowski H-J, Kuske S, von Totth C (2010) Stepping from graph transformation units to model transformation units. Electronic Communications of the EASST 30, 24 pages

Kreowski H-J, Kuske S, von Totth C (2012) Combining graph transformation and algebraic specification into model transformation. In: Mossakowski T, Kreowski H-J (eds) Proceedings of the international workshop on algebraic development techniques (WADT 2010) Lecture Notes in Computer Science, vol 7137. pp 193–208

Laguna M, Marklund J (2004) Business process modeling, simulation, and design. Pearson/Prentice Hall, New Jersey

NSF National Science Foundation (2008) Cyber-physical systems. Program announcements and information. NSF 08–11, http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf08611. Accessed 16 Oct 2013

OMG Object Management Group (2013) Business process model and notation (BPMN), http://www.omg.org/spec/BPMV/2.02/pdf. Accessed 10 Mar 2013

Recker JC (2006) Process modeling in the 21st century. BP Trend, pp 1–6

Scholz-Reiter B, Rippel D, Sowade S (2011a) Limitations in modeling autonomous logistic processes—challenges and solutions in business process modeling. In: Proceedings of the IEEE international symposium on assembly and manufacturing 2011 (ISAM'11). Tampere, USB-Proceedings, 6 pages

Scholz-Reiter B, Sowade S, Rippel D (2011b) Modeling the control system infrastructure for autonomous logistics processes. In: Duffy NA (ed) 44th CIRP conference on manufacturing systems. Omnipress, Madison-Wisconsin, pp 1–6

Van der Aalst W, Stahl C (2011) Modeling business processes: a petri net-oriented approach. Cooperative information systems. MIT Press, Cambridge

Savings Potential Through Autonomous Control in the Distribution of Rental Articles

Florian Harjes and Bernd Scholz-Reiter

Abstract In general, rental articles circulate in closed logistic systems between the lender and one or more dynamically changing customers. The planning processes, related to the allocation of those articles to customer orders, are a challenging task. This is especially the case, if orders have a close temporal distance, as the corresponding order execution takes place between the poles of high customer demands and the lender's economic interests. This paper introduces an autonomously controlled distribution system for rental articles that takes over both the allocation of articles to orders and the related logistic planning. At this, the focus lies on the results of first benchmarks and an estimation of the related potential for savings. A company from the field of event logistics serves as an application example for the distribution approach.

Keywords Autonomous control · Event logistics · Agent-based distribution · Rental articles · Savings potential

Introduction

The allocation of rental articles in event logistics takes place as a sub-process of event management (Harjes and Scholz-Reiter 2012). The latter comprises the complete accomplishment of events, such as concerts, private parties, company anniversaries, etc., including the artistic planning and the logistic services (Harjes and Scholz-Reiter 2013a, b, c, d). Here, the term event logistics defines all logistic

F. Harjes (✉)
BIBA—Bremer InstitutfürProduktion Und Logistik GmbH, University of Bremen, Bremen, Germany
e-mail: haj@biba.uni-bremen.de

B. Scholz-Reiter
University of Bremen, Bremen, Germany
e-mail: rektor@uni-bremen.de

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services and activities related to the letting, transport, construction, and deconstruction of event equipment (Harjes and Scholz-Reiter 2013a, b, c, d; Allen et al. 2010). The corresponding planning processes cover the allocation of resources to customer orders (events), as well as the personnel and route planning for transport to and between different venues (Holzbaur et al. 2005).

Generally, both process planning and execution in event logistics are subject to high customer requirements with regard to due dates and the cost–benefit ratio. Further, dynamic influences, such as rush orders, order changes as well as damaged or stolen equipment lead to complications (Harjes and Scholz-Reiter 2013a, b, c, d). Correspondingly, the planning authority has to find a sensible trade-off between the demands of the customer, the internal process requirements, and the economic interests of the logistics company.

These complex and dynamic parameters often exceed the capacities of central planning and control approaches (Windt and Hülsmann 2007). Therefore, it makes sense to evaluate the applicability of other control methods in the field of event logistics. This paper introduces the first results of a distribution system that follows the principles of autonomous control, a paradigm that aims at robust and flexible processes by shifting decisions from central planning instances to autonomous objects within logistic or production systems (Windt and Hülsmann 2007).

The introduced distribution system applies two autonomous control methods to take over the complete allocation of resources to events, including the tour- and route planning for the transport devices and the corresponding personnel planning (Harjes and Scholz-Reiter 2013a, b, c, d). The presented paper gives a short insight into the concept, implementation, and possible integration by means of an example company. The main focus of the paper lies on the first experimental results and the corresponding potential for savings.

The paper is structured as follows. Section "Example Company" focuses on the example company and section "Autonomously Controlled Distribution" outlines the concept and implementation of the distribution system. Section "Experimental Results" introduces the experimental results that underlie the estimation of the savings potential in section "Savings Potential". Finally, the paper closes with a conclusion and outlook in section "Conclusion".

Example Company

The example company is a full-service agency in the field of event management (Harjes and Scholz-Reiter 2012). Starting from the company headquarters in northern Germany and several branches for marketing and public relations, 60 employees offer a complete set of services for the accomplishment of public or private events.

Its main business segment is the artistic planning, logistic services, and lending of event equipment. The latter comprises equipment reaching from cloak hangers or chairs and tables over catering devices up to stages and related techniques

(Harjes and Scholz-Reiter 2013a, b, c, d). The logistics services mostly deal with the transport of rental articles to and between different venues, including the construction and deconstruction of the equipment at the event. For logistic purposes, the example company runs a central stock directly at the headquarters and owns a car pool consisting of several vans and trucks of varying sizes between 3.5 and 40 t cargo load (Harjes and Scholz-Reiter 2012).

The planning and realization of events decomposes in six phases, starting with the order receipt and ending with post-processing and billing. In between, the customer's wishes first flow into a rough planning according to a local inspection of the venue. Then, the preliminary planning is refined iteratively until the customer is satisfied and the realization can begin (Harjes and Scholz-Reiter 2013a, b, c, d).

This paper addresses the detailed planning of the event execution; the artistic aspects are not of interest. Within the example company, a project manager is responsible for the allocation of specific equipment and personnel to events and the corresponding creation of pick lists and cargo lists. The project manager falls back to his expert knowledge, an automated planning or scheduling does not take place (Harjes and Scholz-Reiter 2012). The only exception is a rudimentary function of the enterprise resource planning software that provides a temporal availability overview for the equipment, comparable to a Gantt chart. The corresponding route planning resides with the transport personnel and often bases on tools such as Google maps or customary navigation systems.

This centralized, knowledge-based proceeding generally results in a high planning effort and is not very flexible. The latter often requires a complete replanning, if the above-mentioned dynamic aspects influence the availability of already disposed equipment, personnel, or transport devices. Further, the handling of order peaks often leads to the leasing of foreign equipment and/or transport devices with additional costs. Overall, the efficiency and robustness of the logistic services shows the potential for greater improvements (Harjes and Scholz-Reiter 2013a, b, c, d).

Autonomously Controlled Distribution

The considered distribution system combines two autonomous control methods to solve the subproblems related to resource allocation in event logistics (Harjes and Scholz-Reiter 2012). The central point of the system is the Platform for Simulations with Multiple Agents (PlaSMA), a multi-agent-based simulation software (MAS) with special features for the consideration of logistic and production systems (Gehrke et al. 2010). PlaSMA was originally developed for the comparative, scenario-based evaluation of autonomous control methods and strategies (Warden et al. 2010). Within the autonomously controlled distribution system, PlaSMA serves as a platform for the agent-based generation of planning decisions (Harjes and Scholz-Reiter 2013a, b, c, d).

All existing resources have a representing agent within the PlaSMA simulation. The agent representation follows the ontologies for goods, transport, and communication given in PlaSMA (Warden et al. 2010; Harjes and Scholz-Reiter 2013a, b, c, d). During a simulation run, all agents try to fulfill their personal objective function, which depends on the kind of individual agent. A transport agent, for example, tries to maximize its load factor and minimize the distance travelled, while an agent who represents a piece of equipment focuses on the punctual arrival at the event (Harjes and Scholz-Reiter 2012).

The final planning decisions are the result of mutual negotiations between the agents within the simulation. The idea behind this proceeding is that the fulfillment of the individual agent's objectives leads in total to a fulfillment of the global planning objectives (Harjes and Scholz-Reiter 2013a, b, c, d). The corresponding order situation and the related parameters, such as the event dates and places or the requested article types, come from the ERP-system and form the scenario that underlies the simulation. The occurrence of dynamic effects leads to a corresponding change of the scenario and requires an additional simulation run with adapted parameters (Harjes and Scholz-Reiter 2013a, b, c, d).

The outcome of a simulation run corresponds to the results of the manual planning process, meaning one pick and cargo list per event and the related personnel planning. Further, the autonomously controlled distribution takes over the route planning (Harjes and Scholz-Reiter 2013a, b, c, d). At this, the Distributed Logistics Routing Protocol (DLRP) comes into operation. It is derived from the routing protocols of data packages in large communication networks, such as the Internet (Rekersbrink et al. 2008; Rekersbrink 2009). Within the distribution system, the transport agents use route planning functions of the DLRP as behavior. The required world model in form of a graph that represents the street network is part of the simulation scenario. The world model consists of the venues and the central stock as nodes, while the available streets between them form the edges of the transport graph (Harjes and Scholz-Reiter 2013a, b, c, d).

The general robustness of the process and the reasonability of the planning results have been proven in first experiments (Harjes and Scholz-Reiter 2013a, b, c, d). The range of the test scenarios took place around five events in four cities. The length of the events was up to 3 days and the amount of requested articles fluctuated between 35 and 100 pieces of equipment. The autonomous distribution system was able to generate reasonable planning results, including transport routes for all scenarios (Harjes and Scholz-Reiter 2013a, b, c, d).

Experimental Results

In contrast to the validation mentioned above, the following experiments aim at the evaluation of the overall performance of the distribution system. The achieved reduction in the travelled distance is of central interest, as this constitutes the main starting point for savings. The capacity utilization is also important, but due to the heterogeneity of the event equipment, it is more difficult to improve and therefore not as meaningful.

Table 1 Results for 20 smaller events in 5 days

Parameter	Days	Events	Articles	Available vehicles	Leasing vehicles	Distance travelled (km)
Actual state	5	20	36/38/42	6	0	730/1504/1359
Autonomous Distribution	5	20	36/38/42	6	0	498/972/709

The foundation of the experiments is a set of scenarios basing on the average workload of the company in the example. The scenarios comprise up to 20 events distributed over a period of 5 days. The size of the events lies between 36 and 175 articles of different volume and weight, reaching from single tables up to heavy stage parts and technical equipment. The venues are located within a radius of 111 × 67 km, the available car pool comprises two vans/small trucks (2 × 3.5 t), three medium trucks (3 × 7.5 t), and one lorry with 40 t. The four cars of the example company only serve for the transport of small devices and personnel, therefore they are not considered in the simulations.

Table 1 shows a first excerpt of the results for 20 smaller events with a varying amount of articles and an event duration of 3 h on average (min 1, max 5 h), plus the time slots for delivery and removal as well as construction and deconstruction of equipment. The first line of the table shows the results of the actual state, the second line contains the results of the autonomously controlled distribution system. The actual state represents the manual centralized planning of the project manager, which has been implemented in the form of a software tool as a reference for experimental purposes. The validation of the tool's propriety took place by means of several reference scenarios.

The results show that both approaches are able to execute all orders using the given car pool. A leasing of vehicles is not necessary. The advantage of the autonomous distribution system is the efficient summary of several orders to one route. The actual centralized planning mostly executes fewer or even single orders per trip for complexity reasons. Further, the central planning only considers event equipment that is currently available at the stock. The autonomous distribution system additionally allocates available equipment at already running events. This decentralized distribution leads to differences regarding the travelled distance between 232 and 650 km for a period of 5 days.

The differences regarding the efficiency of the route planning increase depending on the amount of articles required. Table 2 shows the results of three scenarios with larger events. The average distance to the central stock, as well as the considered time period, correspond to the settings of the first experiments, whereas the available car pool is reduced to one van/small truck of 3.5 t, two medium trucks with 7.5 t, and one lorry with 40 t. The amount of requested pieces of equipment lies between 86 and 175.

The results for the larger scenarios confirm the previous observations. Both approaches are able to handle the orders with the given car pool, but the

Table 2 Results for larger events

Parameter	Days	Events	Articles required	Available vehicles	Leasing vehicles	Distance travelled (km)
Actual state	5	20	86/125/175	4	0	2414/2114/2264
Autonomous distribution	5	20	86/125/175	4	0	1218/1178/1774

autonomous distribution system shows even larger differences regarding the travelled distance of the transport vehicles. Due to the higher article numbers, efficient compilation of transports becomes more important. This results in savings between 490 and 1196 km for autonomous distribution during the considered period.

Savings Potential

The savings potential of the outlined approach for an autonomous distribution system in the field of event logistics mostly centers on the reduction of the distance travelled during the order execution. The efficient compilation of both routes and transports leads to a decent potential for savings. With regard to the example company, a medium enterprise with an annual turnover of around nine million euros, the introduction of the distribution system is worth considering.

Currently, the example company accomplishes around 130 events per year using their own resources. This number contains only the “medium” and “large” events, meaning orders that need more articles than a single van can contain. The number of smaller orders constitutes an additional amount of approximately 130–150 events. Altogether, the number of trips per order is around three.

Starting from these assumptions, the following efficiency analysis considers two scenarios for the introduction of the autonomous distribution system. The first bases on an in-house development carried out by the IT—and the transport department of the company in the example. The second one assumes the issuance of an industrial project, carried out by a specialized external company.

In-House Development

In the first case, the adaption of PlaSMA and the DLRP as well as the implementation of the overall system would cost around 64.000 €. This calculation also includes the integration of the system into the existing software architecture of the company in the example. The individual steps of the development and integration process and the corresponding costs and duration are as follows:

- Software Development, including the documentation (9 months): 44,540 €
- Software Integration, including tests and trainings (1.5 months): 12.271 €
  Hardware Development/integration, including purchase and tests of components (1.5 months): 7093 €.

The calculation above bases on the deployment of an engineer for project management purposes with ca. 3824 € gross salary per month and an IT-specialist for programming with a gross salary of 2612 € (Hans-Böckler-Stiftung 2013; VDI 2012). The hardware development concerns the development and integration of identification and communication devices for an automated recording of material flows directly at the venue. The hardware is attached to the transport vehicles and ensures information transparency which is indispensable for the application of autonomous control (Harjes and Scholz-Reiter 2013a, b, c, d).

With regard to the experimental results in the previous section, the savings due to the shorter distances travelled would be around 28.300 € per year, depending, among other things, on the fuel prices. The assumed savings consider the operational costs of the existing car pool which is, for example, around 82 Cent per km for a van (Mercedes-Benz Sprinter 213 CDI, 3.6 t cargo load) (ADAC 2013). Under these circumstances, an amortization of the investment (64.000 €) is possible after approximately 3 years. Including the development and integration phase, the autonomous distribution could be profitable after 4 years.

Industrial Project

The second case, an industrial project, would cause much higher costs, as the hourly rates of the involved engineers and specialists would increase. The following calculations trace back to the hourly rates for industrial orders of the BIBA—Bremer Institut für Produktion und Logistik at the University of Bremen GmbH. These would amount to 5258 € per month for an engineer and 3950 € per month for an IT-specialist. The points already mentioned for the first case would then be as follows:

- Software Development, including the documentation (9 months): 64.496 €
- Software Integration, including tests and training (1.5 months): 17.095 €
- Hardware Development/integration, including purchase and tests of components (1.5 months): 14.534 €.

The total costs for this case would rise to 96.000 €, which is a third more than the in-house development. The reductions regarding the mileage of the transport does not change, therefore, the amortization per year is again 23.800 €. This results in an amortization period of 5 years, while the system would work profitably after 5 years.

Conclusion

This paper presents a first estimation of the savings potential of an autonomously controlled distribution system in the field of event logistics. The system takes over the allocation of rental articles (event equipment), transport devices, and personnel to orders as well as the corresponding route planning.

A special focus lies on the reduction of the distance travelled during the event accomplishment. Simulations of several periods of 5 days, with 20 events each, show savings between 232 and 1196 km. Extrapolated to 1 year and with regard to an example company from the considered business area, annual savings of about 23.800 € seem to be possible. For the company in the example, an amortization period between 4 and 5 years is feasible. The dimension of the required investment depends on the decision, if the implementation and integration of the system take place in-house or as an industrial project.

Further research will focus on the optimization of the system, especially regarding the target- and cost functions of the agents within the PlaSMA-Simulation. From the economic perspective, the effects of the autonomously controlled distribution on the manpower requirements and possible savings regarding the size and utilization of the car pool will be from major interest.

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References

ADAC (2013) www.adac.de, http://www.adac.de/_mmm/pdf/autokostenuebersicht_mr_47088.pdf. Accessed 21 Nov 2013

Warden T et al (2010) Towards ontology-based multiagent simulations: the plasma approach. Kuala Lumpur, pp 50–56

Allen J, O’Toole W, Harris R, McDonnel I (2010) Festival and special event management. 5. Hrsg. Wiley, Hoboken

Gehrke J et al (2010) An agent-based approach to autonomous logistic processes—colloborative research centre 637: autonomous cooperating logistic processes. KI-Künstliche Intelligenz 24 (2):137–141

Hans-Böckler-Stiftung (2013) Lohnspiegel.de, http://www.lohnspiegel.de/main/zusatzinformationen/fachinformatiker-innen. Accessed 21 Nov 2013

Harjes F, Scholz-Reiter B (2012) Autonomous control in event logistics. Rende (CS), Italy, DIME, University of Genua, pp 302–308

Harjes F, Scholz-Reiter B (2013a) Agent-based disposition in event logistics. Res Logistics Prod 3:137–150

Harjes F, Scholz-Reiter B (2013b) Informationstransparenz in der Veranstaltungslogistik. Ind Manage 29(5):39–42

Harjes F, Scholz-Reiter B (2013c) Selbststeuernde Logistik im Umlaufmanagement von Verleihartikeln. HNI Verlagsschriftenreihe, Paderborn, pp 217–227

Harjes F, Scholz-Reiter B (2013d) Selbststeuerndes Routing für Verleihartikel. Ind Manage 29 (6):1–6

Holzbaur U et al (2005) Logistik. Eventmanagement—Veranstaltungen professionell zum Erfolg führen. Springer, Heidelberg, pp 105–142

Rekersbrink H (2009) Methoden zum selbststeuernden Routing autonomer logistischer Objekte—Entwicklung und Evaluierung des Distributed Logistics Routing Protocol (DLRP), Bremen

Rekersbrink H, Makuschewitz T, Scholz-Reiter B (2008) A distributed routing concept for vehicle routing problems. Logistics Res 1:45–52

VDI (2012) www.ingenieurkarriere.de, http://www.ingenieurkarriere.de/bewerberservice/beratung/gehaltscheck/gehaltscheck.asp. Accessed 21 Nov 2013

Windt K, Hülsmann M (2007) Changing paradigms in logistics—understanding the shift from conventional control to autonomous cooperation and control. In: Hülsmann M, Windt K (eds) Understanding autonomous cooperation and Control—the impact of autonomy on management, information, communication and material flow. Springer, Berlin, pp 4–16

Established Slack-Based Measure in Container Terminal for Risk Assessment

Kasypi Mokhtar, Muhamamad Zaly Shah Muhammad Hussein, Khalid Samo and Ab. Saman Abd Kader

Abstract Container terminal is a dynamic interface worldwide. It portrays national capability in trading with outsider via seaborne. This research aims at measuring operational risk within container terminal besides its efficiency. By means of identify and apply DEA technique towards operationalisation of supply chain and risk, this research is providing final outcome with no adjusted risk rank order of decision-making unit (DMU). A panel data from 6 container terminals in Peninsular Malaysia are retrieved from 2003 until 2010. In turn, 8 years of data with 6 terminals resulting 48 container terminal DMUs. Slacks-Based Measure (SBM) and Super Slacks-Based Measure (SSBM) are used for risk solution. The findings of the research express efficiency based on the allocation of resources must be optimised to achieve optimum outcome. SBM and SSBM findings indicate that no adjusted risks are significantly related with size, planning, equipment and volume of cargoes. This is critical as container segments give a significant contribution to terminal operators. In addition, container terminal is competitive industry, as Malaysia is competing not only with neighbouring countries but also with Asian countries in particular and the world in general.

K. Mokhtar (✉)
Department of Maritime Management, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
e-mail: kasypi@umt.edu.my

M.Z.S.M. Hussein
Department of Urban Regional Planning, Universiti Teknologi Malaysia, Skudai, Malaysia
e-mail: zaly@outlook.com

K. Samo
Department of Applied Science (Marine), Universiti Teknologi Mara, Arau, Malaysia
e-mail: kbsamo@hotmail.com

Ab.S.A. Kader
Department of Technology Marine, Universiti Teknologi Malaysia, Skudai, Malaysia
e-mail: abdsaman@fkm.utm.my

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Introduction

Shipping related industry, especially with regard to container terminal is a complex industry to be analysed. However, these complexities are measureable in terms of the process flow that includes management, equipment, organisation, engineering and maintenance. The challenging economic climate is not the reason for these industries to lower down their productivity, efficiency and performance. But, the scenario is a step to optimise available resources to sustain in the industry. Every aspect of process and procedure, either internally or externally, will face with probabilities and uncertainties. Thus, it is wise for the industry to focus on shaping the organisation by looking at the area of uncertainty. The necessity to measure risk arose from the various reasons that are regulatory requirements of the supervisory authorities, customer satisfaction and company hazard prevention. This will cushion the impact of any potential unexpected losses.

Lately, the awareness of container terminal operators in modernising its terminal is undeniable. It comes with the dynamic growth of shipping related industry. The developments are associated with risk factors in ensuring integrity of terminals. Therefore, this paper is an attempt in applying Data Envelopment Analysis (DEA) in measuring risk at container terminal, based on the success of this technique in financial and banking institution (Pastor 1999; Settlage and Preckel 2002; Davutyan and Kavut 2005; Chang and Chiu 2006; Settlage et al. 2009).

In what follows, section "Related Studies on Container Terminal and Risk" review related studies on DEA at container terminal and operational risk. Section "Research Methodology" then provides research methodology applies for this paper. It follows with section "Analysis and Findings" for the analysis and finding. Section "Conclusions" concludes the paper.

Related Studies on Container Terminal and Risk

The demands for container movements from international trades require greater efficient maritime industry. Seaports need to invest in new technologies and facilities in order to meet these demands. The greater the size of vessel, the larger the facilities are required to accommodate such vessels. Seaport facilities rely on the cargo's type and amount during transit. Thus, port expenditure is increased to enhance terminal facilities for vessels accommodation. The need to integrate these facilities into the domestic infrastructural network is necessary, hence requiring efficient road and rail links with the land networks. Bichou and Gray (2005), Bichou (2005) discuss the seaport terminologies, operations and strategies to ensure seaports are able to sustain in highly competitive industry. The facilities in each port are subject to risk as it does involve multimodal industries. However, seaport facilities may be categorised according to their particular area. Shang and Tseng (2010) highlight human factor for loading and discharging the main accident for risk analysis.

There are numerous DEA researches in container terminal. Roll and Hayuth (1993) pioneered attempts in this area. Since that, there are significant numbers of researches in container terminal efficiency and productivity Kasypi and Shah (2013a, b), Kasypi et al. (2013)

Research Methodology

Data Envelopment Analysis (DEA), first introduced by Charnes, Cooper and Rhodes (CCR) model (Charnes et al. 1978), extended Farrel (1957) that based on the basic Eq. (2). The CCR is able to calculate the relative technical efficiency of similar Decision-Making Units (DMU) through the analysis, with the constant returns to scale (CRS) basis. Banker, Charnes and Cooper (BCC) model (Banker et al. 1984) extended from DEA-CCR by assuming variable returns to scale (VRS) where performance is bounded by a piecewise linear frontier.

The parameters and variables are needed in developing the model. Therefore, the model is based on the following parameters and variables:

N = number of DMU $\{j = 1, 2,\ldots n\}$
y = number of outputs $\{y = 1, 2,\ldots R\}$
x = number of inputs $\{x = 1, 2,\ldots S\}$
y_i = Quantity of output *rth* of output of *jth* DMU
x_i = Quantity of input *sth* of input of *jth* DMU
u_r = weight of *rth* output
v_s = weight of *sth* input

(Table 1).

Table 1 Selection of inputs and outputs

Inputs	Outputs
X1: Total terminal area M^2 (TTA)	Y1: Throughput (TEU: 000) (T)
X2: Maximum draft in meter (MD)	
X3: Berth length in meter (BL)	
X4: Quay crane index (QC)	
X5: Yard stacking index (YS)	
X6: Vehicles (V)	
X7: Number of gate lanes (GL)	

The efficiency measures under CRS are obtained by N linear programming problems under Charnes et al. (1978) as below:

$$
\begin{aligned}
&\mathrm{Min}_{\psi,\lambda}\psi_j \\
&\sum_{i=1}^{N} \lambda_i y_{ri} \geq y_j; \quad r = 1, \ldots, R \\
&\sum_{i=1}^{N} \lambda_i x_{si} \leq \psi_j x_j; \quad s = 1, \ldots, S \\
&\lambda_i \geq 0; \ \forall i
\end{aligned}
\tag{1}
$$

where $Y_i = (Y_{1i}, Y_{2i}, \ldots, Y_{Ri})$ is the output vector, $X_i = (X_{1i}, X_{2i}, \ldots, X_{Si})$ is the input vector. Solving above equation for each one of the N container terminals of the sample, N weights and N optimum solution are found. Each optimum solution Ψ_j^* is the efficiency indicator of container terminal j and, by construction satisfies $\Psi_j^* \leq 1$. Those container terminals with $\Psi_j^* < 1$ are considered inefficient and $\Psi_j^* = 1$ efficient. Charnes et al. (1978) model (CRS) was modified by Banker et al. (1984) by adding the restriction $\sum_{i=1}^{N} \lambda = 1$, this has generalising model to VRS as below:

$$
\begin{aligned}
&\mathrm{Min}_{\vartheta,\lambda}\ \vartheta_j \\
&\sum_{i=1}^{N} \lambda_i y_{ri} \geq y_j; \quad r = 1, \ldots, R \\
&\sum_{i=1}^{N} \lambda_i x_{si} \leq \vartheta_j x_j; \quad s = 1, \ldots, S \\
&\sum_{i=1}^{N} \lambda_i = 1; \ \lambda_i \geq 0; \ \forall_i
\end{aligned}
\tag{2}
$$

Measuring Risk Using Slack-Based Measure

The additive model is used for this paper for the analysis in measuring operational risk from Cooper et al. (2007). Further, Cooper et al. (2007) define Slack-based Measure (SBM) by lowering fractional program in λ, S^- and S^+ as follows:

$$
\min_{\lambda, S^- \text{and}\, S^+} = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io}}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / x_{ro}}
\tag{3}
$$

Subject to $x_o = X\lambda + s^-$, $y_o - s^+$ where $\lambda \geq 0, s^- \geq 0$.

Lets assume that $x \geq 0$, if $x_{io} = 0$, erase the phrase s_i^- / x_{io} in the objective function. However, if $y_{io} \geq 0$, then replace with a very small positive number so, the phrase s_r^+ / y_{ro} as penalty. In addition, to interpret SBM as a product of input and output inefficiencies the ρ in Eq. (5), can be transformed as below:

$$\rho = \left(\frac{1}{m}\sum_{i=1}^{m}\frac{x_{io} - s_i^-}{x_{io}}\right)\left(\frac{1}{s}\sum_{r=1}^{s}\frac{y_{ro} + s_r^+}{y_{ro}}\right)^{-1} \tag{4}$$

Let the ratio $(x_{io} - s_i^-)/x_{io}$ evaluate the relative decrease rate of input i t consequently, the first term matches up the mean proportional reduction rate of inputs or input mix inefficiencies. Next, the second term, the ratio $(y_{ro} - s_r^+)/y_{ro}$ assess relative proportional expansion rate of output r and $(1/s)\sum(y_{ro} - s_r^+)/y_{ro}$ is the mean proportional rate of output expansion. The input-oriented SBM and output-oriented SBM are defined from neglecting the denominator of the objective function Eq. (5) of SBM. Thus, the efficiency values ρ_I^* and ρ_o^* can be derived as follows (Cooper et al. 2007):

$$\text{SBM} - 1 \quad \rho_I = \min_{\lambda, S^-} 1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io} \tag{5}$$

Subject to $x_o = X\lambda + s^-$, $y_o \leq Y\lambda$ where $\lambda \geq 0, s^- \geq 0$.

$$\text{SBM} - 0 \quad \rho_o^* = \min_{\lambda, S^+} 1 - \frac{1}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{ro}} \tag{6}$$

Subject to $x_o \geq X\lambda$, $y_o = Y\lambda - s^+$ where $\lambda \geq 0, s^+ \geq 0$.

Production Possibility Set for Risk Assessment

The risk factor which can be derived from production possibility set (PPS) is determined by the distance. The outcome of super SBM is derived by deleting the efficient DMU from PPS and measure the distance from the DMU to the remaining PPS. Consequently, if the distance is small, the supper efficiency of the DMU to be set as lower as the DMU marginally outperforms other DMUs and vice versa. Super SBM utilised the SBM outcomes and those efficient ranking order in SBM has been set to be super efficient under PPS super SBM.

Conversely, the Non-radial and Non-oriented SBM and Super SBM under MI are also suitable to measure risk as radial approaches of Malmquist Index (MI) suffer from neglecting the slacks. The SBM and Super SBM models used to compute $\delta^s\left((x_o, y_o)^i\right)$ are represented by the following fractional programmes (Cooper et al. 2007).

[SBM]

$$\delta^s\left((x_o, y_o)^t\right) = \min_{\phi,\psi,\lambda} n\left(1 - \frac{1}{m}\sum_{i=1}^{m}\phi_i\right) \Big/ \left(1 + \frac{1}{q}\sum_{i=1}^{q}\psi_i\right) \quad (7)$$

Subject to $(1 - \Phi_i)x_{io}^t = \sum_{j=1}^{n}\lambda_j x_{ij}^s (i = 1, \ldots, m), (1 + \Psi_i)y_{io}^t = \sum_{j=1}^{n}\lambda_j y_{ij}^s$ $(i = 1, \ldots q)$ where $L \leq e\lambda \leq U$ and $\lambda \geq 0, \Phi \geq 0, \Psi \geq 0$.

[SuperSBM]

$$\delta^s\left((x_o, y_o)^t\right) = \min_{\phi,\psi,\lambda} n\left(1 + \frac{1}{m}\sum_{i=1}^{m}\phi_\iota\right) \Big/ \left(1 - \frac{1}{q}\sum_{i=1}^{q}\psi_i\right) \quad (8)$$

Subject to $(1 +)x_{io}^t = \sum_{j=1}^{n}\lambda_j x_{ij}^s (i = 1, \ldots, m), (1 - \Psi_i)y_{io}^t = \sum_{j=1}^{n}\lambda_j y_{ij}^s (i = 1, \ldots, q)$ where $L \leq e\lambda \leq U$ and $\lambda \geq 0, \Phi \geq 0, \Psi \geq 0$.

Analysis and Findings

Figure 1 depicts general panel data container terminal efficiency, for the past 8 years the level of efficiency of particular container terminals show relative differences between DEA-CCR and DEA-BCC. The DEA-CCR and DEA-BCC approach depict efficient 19 DMUs and 26 DMUs respectively. Coincidently, efficient of container terminals not significantly relates with global issues, but explain good management style in managing container terminals operation. However, another 29 (CCR) and 22 (BCC) DMUs are portraying inefficiency of container terminal outcome as a result of internal and external reasons. In general, total throughput is significantly increased. Thus, managing container terminals are sometimes the determinant element to achieve target.

Figure 2 represents SBM input-oriented constant and variable return to scale. The value obtained from derived equation five (5) and six (6), express either efficiencies are able to achieve. The notation SBM and general DEA i.e., CCR postulate similar meaning of efficiency (i.e., SBM inefficient = CCR inefficient). Therefore, the definitions of efficient and inefficient are mutually exclusive. Thus, Fig. 1 represents such as DMUs = 1 i.e., AW03, EPP10, CP04 etc. On the other hand, those DMUs <1 elaborate that particular DMUs are inefficient.

On the one hand, if the distance is wide, super efficient would be high as compared to the remaining DMUs i.e., AW10 (row 6; SBM) 1, it set the rank order to 2 (1.207) under SSBM—lower risk mitigation than using SBM (row 6: efficient 1). It means, the operational risk for the container terminal (AW10) is significantly lower to produce higher outcome for the terminal operator. Hence, by undertaking

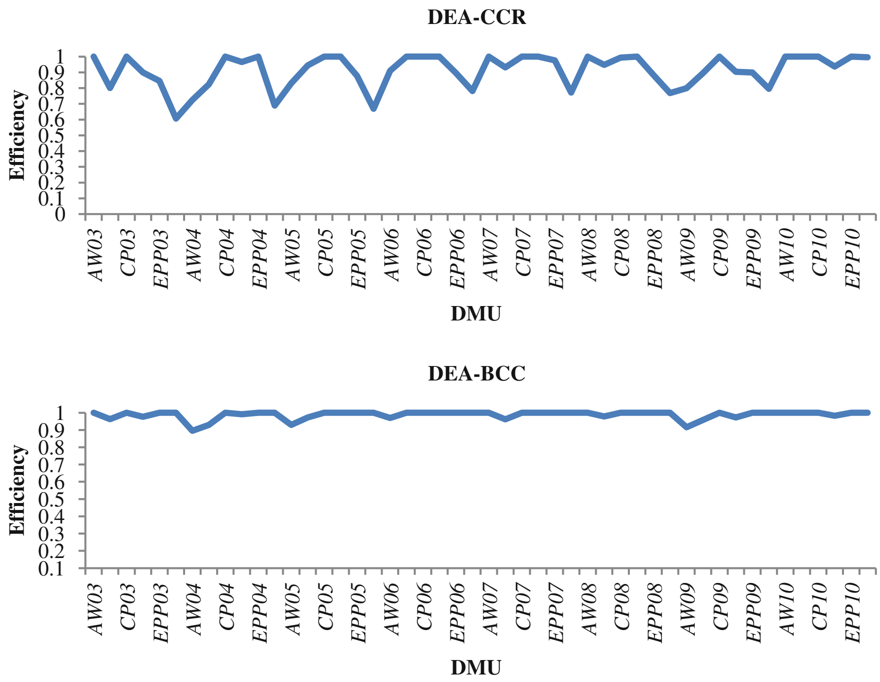
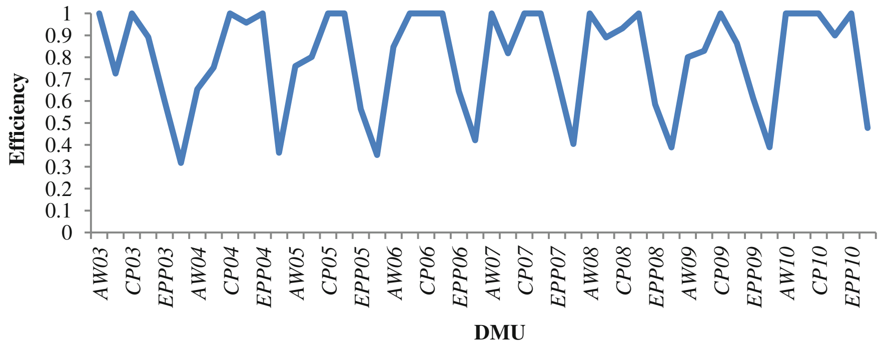


Fig. 1 Yearly efficiency of container terminal

risk (SSBM) it will be able to produce better risk mitigation to the terminal performance. The SSBM is undertaking the PPS distance to produce optimal value. Tables 2, 3 and 4 represent rank order for SSBM.

As far as the lowest rank order is concerned, the PPS distance between SBM and SSBM do not affect risks measure much. As discussed earlier, if the efficiency is low (<1), the super efficiency is set to be low as well. It also reflect SBM, as the lowest SBM rank order (FK03—0.3178; rank order 48) and SSBM (FK03—0.3178; rank order 48) technically reflect the lowest rank order for super SBM. It means, that those inefficient container terminals are technically reflect the higher number of risk. On the operational sites, FK container terminal is representing small terminal in throughput and the operational activity. The possibility of operational risk and the risk that is high such as equipment breakdown, safety, security etc. FK terminal is a multipurpose port; therefore, management prefers to focus on profitable division such as chemical section. At the end, it is difficult for managements to attract new shipping lines client, even the container transactions are growing every year.



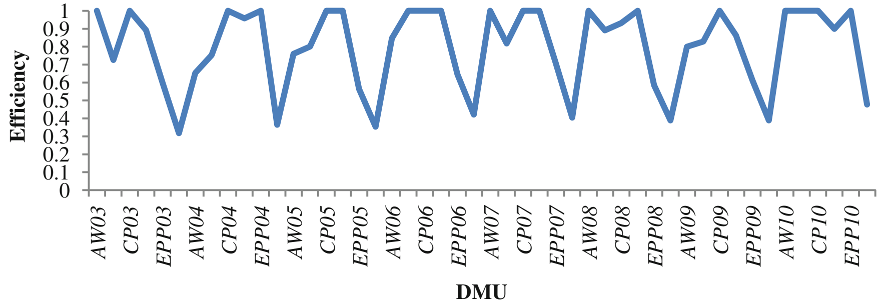


Fig. 2 Slacks-based measure input-oriented constant and variable return to scale

Table 2 Super slack-based measure input constant return to scale ranking order

	No adjusted risk			No adjusted risk			No adjusted risk	
DMU	Rank	Score	DMU	Rank	Score	DMU	Rank	Score
AW03	1	1.20766	BN06	17	1.001925	BN03	33	0.725659
AW10	2	1.076082	DJ08	18	1.000638	EPP07	34	0.709628
CP04	3	1.075129	EPP10	19	1.000601	AW04	35	0.653882
DJ07	4	1.04038	DJ04	20	0.957937	EPP06	36	0.644998
CP06	5	1.036851	CP08	21	0.932089	EPP09	37	0.612313
DJ05	6	1.035432	DJ10	22	0.899244	EPP03	38	0.600884
CP09	7	1.028273	DJ03	23	0.892278	EPP08	39	0.585104
CP07	8	1.025158	BN08	24	0.890703	EPP05	40	0.563758
DJ06	9	1.024109	DJ09	25	0.863498	FK10	41	0.477331
BN10	10	1.023772	AW06	26	0.846934	FK06	42	0.421271
EPP04	11	1.023308	BN09	27	0.829051	FK07	43	0.403913
CP03	12	1.0228	BN07	28	0.818042	FK09	44	0.388923
CP10	13	1.016199	BN05	29	0.800949	FK08	45	0.388558
AW08	14	1.014045	AW09	30	0.800066	FK04	46	0.364376
AW07	15	1.011972	AW05	31	0.759697	FK05	47	0.353458
CP05	16	1.006943	BN04	32	0.753037	FK03	48	0.317869
						Average		0.8109

Table 3 Super slack-based measure input variable return to scale ranking order

	No adjusted risk			No adjusted risk			No adjusted risk	
DMU	Rank	Score	DMU	Rank	Score	DMU	Rank	Score
AW03	1	1.208169	CP05	17	1.007029	DJ10	33	0.899244
AW10	2	1.128509	EPP07	18	1.006998	EPP03	34	0.893459
CP04	3	1.078523	EPP10	19	1.006449	AW06	35	0.892384
FK06	4	1.071423	FK04	20	1.006376	BN08	36	0.892338
FK10	5	1.071401	FK07	21	1.002668	EPP09	37	0.868734
EPP04	6	1.041024	BN06	22	1.001963	DJ09	38	0.863498
CP07	7	1.040695	DJ08	23	1.001063	BN09	39	0.83592
DJ07	8	1.04038	CP08	24	1.000847	BN07	40	0.831675
CP03	9	1.038213	CP10	25	1	AW09	41	0.828998
CP06	10	1.036948	FK05	26	1	EPP08	42	0.812949
DJ05	11	1.035432	FK03	27	0.979578	AW05	43	0.809924
CP09	12	1.028273	DJ04	28	0.975143	BN05	44	0.804372
DJ06	13	1.024164	EPP06	29	0.935947	BN03	45	0.796503
BN10	14	1.023772	DJ03	30	0.935443	EPP05	46	0.791039
AW08	15	1.021348	FK09	31	0.901166	BN04	47	0.779091
AW07	16	1.014952	FK08	32	0.900551	AW04	48	0.724545
						Average		0.9560

Table 4 Super slack-based measure input general return to scale ranking order

	No adjusted risk			No adjusted risk			No adjusted risk	
DMU	Rank	Score	DMU	Rank	Score	DMU	Rank	Score
AW03	1	1.20766	BN06	17	1.001925	FK05	33	0.801952
AW10	2	1.076082	DJ08	18	1.000638	BN05	34	0.800949
CP04	3	1.075129	EPP10	19	1.000601	AW09	35	0.800066
DJ07	4	1.04038	DJ04	20	0.957937	AW05	36	0.784581
CP06	5	1.036851	CP08	21	0.932089	FK08	37	0.778725
DJ05	6	1.035432	DJ10	22	0.899244	FK09	38	0.771121
CP09	7	1.028273	DJ03	23	0.892278	BN04	39	0.76534
CP07	8	1.025158	BN08	24	0.890703	FK03	40	0.761917
DJ06	9	1.024109	FK10	25	0.874254	BN03	41	0.747162
BN10	10	1.023772	FK06	26	0.863909	EPP07	42	0.709628
EPP04	11	1.023308	DJ09	27	0.863498	AW04	43	0.698413
CP03	12	1.0228	AW06	28	0.860519	EPP06	44	0.644998
CP10	13	1.016199	BN09	29	0.829178	EPP09	45	0.612932
AW08	14	1.014045	FK07	30	0.819691	EPP03	46	0.608057
AW07	15	1.011972	BN07	31	0.818042	EPP08	47	0.585104
CP05	16	1.006943	FK04	32	0.809897	EPP05	48	0.563758
						Average		0.8836

Conclusions

This paper concludes that measuring operational risk by using SBM and SSBM show significant result between data collected and actual scenario. This research is an approach of using SBM and SSBM in measuring risk assessment at container terminal. From the approach, it shows that ranking technique is sufficient to portray assessment of risk at container terminal. By having this, management is able to take preventive measures for further operational strategies. Even though this research provides significant outcome for terminal operators, further details on the numerical aspect need to be done for better outcome.

References

Banker RD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage Sci 30(9):1078–1092

Bichou K (2005) Port inland interface assessment: operations and strategies. Report for UNCTAD, UNCTAD, Geneva, pp 1–35

Bichou K, Gray R (2005) A critical review of conventional terminology for classifying seaports. Transp Res A 39:75–92

Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2(6):429–444

Chang TC, Chiu YH (2006) Affecting factors on risk-adjusted efficiency in Taiwan's banking industry. Contemp Econ Policy 24(4):634–647

Cooper WW, Seiford LM, Tone K (2007) Data envelopment analysis: a comprehensive text with models, applications, references and DEA-Solver software, 2nd edn. Springer, New York

Davutyan N, Kavut L (2005) An application of data envelopment analysis to the evaluation of audit risk: a reinterpretation. ABACUS 41(3):290–306

Farrell MJ (1957) The measurement of productive efficiency. J Roy Stat Soc 120:253–290

Kasypi M, Shah MZ (2013a) Efficiency of operations in containerterminal: a frontier method. Eur J Bus Manage 5(2):91–106

Kasypi M, Shah MZ (2013b) Malmquist productivity index for container terminal. Eur J Bus Manage 5(2):58–70

Kasypi M, Shah MZ, Muhammad I (2013) A productivity study of medium container terminal. J Supply Chain Manage 10(1):26–43

Pastor JM (1999) Efficiency risk management in spanish bank: a method to decompose risk. Appl Financ Economies 9(4):371–384

Roll Y, Hayuth Y (1993) Port performance comparison applying data envelopment analysis (DEA). Marit Policy Manage 20:153–161

Settlage DM, Preckel, PV (2002) Robustness of Non-Parametric Measurement of Efficiency and Risk Aversion. American Agriculture Economic Association Annual Meeting, Long Beach Carlifornia

Settlage DM, Preckel PV, Settlage LA (2009) Risk-adjusted efficiency and risk aversion in the agricultural banking industry. Agr Finan Rev 69(3):314–329

Shang KC, Tseng WJ (2010) A risk analysis of stevedoring operations in seaport container terminals. J Mar Sci Technol 18(2):201–210

Improving Wind Turbine Maintenance Activities by Learning from Various Information Flows Available Through the Wind Turbine Life Cycle

Elaheh Gholamzadeh Nabati and Klaus Dieter Thoben

Abstract Maintenance of the offshore wind turbines imposes high cost, effort, and risk on the wind farm owners. Therefore, it is highly demanded to make the wind turbine maintenance activities more reliable and cheaper. To achieve this goal, the focus of current research is to investigate how the available data through the life cycle of an offshore wind turbine can be utilized to improve the maintenance activities. In this work, it will be investigated, how to integrate information feedbacks from the operation phase of an offshore wind turbine to the maintenance stage. A comparison will be done afterwards between the proposed method and existing data-driven maintenance approaches in wind turbine and other industries such as aviation and shipping.

Keywords Offshore wind turbine · Product life cycle information management · Maintenance · Data mining and machine learning

Introduction

The product life cycle information management (PLIM) is the process of gathering, organizing, exchanging, and analysis of key information through all phases of a product's life cycle, which starts with the new idea development and continues with the design, realization, usage, and maintenance and ends with the disposal of the product. In the PLIM process there are different data sources in each of the product's life cycle phases and different information flows to deal with. So far, plenty

E. Gholamzadeh Nabati (✉)
International Graduate School of Dynamics in Logistics, University of Bremen, Bremen, Germany
e-mail: nab@biba.uni-bremen.de

K.D. Thoben
BIBA-Bremer Institute für Produktion und Logistik GmbH, Bremen, Germany
e-mail: tho@uni-bremen.de

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of technologies, such as eXtensible Markup Language (XML), Radio-Frequency Identification (RFID), and Product Embedded Information Devices (PEID), have been developed to support the management of information flows through the life cycle stages.

A problem within the PLIM process is that the captured information flows become weak after the product enters the usage and operation phase, because the data about the condition in which the product is operating or being used is usually not available (Jun and Xirouchakis 2007). This gap has been addressed recently and some advances are made to track and collect product-related data after it enters the usage and operation stage (Abramovici et al. 2008; El Kadiri et al. 2013). Although some advances in this field have been achieved, still there is a need to utilize data in an effective way to improve the information exchange and to integrate the information feedbacks from the usage phase to the other stages of the product life cycle such as the maintenance phase.

An attractive application field of PLIM process is the maintenance of offshore wind turbines. These turbines generate electricity from wind and are located in sea or other bodies of water. The estimated life cycle of a wind turbine is 20 years. Maintenance activities of offshore wind turbines cause most of the costs through the turbine's whole life cycle. According to the National Renewable Energy Laboratory (2013), the operation and maintenance (O&M) activities of offshore wind turbines form one fourth of the lifetime cost of an offshore wind farm and among different O&M tasks, maintenance activities account for almost the largest portion of O&M effort and cost. Therefore, it is highly demanded to reduce maintenance and repair expenses and improve availability of the wind turbines.

To achieve this goal, the focus of current research is to investigate how to enhance offshore wind turbine maintenance activities by utilizing the various data collected during the usage and operation stages. It will be investigated how to generate information feedback flows from the usage phase to the maintenance phase.

Motivation

The main factor that motivates the use of PLIM process in the maintenance of offshore wind turbines is saving of costs. There are various reasons, which make the maintenance activities of offshore wind equipment costly. First of all, the wind turbines are located in the areas surrounded by water and they can only be accessed by boat or helicopter. The use of boat or helicopter depends strictly on the weather condition, because if an unexpected failure occurs turbines are not available until the condition of the sea becomes calm and safe for dispatching the personnel to the site for repair. Also, the distance from shore and number of personnel, who need to be dispatched, as well as turbine's sophisticated technology are among the other parameters, which increase maintenance costs. Therefore, new ways should be developed to reduce expenses arising by breakdown or fault occurrences.

There are currently two maintenance plans for wind farms: corrective maintenance and preventive maintenance. Corrective maintenance is performed when a failure has occurred. In this case, the malfunctioning part will be repaired or replaced. Preventive maintenance involves annual services of the equipment and is usually done in the summer, when the weather condition is more stable (National Renewable Energy Laboratory 2013). In preventive maintenance, some of the components, which are exposed to wear, are changed in a timely manner. Changing the parts on a regular basis is a good strategy to prevent failure, but it imposes extra costs on the system. Because most of the parts being replaced still have not reached their end of lifetime and could have been in service for a longer time. Predictive maintenance approaches can be used instead to help determine the condition of in-service equipment and to predict when maintenance should be performed. This approach saves cost comparing to scheduled preventive maintenance, because by knowing which equipment needs maintenance, the maintenance work can be optimized better (Mobley 2008).

Most predictive maintenance approaches are developed for rotary equipments such as aircraft jet engines and onshore wind turbines (Hameed et al. 2009; Schwabacher and Goebel 2007). The current methods do not consider the special specifications of offshore equipment such as weather condition. Thus, there is a need for research relating to improve maintenance activities in a way to reduce expenses and to meet the specific requirements of offshore conditions.

Moreover, most of the available techniques of predictive maintenance do prediction based on limited data sources. One way to improve predictive maintenance activities is to estimate a better behavior of the system, based on historical data from various data sources and considering the link between a problem and the information from downstream product life cycle phases. For example, one problem in a rotor of a specific wind turbine can be traced by the test results of the manufacturer. Therefore, by linking various data sources and further analyzing them, we can track each maintenance problem more accurately and send feedback to the other stages of product life cycle.

Problem Definition and Research Objective

The problem in a broad view is how to integrate data-based methods, which use life cycle data in offshore wind turbine maintenance. Another part of the problem which needs investigation is to identify best available maintenance strategies either data based or non-data based and compare them with each other as well as with the proposed method. The objective of this study is to investigate how available information of one stage of offshore wind turbine life cycle like usage and operation phase can be converted into effective knowledge. How this generated knowledge can be integrated in the turbine's life cycle in a way that makes improvement to other life cycle phases like maintenance phase. From the practical aspect the objective is to investigate the possibility of developing a maintenance strategy for the offshore wind farms.

Research Methodology

First, different data sources, such as supervisory control and data acquisition (SCADA) system, maintenance operational data, statistical data, weather data, spare part inventory data, drawing plans, geographical and other possible sources, should be identified. Second, the relevant indicators should be selected and measured. Then the data is modeled by means of machine learning and statistical techniques and used to develop a maintenance strategy. Finally the performance of the method is assessed and compared with those of other existing methods.

Expected Results

The expected outcome of this research would be a computer algorithm designed or developed to integrate the information collected from various data sources. This algorithm will be written in a suitable technical software language (e.g., R, or MATLAB). The algorithm will be tested on data available from an offshore wind turbine.

References

Abramovici M, Fathi M, Holland A, Neubach M (2008) Integration of product use information into PLM. Ann CIRP 438–443

El Kadiri S, Milicic A, Kiritsis D (2013) Linked data exploration in product life-cycle management. IFIP advances in information and communication technology, State College, PA, pp 460–467

Hameed Z, Hong Z, Cho Y, Ahn S, Song C (2009) Condition monitoring and fault detection of wind turbines and related algorithms: a review. Renew Sustain Energy Rev 1:1–39

Jun H, Xirouchakis P (2007) Research issues on closed-loop PLM. Comput Ind 8–9:855–868

Mobley R (2008) Maintenance engineering handbook, 7th edn. McGraw-Hill, New York

National Renewable Energy Laboratory-NREL (2013) A guide to UK offshore wind operations and maintenance. Retrieved from http://www.nrel.gov

Schwabacher M, Goebel K (2007) A survey of artificial intelligence for prognostics. In: AAAI fall symposium, pp 107–114

Empty Container Management—The Case of Hinterland

Stephanie Finke

Abstract The empty container management is one of the most popular problems in shipping. The container repositioning is very expensive and shippers cannot generate profit with it, so it is very important for shippers to have an efficient container management. This paper discusses the problem of repositioning empty containers in a cheap way and it shows up a possible optimization for the problem. First, the paper introduces the subject of the empty container management. This section is followed by a problem description and a modified Inland Empty Container Depot (IDEC) model based on Mittal, which solves the container problem. Afterwards, there is a description of the further modification of the model for the empty container management problem in hinterland, which is based on the modified IDEC. This model additionally considers the container transportation by barge and train, while the IDEC only uses the truck. In the last chapter of the paper, some possible results are presented.

Keywords Container management · Empty container repositioning · Inland depot · Modified IDEC · Hinterland

Introduction

The objective of empty container management is to make containers available for reload while minimizing transport costs and maximizing benefits (Furió et al. 2009). Empty transports are often unavoidable, because normally the place of container discharge and the place of loading are not identical. Hence, containers have to be repositioned. Repositioning can be conducted on a local, interregional, and global level (Hautau et al. 2008). The whole process of container logistics starts

S. Finke (✉)
Universität Bremen, Wilhelm-Herbst-Straße 12, 28359 Bremen, Germany
e-mail: sfinke@uni-bremen.de

H. Kotzab et al. (eds.), *Dynamics in Logistics*,
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with discharging at importers place and ends upon positioning boxes at exporters' location (Furió et al. 2009).

It is very important to have an efficient empty container management for shippers, because the transportation of empty boxes causes substantial costs, which are nearly as high as the transportation of full containers. The difference between these sorts of transportation is, that shippers can generate proceeds when they deliver a full container, but they cannot generate any proceeds by repositioning empty containers (Exler 1996). Drewry Shipping Consultants estimates global costs incurred by repositioning empty containers for 2010 to 34.8 billion US-Dollar, which is an increase of 3.5 billion US-Dollar according to 2009 (Drewry Shipping Consultants 2011). Of this amount, 11.4 billion US-Dollars are related to land transport and 23.4 billion US-Dollars to sea transport (Drewry Shipping Consultants 2011). Each repositioning amounts to a total of 400 US-Dollars per container. Overall, the proportion of empty transportation amounted to 21.3 % at sea (Drewry Shipping Consultants 2011) and nearly 40 % at land (Konings 2005).

The global container traffic has more than doubled within the past decade. In the year 2000, there was a traffic of 236.7 million TEU and according to 2010, there was 548.5 million TEU. The percentage of empty containers in the total container amount has only minor fluctuations and conducts in the past five years an average of 21.3 % (Drewry Shipping Consultants 2011).

It is assumed that a container only spends 20 % of its lifecycle at sea and 56 % it is empty, i.e., it is under repair, in maintenance, or in transit (De Brito and Konings 2008). This high unproductive part has to be reduced in order to make the use of containers more efficient. Apart from this, there are also 1.5–2.5 million TEU stored in the hinterland of seaports so that there is a high space requirement, resulting in a shortage of storage areas in ports (Vojdani and Lootz 2011). "For the benefit of port operators, shippers and carriers, the number of empty boxes sitting at the terminals should ideally be nil or very few" (Boile et al. 2004).

Conception of a Mathematical Model

One possible solution of the empty container management is presented by Mittal in her dissertation. She developed a mathematical model, which minimizes the total transport costs and adds additional space for storing containers in the hinterland, by opening new depots next to customer destinations (Mittal 2008). The model is formulated as "an inventory-based capacitated depot location problem under deterministic (…) demand patterns" (Mittal 2008) with a planning horizon of 10 years. In this section, the modified Inland Empty Container Depot (IDEC), which bases on Mittals model, will be presented. The difference to Mittals model is that there is a planning horizon of one year and only one shipper and one depot operator are regarded. In addition some variables are doped off and some variables, like the dummy variable z_{ik} is introduced in the constraints.

Before the objective function can be presented, some assumptions have to be introduced. The first one is that there is no direct transport between an importer and an exporter and there is also no transport between the depots in a region. Furthermore, there is a linear cost structure. The operating costs at each depot are equal. A shipper can get a container out of a depot, if it is assigned to it. Each exporter and importer is also assigned to only one depot. Variables, which are not in the formulation have to be zero.

The objective function is the following:

$$Z = \min \sum_{i \in F} f_i * y_i + \sum_j \sum_i \left(S_j * x_{ji} * c_{ji}\right) + \sum_i \sum_k \left(D_k * x_{ik} * c_{ik}\right) + \sum_i \sum_h \left(x_{ih} * c_{ih}\right) + \sum_h \sum_i \left(x_{hi} * c_{hi}\right)$$

The first term presents the fix costs for opening a depot. The following terms two to five stand for transportation costs within the network. For example, the second and the third term are transportation costs between importer and depot, respectively exporter and depot. At fourth and fifth place, the costs between port and depot or rather depot and port are shown. Beside the objective function, there are some constraints. First of all, there are 4 constraints, which are presenting the demand and supply of empty containers by the port, the exporter, and the importer. Additionally, there is another constrain, which describes the initial inventory of containers in a depot. A sixth constrain keeps a depot open, when a volume of containers arrives, furthermore it ensures that the capacity of the depot would not be passed. In a seventh constraint it is ensured that depots, which already exist in the region, will stay open. In addition, there also will be needed 4 constraints, which define the variables of the port, the exporters, the importers, the depots, and the depot inventory as non-negative. At least, there are two last constraints, which are integrality constraints (Mittal 2008). Beside these constraints, there are some totally new constraints, which Mittal did not have and which are not modified. There are two constraints, which ensure that the whole transport volume uses the same link. Another two constraints assigns the importers and exporters to only one depot, when it is open. Because of this simple assignment two dummy variables have to be introduced and two constraints defines this as binary.

Further Model Development

In order to develop a new model from the presented relationships above, the following steps have to be done: As a first step to solve the empty container problem in the hinterland, the literature should be reviewed in order to seek out existing solutions. After that in a second step, the network of waterways and rail in Germany should be analyzed in order to get rid of free potentials in intermodal transportation. As a third part, a mathematical model should be setup. For this model, the modified

IDEC will be modified by expending it about intermodal transportation. That means the model will regard the transportation by truck, by train, and by barge. Also the assumptions and the constraints have to be modified, i.e., a new variable for train and barge have to be introduced and there have to be a constraint for the cost structure for all types of transportation. The purpose of IDEC and the modified IDEC is to reduce transportation costs by building up depots in inland, and in addition to create new storage capacity out of the ports. Another and or additional idea is to integrate the model of Dry Ports in the modified IDEC and to generate a hub and spoke network between the port, the importers, the exporters, and the terminals. In conclusion, the modified model will be tested in a case study. This study will focus on the port of Bremerhaven with its hinterland. The hinterland will be represented by Germany. All in all I will focus on hinterland transportation and regional repositioning.

Expected Results

After implementing the modified model, the total transportation costs should be reduced by avoiding preventable empty trips. In total, the model should be very realistic and it should be able to implement the intermodal transport in empty container repositioning. Ideally, the modal split will be equal in all the types of transportation, by truck, by train, and by barge.

References

Boile M, Theofanis S, Mittal N (2004) Empty intermodal containers—a global issue. In: Annual forum of the transportation research forum, Northwesten University, Transportation Center, Evanston, Illinois, 21–24 Mar 2004

De Brito MP, Konings R (2008) Container management strategies to deal with the East-West flows imbalance. Paper during: logistics and freight cluster meeting in the Netherlands, Delft, Netherlands, 27–28 Mar 2008

Drewry Shipping Consultants (2011) Container market 2011/12: annual review and forecast. Drewry, London

Exler M (1996) Containerverkehr: Reichweiten und Systemgrenzen in der Weltwirtschaft. (Nürnberger wirtschafts- und sozialgeographische Arbeiten, Bd. 50, Hrsg.: Prof. Dr. Ritter, W., Prof. Dr. Ruppert, R., Prof. Dr. Weigt, E.) 1. Aufl. Nürnberg: Wirtschafts- und Sozialgeographisches Inst. der Friedrich-Alexander-Univ. Erlangen-Nürnberg

Furió S, Andrés C, Lozano S, Adenso-Díaz B (2009) Mathematical model to optimize land empty container movements. Papers during: the 6th international mediterranean modeling multiconference, the international conference on harbor, maritime & multimodal logistics modelling and simulation, Puerto de la Cruz, Tenerife, 23–25 Sept 2009

Hautau H, Hüttmann B, Kasiske F (2008) Bedeutung der Leercontainerlogistik für die Hamburger Hafenwirtschaft. In: Internationales Verkehrswesen, Bd. 60, Nr. 1+2, S. 25–31

Konings R (2005) Foldable containers to reduce the costs of empty transport? A cost-benefit analysis from a chain and multi-actor perspective. Marit Econ Logistics 7(3):223–249

Mittal N (2008) Regional empty marine container management. Dissertation Rutgers, The State University of New Jersey, Graduate School-New Brunswick

Vojdani N, Lootz F (2011) Modellierung und Bewertung der maritimen Leercontainerlogistik unter Berücksichtigung des Container-Poolings. (7. Fachkolloquium der wissenschaftlichen Gesellschaft für Technische Logistik (WGTL): Proceedings, 03. Und 04. Mai 2011, Hrsg.: Vojdani, N.). 1. Aufl. S. 112–125. Dortmund: Praxiswissen Service

Part II
Synchronization

Synchronization in Vehicle Routing: Benders' Decomposition for the Home Health Care Routing and Scheduling Problem

Dorota Slawa Mankowska

Abstract This chapter investigates a vehicle routing problem with synchronization requirements for the services provided to customers. The problem finds an application in the home health care branch, where staff members of health care agencies have to be routed and services at patients' homes have to be scheduled. The latter can involve simultaneous services, where two staff members have to serve one patient jointly, and services with given precedence, where two service operations have to be provided to a patient within a given time distance. This paper presents a Benders' decomposition method for solving this problem exactly.

Keywords Routing · Scheduling · Synchronization · Interdependent services · Home health care · Benders' decomposition

Introduction

One of the currently established extensions in the research on vehicle routing problems is the synchronization of vehicle routes. Synchronization is necessary if two or more vehicles or service operators must visit a location to provide a service (Drexl 2012). One example is found in cross-docking, where cargo is transferred from one vehicle to another (see e.g. Wen et al. 2008). Here, the routes of the involved vehicles must be synchronized such that the vehicle which provides the cargo, arrives earlier at the cross-dock than the vehicle which receives the cargo.

The problem considered in this paper is an uncapacitated VRP with application to home health care. It gains in importance due to a growing number of care-dependent people, see the report of the World Health Organization (Tarricone and Tsouros 2008). In order to relieve family members of supporting their care-dependent relatives, Home Health Care Companies (HHCCs) take over on-site

D.S. Mankowska (✉)
Martin-Luther-University Halle-Wittenberg, Grosse Steinstrasse 73, 06108 Halle, Germany
e-mail: dorota.mankowska@wiwi.uni-halle.de

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services for persons in need. Different staff members work for a HHCC, for example nurses, doctors, social workers, physiotherapists, food couriers, and the like. The offered services include, for example, administration of medications, help by performing daily tasks (bathing, washing or getting dressed), delivery of meals, housekeeping, therapeutic exercises, etc. The different qualifications of staff members can comprise, for example, number of languages spoken, permission to run errands, or a license to administer drugs. Each patient requires certain services that must be performed by suitably qualified staff members. Three general types of service requirements are distinguished:

- *Single service*:
  One staff member provides a single service at a patient's home.
- *Simultaneous double service*:
  Two staff members provide a joint service at a patient's home as needed if, for example, a physically disabled patient must be lifted or bathed.
- *Double service with precedence relation*:
  Two staff members have to visit a patient at different times. The time distance between the first and the second service operation is given and must be kept in a work plan. This situation occurs if, for example, drugs have to be administered exactly 30 min after lunch.

For the described problem setting, the so-called Home Health Care Routing and Scheduling Problem (HHCRSP) is to route the staff members and to schedule the service operations. The contribution of this paper is to provide an exact solution method for the HHCRSP, which can accommodate the HHCC's wishes of high-quality plans as well as high-quality services and, thus, level up the satisfaction and comfort of the patients.

Literature

Synchronization in VRPs is a constantly growing research field. A survey on this topic is presented by Drexl (2012). The author classifies synchronization in four types. *Operations synchronization* means that more than one vehicle is involved in performing a service task. *Movement synchronization* describes a joint movement of autonomous and nonautonomous vehicles. *Load synchronization* refers to capacity restrictions for the vehicles. *Resource synchronization* requires decisions on the use of scare resources by vehicles, e.g., capacity of a vehicle. Obviously, only operations synchronization has application to the problem considered in this paper. In particular, the double service operations involved in home health care operations management belongs to this category.

Papers dealing with operations synchronization in various practical applications are found, for example, in Li et al. (2005), Goel and Meisel (2013), Haase et al. (2001), and Freling et al. (2003). Li et al. (2005) synchronize film shooting activities performed by a media company at various sites, where workers have to wait for each other to start a task simultaneously. In Goel and Meisel (2013), maintenance tasks in electricity networks have to be synchronized such that the downtime of power lines is as short as possible. Haase et al. (2001) and Freling et al. (2003) consider a combined vehicle and crew scheduling problem for urban mass transit systems. Here, the drivers are allowed to change buses at some locations in the transport network. The synchronization of arrival times of the bus drivers is incorporated within the time table.

Within the young but growing field of health care operations management have been developed different routing problems. However, only few papers deal with synchronization among services. Bredström and Rönnqvist (2008) propose a mixed-integer linear programming (MILP) model for the homogeneous HHCRSP together with a simple heuristic. Rasmussen et al. (2012) model the HHCRSP with homogeneous staff members as a set-partitioning model with side constraints and develop a Branch-and-Price algorithm. Heterogeneous staff members are considered by Eveborn et al. (2006). They present a system for staff planning called LAPS CARE. The problem is solved by a repeated matching heuristic. Synchronized visits are split two visits with fixed start times. Another paper dealing with the heterogeneous HHCRSP is presented by Kergosien et al. (2009). They propose a MILP model with additional cuts and technical improvements. Here, the double service patients are modeled by duplicating nodes, for which a temporal synchronization must be respected. Also in Mankowska et al. (2014), heterogeneous staff members and synchronization requirements are considered. A MILP model is proposed together with a heuristic solution method. Still, there is a lack of exact solution methods for this problem. The contribution of this paper is to provide such a method for the HHCRSP.

Mixed-Integer Programming Model for HHCRSP

In order to make this paper self-contained, we provide the mathematical formulation for the HHCRSP as has been proposed in Mankowska et al. (2014). This model is later used to develop the Benders' decomposition method.

Given are a set of patients C, a set of service types S, and a set of differently qualified staff members V. The qualifications of the staff members are defined by binary parameter a_{vs} which equals 1, iff staff member $v \in V$ is qualified to perform service operation $s \in S$, 0 otherwise. The set of patients' homes and the central office of the HHCC (node 0) are represented by set $C^0 = C \cup \{0\}$. The binary parameters r_{is} define whether or not service $s \in S$ is required by patient $i \in C$. According to the patients' service requirements, set C can be partitioned into a set of single service patients C^s and a set of double service patients C^d. Furthermore, minimal and maximal time distances for double service operations are given by non-negative parameter $\delta_i^{\min}$ and $\delta_i^{\max}$, respectively. For $\delta_i^{\min} = \delta_i^{\max} = 0$, a simultaneous service is required. The case $0 \neq \delta_i^{\min} \leq \delta_i^{\max}$ implies that the second service operation required by the patient must start at least $\delta_i^{\min}$, but not later than $\delta_i^{\max}$ time units after the first service operation. For double services with precedence, we assume that the service operation with the lower index s must be performed before the service operation with the higher index.

The distance and traveling time between two locations i and j is given by d_{ij}. The duration of service s at patient i is denoted by p_{is}. For each patient i a time window $[e_i, l_i]$ is given for the start of the service operation(s). In case of a too early arrival of the staff member, he or she has to wait until time e_i. Services starting later than l_i effect tardiness, which allows taking up all services into a work plan even if time windows are very tight. This is because all care-dependent people should receive their help every day even if the workers are behind schedule.

The model uses the routing variables x_{ijvs}, equal to 1 iff staff member v moves from i to j to provide service operation s at patient j, 0 otherwise. The scheduling variable t_{ivs} measures the service start time of service operation s at patient i provided by staff member v. The tardiness of the service operation s at patient i is measured by z_{is}.

The HHCRSP is modeled in (1a, 1b)–(11). Objective function (1a) minimizes the total distance traveled by the staff members as this incurs the relevant cost for the HHCC. Secondary goal (1b) is to minimize the overall tardiness of services. It means that for an optimal routing determined by (1a) a scheduling with the minimal overall tardiness (1b) is determined.

$$\min \rightarrow \sum_{i \in C^0} \sum_{j \in C^0} \sum_{v \in V} \sum_{s \in S} d_{ij} \cdot x_{ijvs} \tag{1a}$$

$$\min \rightarrow \sum_{i \in C^0} \sum_{s \in S} z_{is} \tag{1b}$$

$$\sum_{i \in C^0} \sum_{s \in S} x_{0ivs} = \sum_{i \in C^0} \sum_{s \in S} x_{i0vs} = 1 \quad \forall v \in V \tag{2}$$

$$\sum_{i \in C^0} \sum_{s \in S} x_{jivs} = \sum_{i \in C^0} \sum_{s \in S} x_{ijvs} \quad \forall i \in C,\ v \in V \tag{3}$$

$$\sum_{v \in \mathrm{V}} \sum_{j \in C^0} a_{vs} \cdot x_{jivs} = r_{is} \quad \forall i \in C,\ v \in V \tag{4}$$

$$t_{ivs_1} + p_{is_1} + d_{ij} \leq t_{jvs_2} + M_1\left(1 - x_{ijvs_2}\right) \quad \forall i \in C^0,\ j \in C,\ v \in V,\ s_1,\ s_2 \in S \tag{5}$$

$$t_{ivs} \geq e_i \quad \forall i \in C,\ v \in V,\ s \in S \tag{6}$$

$$t_{ivs} \leq l_i + z_{is} \quad \forall i \in C,\ v \in V,\ s \in S \tag{7}$$

$$t_i v_2 s_2 - t_i v_1 s_1 \geq \delta_i^{\min} - M_2 \left(2 - \sum_{j \in C^0} x_{jiv_1 s_1} - \sum_{j \in C^0} x_{jiv_2 s_2} \right) \tag{8}$$
$$\forall i \in C^d,\ v_1, v_2 \in V,\ s_1, s_2 \in S : s_1 < s_2$$

$$t_i v_2 s_2 - t_i v_1 s_1 \leq \delta_i^{\max} + M_3 \left(2 - \sum_{j \in C^0} x_{jiv_1 s_1} - \sum_{j \in C^0} x_{jiv_2 s_2} \right) \tag{9}$$
$$\forall i \in C^d,\ v_1, v_2 \in V,\ s_1, s_2 \in S : s_1 < s_2$$

$$x_{ijvs} \in \{0,\ a_{vs} \cdot r_{js}\} \quad \forall i, j \in C^0,\ v \in V,\ s \in S \tag{10}$$

$$t_{ivs},\ z_{is} \geq 0 \quad \forall i \in C^0,\ v \in V,\ s \in S \tag{11}$$

Constraints (2) guarantee that the central office of the HCC is the start and end location of all routes. The route inflow–outflow conditions are ensured by (3). Constraints (4) ensure the assignment of each service to exactly one suitably qualified staff member. The service start times are determined by (5) accordingly to the service durations and traveling times. Constraints (6) guarantee that services start after the beginning of the corresponding time windows. Constraints (7) measure the tardiness of services. The minimal time distance between the two service operations involved in a double service is guaranteed by (8) and the maximal time distance is guaranteed by (9).

Exact Solution Method

Decomposition approaches are effective methods for solving linear problems by breaking them up into smaller ones and solving them separately, either parallelly or sequentially. One of the powerful decomposition approaches is Benders' decomposition for solving MILP models (Benders 1962). This method has been successfully adapted for various problems, for example, in aircraft routing and crew scheduling (Cordeau et al. 2001), locomotive and car assignment (Cordeau et al. 2000), and hub location (de Camargo et al. 2008). For adopting the Benders' decomposition procedure to the HHCRSP, we present the model in a matrix form:

$$\min \rightarrow \boldsymbol{d}^{\mathrm{T}} \boldsymbol{x} \tag{12a}$$

$$\min \rightarrow \boldsymbol{c}^{\mathrm{T}} \boldsymbol{z} \text{ subject to} \tag{12b}$$

$$\boldsymbol{Ax} \leq \boldsymbol{b} \tag{13}$$

$$\boldsymbol{Tx} + \boldsymbol{Qt} \geq \boldsymbol{r} \tag{14}$$

$$\boldsymbol{l} \geq \boldsymbol{t} - \boldsymbol{z} \tag{15}$$

$$\boldsymbol{x} \in \{0,\ 1\}^{\left|C^0\right| \cdot \left|C^0\right| \cdot |V| \cdot |S|},\ \boldsymbol{t} \in \mathbb{R}_+^{\left|C^0\right| \cdot |V| \cdot |S|},\ \boldsymbol{z} \in \mathbb{R}_+^{\left|C^0\right| \cdot |S|} \tag{16}$$

The corresponding matrices $\boldsymbol{A}$, $\boldsymbol{T}$, $\boldsymbol{Q}$, and vectors $\boldsymbol{b}$, $\boldsymbol{r}$ can be easily derived from model (1a, 1b)–(11). The objective functions (1a) and (1b) correspond to (12a) and (12b). Constraints (2)–(6) as well as (8)–(9) constitute matrices $\boldsymbol{T}$, $\boldsymbol{Q}$, and $\boldsymbol{r}$ in (13). Constraint (15) is the matrix form of (7). The domains of the decision variables (10) and (11) correspond to (16). The Benders' decomposition procedure partitions the model into two subproblems called master problem and slave problem. In the master problem (17)–(19), only binary decision variables and their corresponding constraints are included. This problem is assumed to be bounded, which means that at least one solution of the problem exists.

$$\min \rightarrow \boldsymbol{d}^{\mathrm{T}}\boldsymbol{x} \text{ subject to} \tag{17}$$

$$\boldsymbol{Ax} \leq \boldsymbol{b} \tag{18}$$

$$\boldsymbol{x} \in \{0,\ 1\}^{\left|C^0\right| \cdot \left|C^0\right| \cdot |V| \cdot |S|} \tag{19}$$

The optimal integer solution of master problem $\boldsymbol{x}^*$ is then sent to the slave, which tests feasibility with compliance to the continuous variables. Since the slave problem serves as a feasibility check for the master's solution, its objective function plays a secondary role in the Benders' decomposition. More precisely, slave problem (20)–(23) strives for the secondary objective (1b). This means, for a given routing delivered by the master problem, the slave finds the tightest possible schedule for the service operations.

$$\min \rightarrow \boldsymbol{c}^{\mathrm{T}}\boldsymbol{z} \text{ subject to} \tag{20}$$

$$\boldsymbol{Tx}^* + \boldsymbol{Qt} \geq \boldsymbol{r} \tag{21}$$

$$\boldsymbol{l} \geq \boldsymbol{t} - \boldsymbol{z} \tag{22}$$

$$\boldsymbol{t} \in \mathbb{R}_+^{\left|C^0\right| \cdot |V| \cdot |S|}, \boldsymbol{z} \in \mathbb{R}_+^{\left|C^0\right| \cdot |S|} \tag{23}$$

Since we assume the master problem to be bounded, two situations can occur when trying to solve the slave problem:

1. A *feasible* schedule can be found for the optimal routing $\boldsymbol{x}^*$.
2. *No feasible* schedule can be found for the optimal routing $\boldsymbol{x}^*$.

If the slave problem is solved *feasibly*, the method terminates returning the optimal solution for the problem. If the slave problem is *infeasible*, a so-called Benders' feasibility cut must be added to the master problem. Then, the solution process is repeated to obtain a feasible solution to the overall problem or to add further feasibility cuts if required. Codato and Fischetti (2006) propose to use combinatorial feasibility cuts for MILP models which we also use in our implementation. For these cuts, we identify those scheduling constraints which cause the infeasibility of the slave under the current routing $\boldsymbol{x}^*$. From these constraints, we derive a minimal infeasible subsystem MIS which refers to indexes corresponding to these x^* from which at least one value has to be changed to break the infeasibility. The MIS is any inclusion-minimal set of quadruples (i, j, v, s) such that the linear subsystem $T_{ijvs}x^*_{ijvs} + Q_{ivs}t_{ivs} \geq r_{ijvs} \forall i, j, v, s \in$ MIS has no feasible (continuous) solution t. This condition can be formulated as linear inequality (24). This inequality is added to the master which is then solved again to get a new routing.

$$\sum_{i,j,v,s \in MIS: x^*_{ijvs}=0} x_{ijvs} + \sum_{i,j,v,s \in MIS: x^*_{ijvs}=1} \left(1 - x_{ijvs}\right) \geq 1 \tag{24}$$

In the HHCRSP, if the solution obtained from the master is infeasible for the slave, no feasible schedule can be found for the given routing. Since binary and continuous variables are linked by big-M expressions in (5), (8), (9), only variables x^*_{ijvs} with value 1 can cause infeasibility. This means that the MIS will not include any $x^*_{ijvs} = 0$ for some $i, j \in C^0$, $c \in v$, $s \in S$ and, thus, we can remove the first summand from (24). In other words, the only situation in which no schedule can be found for a given routing is if the routing includes a cycle. Hence, the MIS includes those indexes corresponding to variables $x^*_{ijvs} = 1$ which constitute the cycle with the smallest number of edges. The purpose of the feasibility cut is then to change at least one value of the MIS-indexed x-variables from 1–0 to break the cycle. An alternative representation of feasibility cut (24) is therefore given by (25), where $|\text{MIS}|$ refers to the cardinality of the minimal infeasibility subsystem.

$$\sum_{i,j,v,s \in \text{MIS}} x_{ijvs} \leq |\text{MIS}| - 1 \tag{25}$$

The complete scheme of our implementation of Benders' decomposition is sketched in Fig. 1.

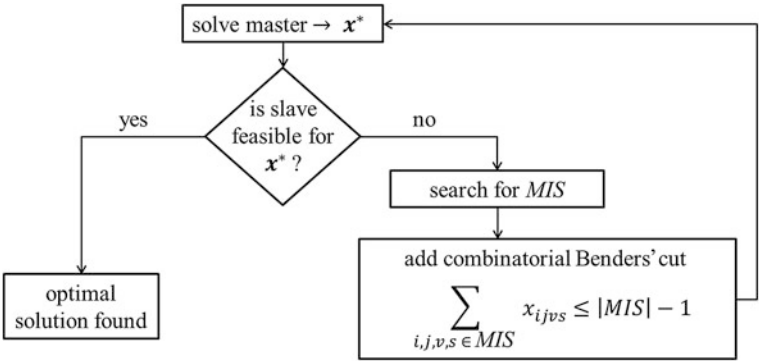

Fig. 1 Combinatorial benders' decomposition scheme

Computational Experiments

We conduct a numerical experiment to evaluate the performance of the proposed Benders' decomposition. The procedure has been implemented in JAVA using Ilog Cplex Concert Technology. The experiment is performed on a 3.40 GHz Intel Core computer. Test instances.

We use two sets of test instances (*A* and *B*) that contain ten instances each. These instances are taken from Mankowska et al. (2014). In set *A*, each instance contains three staff members and ten patients (seven single service patients, one simultaneous double service patient, and two double service patients with precedence). In set *B*, each instance includes five staff members and 25 patients (17 single service patients, four simultaneous double service patients, and four double service patients with precedence). The rest of the parameters are described in Mankowska et al. (2014) in greater detail.

Test Results

We compare the performance of our Benders' decomposition approach with ILOG Cplex 12.5.1. The runtime limit is set to two hours per instance for each method. Note that Benders' decomposition delivers a feasible (and optimal) solution only if it terminates within the given runtime limit. If it does not terminate, merely a lower bound on the objective function value is obtained from this method.

The computational results are presented in Table 1. For each instance and method, upper bounds (UB), lower bounds (LB), and runtimes (cpu) in seconds are reported. UB are the routing cost measured by (1a) of feasible integer solutions found within the given runtime limit.

Table 1 Numerical results for Cplex and benders' decomposition

Set *A*							Set *B*						
Cplex				Benders			Cplex				Benders		
Instance	UB	LB	cpu	UB	LB	cpu	Instance	UB	LB	cpu	UB	LB	cpu
A_1	537	537	2	537	537	4	B_1	1060	718	7200	–	644	7200
A_2	596	596	5	596	596	14	B_2	996	871	7200	–	762	7200
A_3	581	581	2	581	581	7	B_3	767	548	7200	–	661	7200
A_4	405	405	2	405	405	16	B_4	744	637	7200	686	686	5573
A_5	426	426	13	426	426	102	B_5	939	743	7200	772	772	5889
A_6	462	462	15	462	462	18	B_6	912	493	7200	–	476	7200
A_7	501	501	7	501	501	86	B_7	854	720	7200	–	587	7200
A_8	597	597	5	597	597	63	B_8	905	723	7200	–	648	7200
A_9	604	604	57	604	604	3634	B_9	843	538	7200	–	511	7200
A_{10}	661	661	1	661	661	4	B_{10}	1096	752	7200	–	782	7200

Both of the methods solve all instances from set A to optimality, where Cplex is clearly faster than Benders' decomposition. For set B, Cplex obtains integer feasible solutions for all instances but none of the solutions is optimal. To the contrary, Benders' decomposition is capable of solving two instances to optimality. In addition, it finds a better lower bound for instances B_3 and B_{10}. Although the performance of Benders' decomposition is not stable, it is the only method that delivers at least some optimal solutions for these test instances. Together with the improved lower bound, these results can be used, for example, to investigate the performance of new heuristic solution methods.

Conclusion

In this paper, we have presented an exact solution method for a vehicle routing problem with synchronization requirements. This problem is found in the field of home health care operations management, where double services provided by two staff members are required by the patients, i.e., simultaneous double services and double services with precedence relation. The proposed solution method is based on Benders' decomposition approach with combinatorial Benders' cuts adapted to the needs of the HHCRSP. The solution method delivers some improved LB and some new proven optimal solutions. Future research will address improvements of the method in order to achieve a more stable performance of the algorithm.

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References

Benders JF (1962) Partitioning procedures for solving mixed-variables programming problems. Numer Math 4:238–252

Bredström D, Rönnqvist M (2008) Combined vehicle routing and scheduling with temporal precedence and synchronization constraints. Eur J Oper Res 191(1):19–31

Codato G, Fischetti M (2006) Combinatorial Benders' cuts for mixed-integer linear programming. Oper Res 54(4):756–766

Cordeau J-F, Soumis F, Desrosiers J (2000) A Benders decomposition approach for the locomotive and car assignment problem. Transport Sci 34(2):133–149

Cordeau J-F, Stojkovic G, Soumis F, Desrosiers J (2001) Benders decomposition for simultaneous aircraft routing and crew scheduling. Transport Sci 35(4):375–388

De Camargo RS, Miranda G Jr, Luna HP (2008) Benders decomposition for the uncapacitated multiple allocation hub location problem. Comput Oper Res 35(4):1047–1067

Drexl M (2012) Synchronization in vehicle routing–A survey of VRPs with multiple synchronization constraints. Transport Sci 46(3):297–316

Eveborn P, Fliesberg P, Rönnqvist M (2006) Laps care–an operational system for staff planning of home care. Eur J Oper Res 171:962–976

Freling R, Huisman D, Wagelmans APM (2003) Models and algorithms for integration of vehicle and crew scheduling. J Sched 6(1):63–85

Goel A, Meisel F (2013) Workforce routing and scheduling for electricity network maintenance with downtime minimization. Eur J Oper Res 213(1):210–228

Haase K, Desaulniers G, Desrosiers J (2001) Simultaneous vehicle and crew scheduling in urban mass transit systems. Transport Sci 35(3):286–303

Kergosien Y, Lenté C, Billaut J-C (2009) Home health care problem: an extended multiple traveling salesman problem. In: Blazewicz J et al. (2009) Proceedings of the 4th multidisciplinary international scheduling conference: theory and applications (MISTA 2009), Dublin, 85–92

Li Y, Lim A, Rodrigues B (2005) Manpower allocation with time windows and jobteaming constraints. Nav Res Log 52(4):302–311

Mankowska DS, Meisel F, Bierwirth C (2014) The home health care routing and scheduling problem with interdependent services. Health Care Manag Sci 17(1):15–30

Rasmussen MS, Justesen T, Dohn A, Larsen J (2012) The home care crew scheduling problem: preference-based visit clustering and temporal dependencies. Eur J Oper Res 219(3):598–610

Tarricone R, Tsouros AD (2008) Home care in Europe: the solid facts. Regional Office for Europe of the World Health Organization, Copenhagen

Wen M, Larsen J, Clausen J, Cordeau J, Laporte G (2008) Vehicle routing with cross-docking. J Oper Res Soc 60(11):1708–1718

Heterogeneity of Velocity in Vehicle Routing—Insights from Initial Experiments

Jörn Schönberger and Herbert Kopfer

Abstract Vehicle routing comprises a variety of fleet disposition problems. We compare the performance of a homogeneous fleet of vehicles with the performance of a mixed (or heterogeneous) fleet of vehicles consisting of big but slow trucks and small but fast vans. We consider a scenario with operation starting time synchronization, e.g., a scenario in which two vehicles have to be assigned to a customer location and both selected vehicles must start their unloading operations at the same time. Within computational simulation experiments, we demonstrate that the fuel consumption as well as the makespan benefit from the deployment of a mixed fleet.

Keywords Vehicle routing · Heterogeneity · Velocity · Planning goals · Synchronization

Introduction and Motivation

Vehicle routing comprises a variety of fleet disposition problems (Golden et al. 2008). Planning goals targeted in vehicle routing comprise the minimization of (i) the total travel distance of the available vehicles (ii) driver working hours or (iii) fuel consumption (Kopfer et al. 2013). Time-related aspects are quite important for the determination of transport processes. Explicit time windows are considered in the determination of vehicle routes, but sometimes, a temporal coordination between the operations of two or even more vehicles commonly serving a customer demand is necessary. A vehicle routing problem with intervehicle operation time

J. Schönberger (✉) · H. Kopfer
University of Bremen, Bremen, Germany
e-mail: jsb@uni-bremen.de

H. Kopfer
e-mail: kopfer@uni-bremen.de

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requirements belongs to the class of vehicle routing problems with synchronization requirements (Drexl 2012).

In this paper, we report about a project in which two vehicles commonly fulfill a customer location and must start their unloading operation at nearly the same time. At such a customer side it is required that the first arrived vehicle postpones the start of its unloading operation until the second vehicle has arrived. In order to reduce or even prevent waiting times the incorporation of quicker vehicles is reasonable. Although, these vehicles might reach customer locations earlier (and potentially contribute to the reduction of waiting times) the incorporation of such a vehicle requires the solving of two challenges. First, the payload of a quicker vehicle is reduced and, second, the margin fuel consumption for each additionally carried payload ton is also increased (Kopfer et al. 2013). In the research reported here, we want to find first answers to the following research question: *Is it useful to enrich a homogeneous fleet by a smaller but faster vehicle if the goal is to minimize makespan and waiting times in a vehicle routing problem with operation time synchronization? Is there a tradeoff between the reduced waiting times a shortened makespan and the increased margin fuel consumption (per each ton of payload)*?

A Heterogeneous Vehicle Routing Problem

Literature. Recent surveys on vehicle routing problems are delivered in the papers by Kumar and Panneerselvam (2012a, b) and the book by Golden et al. (2008). Drexl (2012) proposes a classification scheme for different types of synchronization requirements. A recent compilation of different contributions to the understanding and management of heterogeneous vehicle routing problems can be found in Subramanian et al. (2012). Lecluyse et al. (2013) investigate a scheme to consider travel times in vehicle routing problems. Time-oriented objective functions for vehicle routing problems are discussed in the context of rich vehicle routing problems (Drexl 2012a). Lahyani et al. (2011) investigates the minimization of the total waiting times in a route set as one objective function in a bi-objective-function model. The makespan minimization in vehicle routing is addressed by Rambau and Schwarz (2013).

Verbal Problem Outline. A fleet F of m vehicles is available. Each vehicle f provides payload capacity $C(f)$ and it travels with the speed $V(f)$. Vehicle f is located at a start node $S(f)$. From here, it serves some customer locations and finally travels to a terminal node $T(f)$. An individual transport demand specified by a customer is called a request. A request requires the transport of different commodities of known quantities. Here, we assume that the quantities of the different commodities are equal. Then a request $r = (r^+; r^-; q_r)$ expresses the necessity of a freight carrier to transport the quantity q_r of a commodity from the pickup location r^+ to the delivery location r^-. All known requests are collected in the request portfolio P. This portfolio is partitioned into the two sets P^{flex} and P^{reg}. Each request contained in the first mentioned set requires the assignment of exactly two vehicles from F. Such a request is called a *flexible request*. A flexible request comprises two commodities (each has the size q_r) that are not allowed to be consolidated within one vehicle. A regular request r comprises only of commodity of size $q_{r,}$ and it has to be fulfilled by one vehicle. In contrast to a split delivery vehicle routing problem (Archetti and Speranza 2013), the assignment of two vehicles to a flexible request in the here reported situation is mandatory but not an option. We first construct a directed and double-weighted mathematical graph $G = (N, A, d, s)$ from the available data as the groundwork for the definition and modeling of the investigated decision problem. Without loss of generality, we assume that all involved locations are pairwise different. Let N^+ be the set of all pickup locations r^+ ($r \in P$), and N^- is defined as the set of all delivery locations, respectively. The set $N^{\text{cust}} = N^+ \cup N^-$ comprises all customer locations, but the sets N^{start} and N^{stop} contain the home nodes and stop nodes of the vehicles. The node set N of the graph is then defined by $N: = N^{\text{cust}} \cup N^{\text{start}} \cup N^{\text{stop}}$. Each arc $(i, j) \in A: = N \times N$ has a length $d(i, j)$. For each node $i \in N$ the least stopover time $s(i)$ is known. The value $s(i)$ corresponds to the time needed to load or to unload a commodity at node i and $s(i)$ equals 0 if i belongs either to N^{start} or to N^{stop}.

The decision task to be solved is now to determine exactly one path for each vehicle $f \in F$, so that the path of vehicle f originates from node $S(f)$ (C1) and terminates in node $T(f)$ (C2). Two vehicles must be assigned to each flexible request (C3) and one vehicle has to be assigned to a regular request (C4). For request r it is necessary that the pickup node r^+ is visited before the associated delivery node r^- (C5). It is not allowed to exceed the maximal allowed payload $C(f)$ of a vehicle f at any stage of the assigned path (C6). After the paths of the vehicles are fixed it is necessary to determine the starting times of the operations to be executed in the sequence predicted by the determined paths. For each vehicle f, the earliest possible arrival time at_{fi} at node i is calculated. Furthermore, the starting time st_{fi} of the operation to be executed at i is derived as well as the completion time $ct_{fi}: = st_{fi} + s(i)$ and the time lt_{fi} at which vehicle f leaves node i. Obviously, it is $at_{fi} \leq st_{fi} \leq ct_{fi} \leq lt_{fi}$ in case that vehicle f visits node i. The maximal time granted to vehicle f for traveling from $S(f)$ to $T(f)$ is limited. It is not allowed that the time between leaving the start node and arriving at the terminal node exceeds $T^{\max}$ time units (C7). A flexible request must be visited by the two vehicles f and g. It is necessary to coordinate the two associated delivery operation starting times st_{fi} and st_{gi}. Here, coordination is achieved if st_{fi} and st_{gi} do not differ more than $\text{DT}^{\max}$ time units (C8). A feasible solution of the outlined decision problem fulfills all the conditions (C1)–(C8).

The postulated coordination requirement let intervehicle coordination of the operation schedules of different vehicles become inevitable. Assume that vehicle f arrives at time at_{fi} at node i which is the delivery location of a flexible request. A fleet dispatcher has two options to prevent violations of the coordination requirement (C8) if the second selected vehicle g will arrive at time $at_{gi} > at_{fi} + \text{DT}^{\max}$. Option one is that the dispatcher postpones the start of the unloading operation of vehicle f at node i until time $at_{gi} - \text{DT}^{\max}$. However, the insertion of waiting times along the vehicle paths could lead to the exceeding of the maximal allowed path duration T^{max} and it can contribute to the prolongation of the makespan. For option two, the dispatcher instructs vehicle f to go to another node before going to node i at the expense of detours resulting in additional travel expenses and additional fuel consumption. In order to meet the makespan constraint (C7) and the coordination requirement (C8) it is necessary to consider both options for each node that requires operation starting time coordination. We will investigate the objective functions that minimize the total travel distance (MINDIST), the fuel consumption (MINFUEL), the waiting times (MINWAIT), or the makespan (MINMS).

Decision Model. Parameters are introduced in order to describe if a certain node i is a loading node or an unloading node associated with a request r. The binary parameter $p^+(r, i)$ is set to *1* if and only if node i is the pickup node associated with request r. Similarly, the binary parameter $p^-(r, i)$ is set to *1* if and only if node i is the delivery node of request r. We are going to model the aforementioned decision situation as a mixed-integer linear program using the following decision variable families: y_{rf} (binary decision variable, equals 1 if and only if request r is assigned to vehicle f); x_{ijf} [binary decision variable, equals 1 if and only if vehicle f travels along arc (i, j)]; at_{fi} (non-negative and continuous decision variable, arrival time of vehicle f at node i); st_{fi} (non-negative and continuous decision variable, starting time of un/loading vehicle f at node i); ct_{fi} (non-negative and continuous decision variable, completion time of un/loading operation of vehicle f at node i); lt_{fi} (non-negative and continuous decision variable, time when vehicle f leads node i); ω_{fi} (non-negative and continuous decision variable, inbound load carried by vehicle f to node i); Δ_{fi} (continuous decision variable, variation of the payload of vehicle f at node I, ≥0 if i is a pickup node, ≤0 if i is a delivery node contained in the path of vehicle f); MS (non-negative and continuous decision variable, represents the makespan associated with the fulfillment of the request portfolio P by fleet F).

Two different vehicles are selected to serve a flexible request (1) but a regular request is served by exactly one vehicle (2). It is not allowed to travel to a start node (3), exactly one vehicle leaves a start node (4) and constraint (5) ensures that the path constructed for vehicle $f \in F$ originates from its start node $S(f) \in N^{start}$. Similarly, it is prohibited to leave a stop node (6), exactly one vehicle terminates its path in a stop node (7), and constraint (8) enforces the termination of the path of vehicle $f \in F$ in the dedicated destination node $T(f) \in N^{stop}$. If vehicle f visits customer node i then it also leaves this node and vice versa (9). Vehicle f visits r^+ if and only if f serves request r (10) and f visits r^- if and only if f is assigned to request r (11).

$$\sum_{f \in F} y_{rf} = 2 \, \forall r \in P^{flex} \tag{1}$$

$$\sum_{f \in F} y_{rf} = 1 \, \forall r \in P^{reg} \tag{2}$$

$$\sum_{j \in N} \sum_{f \in F} x_{jif} = 0 \, \forall i \in N^{\text{start}} \tag{3}$$

$$\sum_{j \in N^{\text{cust}}} \sum_{f \in F} x_{ijf} + \sum_{j \in N^{\text{stop}}} \sum_{f \in F} x_{ijf} = 1 \, \forall i \in N^{\text{start}} \tag{4}$$

$$\sum_{j \in N} x_{S(f)jf} = 1 \, \forall f \in F \tag{5}$$

$$\sum_{j \in N} \sum_{f \in F} x_{ijf} = 0 \, \forall i \in N^{\text{stop}} \tag{6}$$

$$\sum_{j \in N^{\text{cust}}} \sum_{f \in F} x_{jif} + \sum_{j \in N^{\text{start}}} \sum_{f \in F} x_{jif} = 1 \, \forall i \in N^{\text{stop}} \tag{7}$$

$$\sum_{j \in N} x_{jT(f)f} = 1 \, \forall f \in F \tag{8}$$

$$\sum_{j \in N} x_{jif} = \sum_{j \in N} x_{ijf} \; \forall \, f \in F, \; \forall \, i \in N^{\text{cust}} \tag{9}$$

$$\sum_{i \in N^{\text{start}} \cup N^{\text{cust}}} x_{ir^+f} = y_{rf} \forall \, r \in P, \; \forall \, f \in F \tag{10}$$

$$\sum_{j \in N^{\text{stop}} \cup N^{\text{cust}}} x_{ir^-jf} = y_{rf} \; \forall \, r \in P, \; \forall \, f \in F \tag{11}$$

$$\omega_{fS(f)} = 0 \; \forall \, f \in F \tag{12}$$

$$\Delta_{fi} = \sum_{r \in P} r^+(r,i) q_r y_{rf} - \sum_{r \in P} r^{-+}(r,i) q_r y_{rf} \; \forall \, f \in F, \; \forall \, i \in N \tag{13}$$

$$\omega_{fi} + \Delta_{fi} \leq \omega_{fj} + \left(1 - x_{ijf}\right) \cdot M \; \forall \, f \in F, \; \forall \, i,j \in N \tag{14}$$

$$\omega_{fj} \leq C(f) + \left(1 - \sum_{i \in N} x_{ijf}\right) \cdot M \; \forall \, f \in F, \; \forall i, \; j \in N \tag{15}$$

$$\omega_{fT(f)} = 0 \; \forall \, f \in F \tag{16}$$

At the beginning of the route the vehicle load is 0 (12). Constraint (13) recursively determines the load variation of vehicle f at node i. The calculated load variation Δ_{fi} is used to update the vehicle payload along the vehicle path (14). The payload of a vehicle is limited by restriction (15). Finally, constraint (16) ensures that a vehicle terminates without carrying any payload. Following the classification in Drexl (2012), the constraints (12)–(16) are resource synchronization constraints that control the usage of the vehicle capacities.

$$at_{fS(f)} = st_{fS(f)} = ct_{fS(f)} = lt_{fS(f)} = 0 \; \forall f \in F \tag{17}$$

$$at_{fi} \leq st_{fi} \; \forall f \in F, \; \forall i \in N \tag{18}$$

$$st_{fi} + s(i) = ct_{fi} \; \forall f \in F, \; \forall i \in N \tag{19}$$

$$ct_{fi} \leq lt_{fi} \; \forall f \in F, \; \forall i \in N \tag{20}$$

$$ct_{fi} + \frac{d_{ij}}{v(f)} \leq at_{fi} + \left(1 - x_{ijf}\right) \cdot M \; \forall f \in F, \; \forall i, \, j \in N \tag{21}$$

$$ct_{fr^+} \leq at_{fr^-} + (1 - y_{rf}) \cdot M \; \forall r \in P, \; \forall f \in F \tag{22}$$

The requirement to visit the pickup node earlier than the associated delivery node of a request is coded in the constraint families (17)–(22). The operation times at the start nodes are set to 0 for all vehicles (17). It is ensured that the arrival time of a vehicle at a node precedes the start time of an operation at this node (18). The completion time is calculated for each operation (19). It must be earlier than the associated leaving time (20). The operations along the path of vehicle f are calculated recursively (21), taking into account the individual vehicle speeds. Vehicle f completes its loading operation at node r^+ before the unloading operation at r^- is started (22). It is reasonable to assume that the service time $s(i)$ at node $i \in N^{\text{cust}}$ is >0 and therefore the recursive arrival time calculation prevents the installation of *short cycles* which remain unconnected either to a start node or to a stop node.

$$st_{f_1 r^-} - st_{f_2 r^-} \leq DT^{\max} + \left(2 - y_{rf_1} - y_{rf_2}\right) \cdot M \; \forall r \in P, \; \forall f_1, \, f_2 \in F \tag{23}$$

$$st_{f_2 r^-} - st_{f_1 r^-} \leq DT^{\max} + \left(2 - y_{rf_2} - y_{rf_1}\right) \cdot M \; \forall r \in P, \; \forall f_1, \, f_2 \in F \tag{24}$$

Let r be a flexible request and let the two vehicles f_1 as well as f_2 be assigned to r. In order to ensure that both vehicles start the execution of the unloading operation at r^- in a coordinated fashion it is necessary that the starting times of the operations at r^- of both involved vehicles are similar, e.g., they differ not more than $\text{DT}^{\max}$ time units. To code this condition in terms of linear constraints, the two constraint families (23)–(24) are setup. Again, the M-factor ensures that any of these two constraints is only activated if (and only if) request r is served by both services f_1 as well as f_2.

$$lt_{fT(f)} \leq \text{MS} \leq T^{\max} \tag{25}$$

Constraint family (25) limits the makespan MS to $T^{\max}$.

$$Z^{\text{MINDIST}} = \sum_{f \in F} \sum_{i \in N} \sum_{j \in N} d(i, j) \cdot x_{ijf} \tag{26}$$

$$Z^{\text{MINFUEL}} = \sum_{f \in F} \sum_{i \in N} \sum_{j \in N} d(i, j) \cdot (a_f x_{ijf} + b_f \omega_{jf}) \tag{27}$$

$$Z^{\text{MINWAIT}} = \sum_{f \in F} at_{fT(f)} - \sum_{f \in F} \sum_{i \in N} \sum_{j \in N} \frac{d(i,j)}{v(f)} \cdot x_{ijf} - \sum_{r \in P} \sum_{f \in F} y_{rf}(s(r^{+}) + s(r^{-})) \tag{28}$$

$$Z^{\text{MINMS}} = \text{MS} \tag{29}$$

The mixed-integer linear program (1)–(25) is a multi-commodity network flow problem enriched by additional intercommodity restrictions on the node visiting times. Each flow can be evaluated by different performance indicators whose value is subject of optimization. In the here reported research, we combine the constraint set (1)–(25) with the minimization of the overall travel distance (26), the minimization of the quantity of the consumed fuel (27) as proposed in Kopfer et al. (2013) and the minimization of the total inserted waiting times (28), and the minimization of the makespan (29).

With the goal to verify the proposed decision model we have setup the transportation scenario outlined in Fig. 1. Vehicles are positioned at the depot node 0 waiting to be deployed to serve the three requests (1; 2), (3; 6), and (4; 5). The request (3; 6) is flexible, but the two remaining requests are regular. Request (4; 5) requires the movement of a quantity of 2 tons, but the request (1; 2) demands the movement of 0.5 tons. Each vehicle serving the flexible request (1; 2) must move 0.5 tons. The unloading operations of the two vehicles at node 6 must start at the same time ($\text{DT}^{\max} = 0$).

We distinguish two configurations. In the first configuration (HOM), a homogeneous fleet comprising four identical vehicles of category $VC_{7.5}$ (Kopfer et al. 2013) is available. Each of these vehicles has a payload capacity of 3.25 tons, and the speed is scaled to 1 distance unit per time unit. The fuel consumption is determined by the parameters $a_f = 15$ and $b_f = 1.54$ for $f = 1, \ldots, 4$. In the second

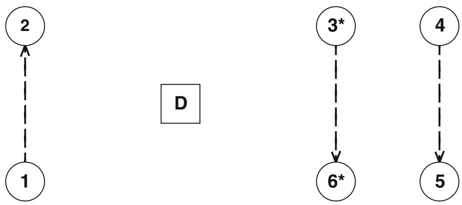

Fig. 1 Layout of the test scenario

configuration (HET), a fifth vehicle is added to the fleet. This additional vehicle belongs to the vehicle category $VC_{3.5}$. It has a payload capacity of 1.5 tons, but its speed is 1.5 distance units per time unit. Its fuel consumption is determined by $a_3 = 8$ and $b_3 = 3.31$.

Computational Experiments

We observe the four performance indicators travel distance, fuel consumption, makespan, and waiting time of a route set. In an initial experiment (first phase experiment), we optimize these four indicators individually. To do this, we combine the constraints (1)–(25) with each of the four objective functions (26)–(29) into a mixed-integer linear program. This program is configured for the two settings HET and HOM and each of the resulting 8 instances is solved using IBM CPLEX 12.4. We get the minimal objective function values $Z(\alpha, \beta)$ ($\alpha \in$ {MINDIST; MINFUEL; MINWAIT; MINMAKESPAN}, $\beta \in$ {HOM; HET}).

$$Z(\text{MINDIST}, \beta) \geq \sum_{f \in F} \sum_{i \in N} \sum_{j \in N} d(i,j) \cdot x_{ijf} \tag{30}$$

$$Z(\text{MINFUEL}, \beta) \geq \sum_{f \in F} \sum_{i \in N} \sum_{j \in N} d(i,j) \cdot (a_f x_{ijf} + b_f \omega_{jf}) \tag{31}$$

$$\begin{aligned} Z(\text{MINWAIT}, \beta) \geq & \sum_{f \in F} at_{fT(f)} \\ & - \sum_{f \in F} \sum_{i \in N} \sum_{j \in N} \frac{d(i,j)}{v(f)} \cdot x_{ijf} \\ & - \sum_{r \in P} \sum_{f \in F} y_{rf}(s(r^+) + s(r^-)) \end{aligned} \tag{32}$$

$$Z(\text{MINMAKESPAN}, \beta) \geq \text{MS} \tag{33}$$

In another experiment (second phase experiment), we repeat the previous eight experiments but we add one of the constraints (30)–(33) to the original model in order to control the corresponding performance indicator value that is not addressed in the objective function. If we use for example, the distance minimization objective function (26) then we setup and solve the following decision models consisting of the original constraint set (1)–(25) plus (a) constraint (31), (b) constraint (32), and (c) constraint (33).

Table 1 Results from computational experiments

Obj.	Ref.	Ref.	(31)	(32)	(33)
Z^{MINDIST}	HOM	(994.32)	1052.44 (+6 %)	1056.13 (+6 %)	1263.45 (+27 %)
	HET	(994.32)	1052.44 (+6 %)	994.32 (+6 %)	1263.45 (+27 %)
			(30)	(32)	(33)
Z^{MINFUEL}	HOM	(273.05)	300.58 (+10 %)	273.60 (+0 %)	304.70(+12 %)
	HET	(268.42)	295.92 (+10 %)	268.42 (+0 %)	301.23 (+12 %)
			(30)	(31)	(33)
Z^{MINWAIT}	HOM	(0)	128.90	320	0
	HET	(0)	24.65	166.07	0
			(30)	(31)	(32)
Z^{MINMS}	HOM	(436.23)	601.81(+40 %)	850.63 (+95 %)	436.23 (+0 %)
	HET	(436.23)	472.52 (+8 %)	696.70 (60 %)	436.23 (+0 %)

The different optimal objective function values from the HOM and HET settings are reported in the second column in Table 1. The incorporation of the faster vehicle has several benefits which are striking for the time-oriented waiting time objective function as well as for the makespan minimization if one of the other available performance indicators is limited to the least possible amount (shown in columns 4–6 in Table 1). In case that the distance is not allowed to exceed the minimal distance 994.32, then the amount of required waiting time (at node 6) is reduced significantly if the faster vehicle is considered (compared to the HOM scenario). Also the increase of the makespan as a response to the limitation of the allowed fuel consumption and the prohibition of waiting at node 6 is less if the faster vehicle is deployed (HET). The overall required fuel consumption does not increase compared to the situation that can use only the bigger vehicles.

Figure 2 shows the variation of the optimal route set in response to controlling one of the additional performance indicators in the MINMS experiments. Here, one of the constraints (30)–(32) is added to the original decision model (1)–(25), (29) in each experiment. The impacts of the utilization of the faster vehicle are striking. First, in case that the minimal travel distance is limited ((HET; MINMS) + (30)), the fastest vehicle is assigned to the longest route in order to keep the makespan as short as possible. Second, in case that it is necessary to keep the fuel consumption as low as possible then the faster vehicle is assigned to the longest route, but a long part of this route requires empty travel. In the last experiment ((HET; MINMS) + (32)), the fastest vehicle cannot be assigned to the longest route since 2 tons must be moved from 4 to 5 and the faster vehicle can carry only a payload weight of 1.5 tons.

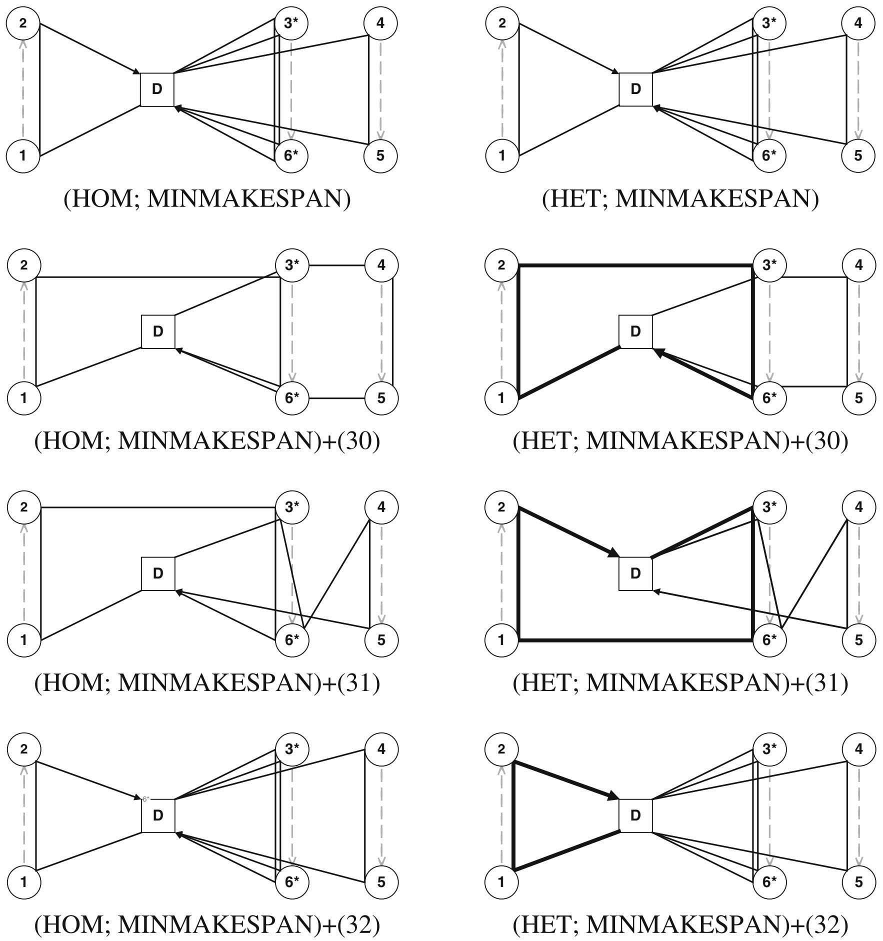

Fig. 2 Variations of the routes in case that the makespan minimization is targeted and one of the other performance indicators is under control by an additional constraint

Conclusion

We have investigated the benefits of enriching a homogeneous fleet of identical vehicles by a faster vehicle. This vehicle consumes more fuel and its payload is reduced compared to the other vehicles. However, in case that it is assigned to execute a route then it helps to reduce the consumption of fuel, and the makespan if the total travel distance is limited or if the total fuel quantity available is limited to a quite low quantity.

Future research will address more complex scenarios. The incorporation of small but fast vehicles is promising, if explicit time windows compromise the compilation of comprehensive routes. Here, we expect that the deployment of fast vehicles will lead to the reduction of the makespan and to the saving of fuel.

References

Archetti C, Speranza MG (2013) Vehicle routing problems with split deliveries. Int Trans Oper Res 19(1–2):3–22

Drexl M (2012a) Synchronization in vehicle routing—a survey of VRPs with multiple synchronization constraints. Trans Sci 46(3):297–316

Drexl M (2012b) Rich vehicle routing in theory and practice. Logistics Res 5(1–2):47–63

Golden BL, Raghavan S, Wasil EA (2008) The vehicle routing problem: latest advances and new challenges. Springer, Berlin

Kopfer HW, Schönberger J, Kopfer H (2013) Reducing greenhouse gas emissions of a heterogeneous vehicle fleet, Flexible services and manufacturing (FSM), doi:10.1007/s10696-013-9180-9

Kumar SN, Panneerselvam R (2012a) A survey on the vehicle routing problem and its variants. Intell Inf Manage 4:66–74. doi:10.4236/iim.2012.43010

Kumar SN, Panneerselvam R (2012b) A survey on the vehicle routing problem and its variants. Intell Inf Manage 4:66–74. doi:10.4236/iim.2012.43010

Lahyani R, Khemakhem M, Semet F, Chabchoub H (2011) Rich vehicle routing problem: model and experimental design analysis. In: Proceedings of the international conference on industrial engineering and systems management, ENIM&I4e2. Accessed 28 Oct 2013

Lecluyse C, Sörensen K, Peremans H (2013) A network-consistent time-dependent travel time layer for routing optimization problems. Eur J Oper Res 226(3):395–413

Rambau J, Schwarz C (2013) Solving a vehicle routing problem with resource conflicts and makespan objective with an application in car body manufacturing. Optim Methods Software 29(2):353–375

Subramanian A, Penna PHV, Uchoa E, Ochi LS (2012) A hybrid algorithm for the heterogeneous fleet vehicle routing problem. Eur J Oper Res 221(2):285–295

New Design of a Truck Load Network

Andy Apfelstädt and Matthias Gather

Abstract The production of full truck load (FTL) services has no standardisation and industrialisation characteristics today. Despite the anticipated cost increases in road freight transport, a large-scale and cross-company pooling of relation-related transport volumes is not expected in the medium term. The main reason for this situation is the 'artisanal' kind of production, characterised by an insurmountable driver vehicle bond (often including trailer) resulting in a tight coupling between the driver's working time and vehicle operating time. The implementation of the multi-shift operation as presented in this research follows a new, not previously practised implementation process. Due to the fact that individual companies cannot create their own synergies and coordinate individual transports in terms of a sequential multi-layer operation, an enterprise-wide network has to be created. This should be a network in which the 'industrialised' full load transport, in the form of broken traffic (encounter traffic and shuttle services), can be mapped. The research results are made available for practise and combined in a model-based framework for modeling transport logistics processes and analyses. In a field experiment, the economic effects of the restructured production processes will be investigated to provide reliability for permanent participation to any company in the network. Finally, after the establishment of the developed transportation network, highly frequented depot links will be tested for their potential of bundling and following shift to rail.

Keywords Transport networks · Logistic process modeling · Shared resources in logistics

A. Apfelstädt (✉) · M. Gather
Transport and Spatial Planning Institute, Erfurt University of Applied Sciences,
Altonaer Straße 25, 99085 Erfurt, Germany
e-mail: andy.apfelstaedt@fh-erfurt.de

M. Gather
e-mail: matthias.gather@fh-erfurt.de

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Introduction

As part of the discussion about the sustainable design of freight transports' future, increased shift from truck traffic to rail is the declared political objective. According to the latest studies and despite the best efforts, road transport remains by far the strongest mode in the medium to long term (Ickert et al. 2007). Nevertheless, the full truck load (FTL) traffic (so-called "house-to-house"—or "ramp-to-ramp traffic" with non-specialised trucks) offers enormous potential to shift in favour of the combined transport. This kind of transport represents the largest segment of road transport with an estimated revenue of 15.8 billion € per year in total, directly caused by shipper transport volume (Klaus et al. 2011).

Since the production of truck load services has no standardisation and industrialisation characteristics today, a large-scale and cross-company pooling of relations related transport volumes is not expected in the medium term. This is the case which despite the anticipated cost increases in road freight transport. So it must be an objective of this research to make truckload shipments more efficient and thus environmentally friendly. Beside, this research has to identify bundling potentials through industrialisation and systematisation processes in order to facilitate the shifting of a large part of this kind of traffic to other modes.

The German-language research on the subject of 'FTL-transports in Europe' is limited to the work of Klaus and Müller from Fraunhofer Institute Nürnberg. The currently available literature on the topic of 'industrialization of FTL traffic' (Müller and Klaus 2009) in Europe describes the characteristics of the production of large American fleet operators (Corsi and Grimm 1987) and attempts to transfer the advantage characteristics of the so-called Advanced Truckload Firms (ATLF) (Corsi and Strowers 1991; Rakowski et al. 1993) to the European market. ATLF in North America have a very high degree of industrialisation and they produce truck load much more efficiently than European companies. Within the research project 'cargo exchange' (Fraunhofer 2011a) this approach has been taken up and tried to establish driver change stops 'on the way' (one of the key success factor of ATLF) in order to ensure a multi-shift operation of the vehicle, according to the American model. However, the separate scheduling of drivers and vehicles caused basically a substantially increased effort for planning and control. Barriers to the implementation of cross-company driver pools and the driver exchange 'on the way' are mainly related to the lack of legal protection and the lack of acceptance of the relevant drivers. The ongoing development of innovative planning tools for vehicle scheduling was in recent focus of science.

The research project 'SILK' (Fraunhofer 2011b) pursued, for example, the goal of "merging individual local planning units (dispositions of the individual companies) into a joint planning and combination of a 'great commission pool while maintaining the local decision suzerainty.'" The projects mentioned above are each completed. A measurable productivity increase by FTL-transport providers in Europe has not yet been achieved.

Additionally the success of cooperation between transport companies is limited to the bilateral exchange of shipments between individual partners in the context of closed user groups in ‘Timocom’—a freight and cargo space exchange and market place in the internet, own portals (similar to Timocom) and the creation of joint purchasing advantages. Increased productivity of individual members has been hardly measurable. Certainly bilaterally agreed encounter traffic takes place between individual transport partners. These are subject to strong seasonal fluctuations in volume and cannot be maintained throughout the year in the majority of the cases.

This chapter is organised as follows. In the next section a short description of the research topic is provided. In section “Idea of the Design and the Structure of a new FTL Network” the idea of designing and structuring of the new network is shown. The following chapter “Application of Topological Network Measures in Manufacturing Systems” explains benefits and advantages of the new organisation and in the last section a conclusion and an outlook to further research steps is given.

Problem Description

The production process in FTL transport is characterised today by a significant lack of productivity. The main reason for this situation is the so-called ‘artisanal’ kind of production, characterised by an inevitable driver-vehicle bond (often including trailer), and therefore a tight coupling between working time (BAG 2013) of the driver and the deployment time of the vehicle. The processing of a transport order is accompanied from the beginning to the end of the contract by the same driver who actually performs the transport with ‘his/her truck’. The value added share of the truck (means of production) is—also due to statutory driving and rest periods, and the applicable law on working hours for the driver—lower than 30 % (Apfelstädt 2009). Even doubly occupied vehicles (two drivers at the same time at the vehicle) have to rest at least 9 h within a 30 h operation period, to allow the drivers to rest in the framework of the current driving and rest time regulation (BAG 2013). Optimisation potentials in the context of planning support for the individual tour and creating virtual so-called ‘big application pools’ are also largely exhausted today and create only small changes in productivity. The current situation with focus on the productivity of German FTL companies is summarised in Fig. 1.

Due to the regulation VO (EG) 561/2006, a driving time of 9 h per day is allowed (twice a week at most 10 h), with a maximum of 90 driving hours for two weeks. Therefore, the maximum of driving hours per week in a long-term average is almost 45 h. The working time law limits the maximum weekly working time to 48 h in the long-term average. So nearly any driver’s activity is reducing the usable driving time (average 45 h per week, nearly the same). By a minimum working activity of 1.5 h per day, 45 min for loading activity and 45 min for unloading activity, the maximum driving time decreases to 7.5 h per day.

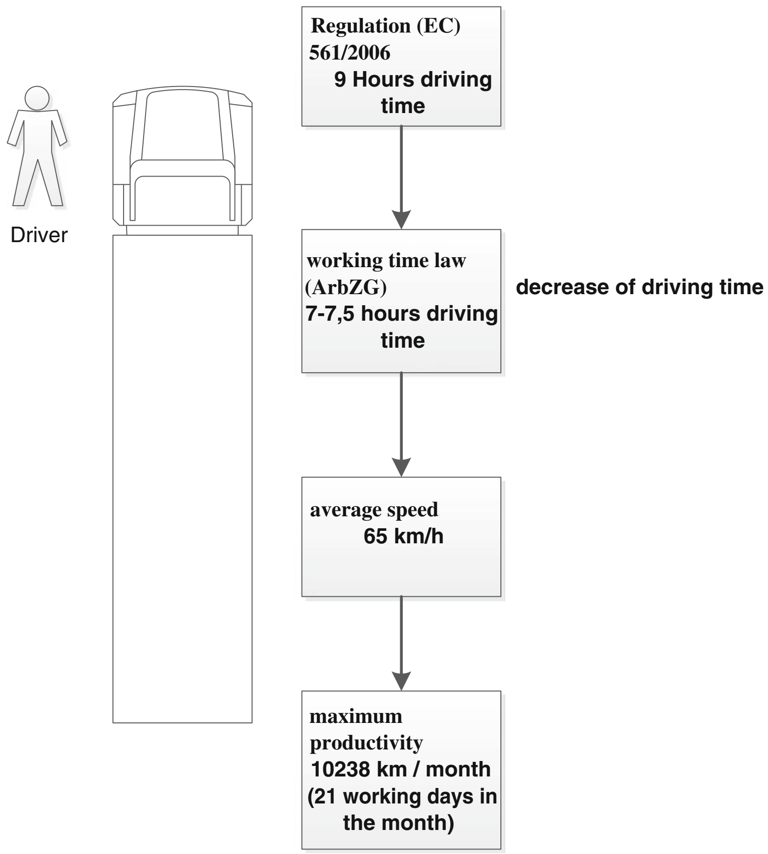

Fig. 1 Productivity of single—driver operational

The maximum of the truck's value-added activity by the single-driver model is in dependence on the average speed of 65 km/h only a little more than 10,000 km per month (Apfelstädt 2009). The Maximum of truck's value-added activity per day = 9 h, driving time—1.5 h, working time = 7.5 h, driving time × 65 km/h average speed = 488 km, this means per month = (488 km × 21 working days) 10,238 km.

To design road transport more efficiently, the operating times of the vehicles must be extended. Due to the following conditions no practical implementation of concepts exists in the FTL-Market, while LTL transport networks and industrialised general cargo production successfully exist since many decades:

(a) Because of the dominance of small and smallest providers in the FTL transport market and the so established lack of innovation (R&D weakness in the industry), individual companies cannot create their own synergies and coordinate individual transports in terms of a sequential multi-layer operation because of their structure and size.

(b) The equipment currently in use by the FTL—market participants are not exchangeable mutually.
(c) The possibility of building an enterprise-crossing transport network and its economic benefits for the individual partner companies has not been studied adequately and proven so far.

Idea of the Design and the Structure of a New FTL Network

A significant increase in productivity of the truck can be achieved by the use of a driver-vehicle decoupling by sequential multiple occupation with the aim to increase the operating time of the truck regardless of the individual drivers work time. The intended driver change in turn can only take place in a purposeful way if realised always at the same place (home depot) and it has to be separated from the actual destination of the transport order. The benefit in terms of the vehicle productivity of the vehicle is shown in Fig. 2.

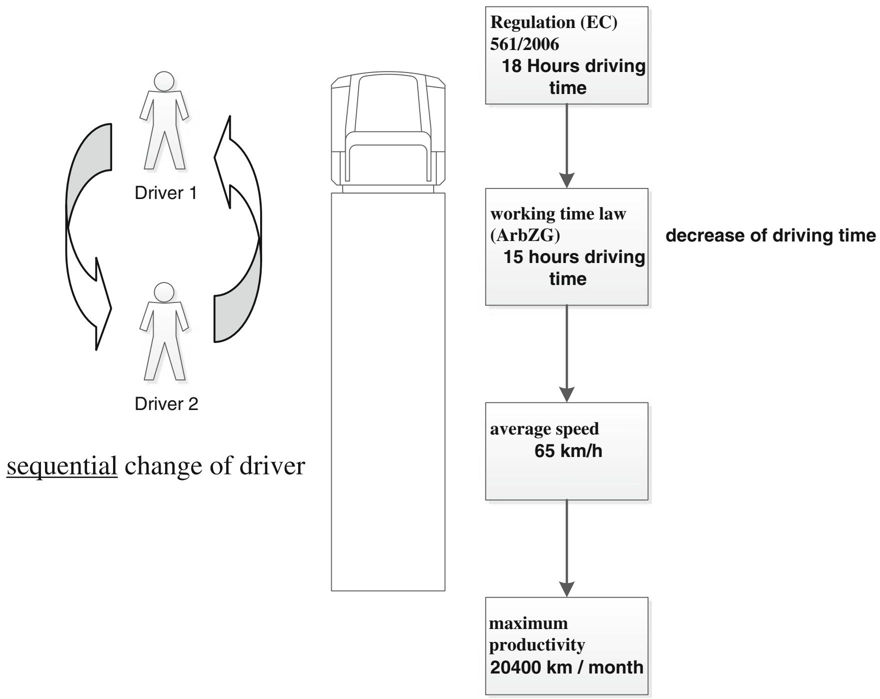

Fig. 2 Productivity of sequential change of driver operational

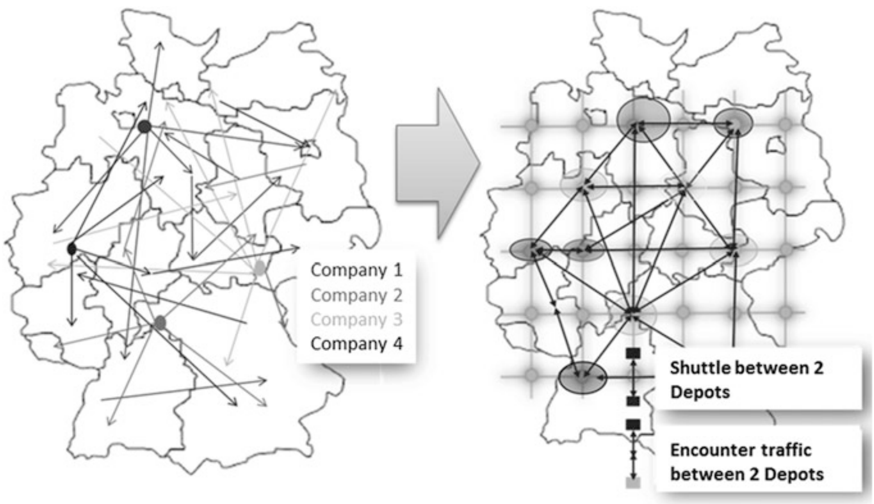

Fig. 3 The current situation and the new approach

These multi-shift operations have to be implemented according to a new, not previously practised implementation process. Currently no research and development projects or other activities in relation to this solution are known.

Since individual companies cannot create their own synergies and coordinate individual transports in terms of a sequential multi-layer operation, an enterprise-wide network has to be created in which the industrialised full load transport, in the form of broken traffic (encounter traffic and shuttle services) can be mapped. The concept of the new network is shown in Fig. 3.

Thus, the option to transfer the working distance (main run, Line haul) pro rata to the network partner, the use of own vehicles of every network partner will be restricted on a fixed radius of action. Because of this, the possibility to realise productivity increases by each multi-layer operation (driver change “at the home depot”) in each participating company in the network will be given. An outline of the first concrete benefits is shown by Nieberding and Dashkovskiy (Nieberding and Dashkovskiy 2014).

Advantages of the New Organisation of FTL in a Network

Compared to the operation in existing ‘simple’ networks (in general cargo or LTL) in the FTL-network no bundling effects can be used. Therefore, the biggest challenge will be to make the overall network robust against fluctuations in volume and temporary individual traffic imbalances. For that reason, a novel system for dynamic routing of the line haul steering settlements and nodes will be developed as a function of the total amounts in the network.

The network operation (line hauls) will be the basis for the initial expansion of the network design with the inclusion of alternative transport modes. This leads to a new networking and dynamics of transport processes. The significant increase in the productivity of the means of production in the national freight transport will be made possible by the following processes (see also Fig. 3):

- Splitting the single-term transport chain in (pre-), main-and post-run
- Establishing a network of depots (or regional hubs) with area responsible carriers (thus fixed radius of each vehicle)
- Developing a mathematical model which allows the simulation of this approach to the design, control and assist the network
- Implementation of the respective main runs through an innovative system for dynamic routing of the line steering settlements, and nodes in a network of fixed shuttle services between the respective depots.

As part of the research project 'I-LAN' FH Erfurt, we will investigate and quantify whether and what benefits can be achieved by a sequential multi-cast truck operation in cargo networks. The necessity of driver-vehicle decoupling and introduction of variable crossover traffic (swapping trailers and trucks) requires reorganisation and new planning of the entire FTL traffic. However, it opens up new possibilities and potentials of productivity increase due to longer operating times of each vehicle, the improvement of working conditions for the drivers and a more efficient use of the existing infrastructure. Furthermore in medium term a modal shift of the network-main run to environmentally friendly transportation can be achieved. Under this premise, the project has the following sub-objectives:

- Developing new approaches to the organisation, coordination, planning and management of national FTL transport to decouple the operating time of the truck from the drivers' working time
- Developing generic and extensible model of the reorganisation of transport, development of a simulation software that models the new concept and allows theoretical experiments
- Analysing the economic, environmental and further effects of the model and in a field test
- Analysing the options for modal shift of the network line haul transports.

Conclusions and Future Work

In contrast to previous approaches, the proposed new model of transport organisation is not aim of the optimise vehicle disposition and tours, but to ensure a re-designed, systematic dealing with traffic. That means, all vehicles move in a restrictive radius of action and take over the pro rata processing in the transport chain taking place in this field. The drivers' return to the (home-) depot at the end of his working shift will be realised for the first time in this transport segment, regardless of the actual order distance. Each network company will be able to participate in the process of industrialised FTL production processing, regardless of its corporate fleet size and company strength.

Due to the already available (partner) infrastructure of the project partner ELVIS AG (more than 150 transport companies) and the already available exchangeable equipment (currently more than 100 single semi-trailers), a practical implementation as a pilot project in the framework of the overall project is guaranteed. The modeling and analysis of national FTL transports from industrial engineering and scientific perspective will be done on the basis of freight flow analyses, transport chain management methods, costing and pricing models and economic considerations (Gather et al. 2011). This allows to analyse transportation networks with a high degree of detail and logistical properties such as the capacity and performance. An equation-based modeling is formulated mathematically using dynamic systems and control theory (Dashkovskiy et al. 2012). Thus, general statements about the system performance, robustness and stability can be made. With these models, the new transport processes are analyzed in terms of efficiency, sustainability, environmental impact and other dynamic effects and characteristics. The research results are finally made available for practise and combined in a model-based framework for modeling transport logistics processes and analyses. By theoretical studies, simulations and field tests, the following positive effects are expected and will be analysed and quantified in the course of the project:

- Increase in revenue per vehicle, by the sequential multi-shift operation of the means of production used (truck) is made possible with the approach
- Improving the competitive position of national transport companies by reducing the total production costs by up to 15 %
- Reduction of polluting emissions by reducing empty mileage
- Minimizing the susceptibility of the system by using the fixed radius of the vehicles and the resulting response time by technical problems
- Reduction of the total vehicle population due to an accumulation of orders per vehicle, despite the general increase of cargo
- Improve the predictability and timeliness of FTL transports through the system-guided processing
- Increase the attractiveness of the occupation 'truck driver' through a driver daily return to his home, which is realised through the network use
- Weakening of the currently escalating problem of driver deficiency
- Favourable infrastructure utilisation by an inherent time shift in the settlement of the main run mainly during night hours
- Reduction of public parking stall requirements, network driver do not have to spend their break in the vehicle on public roads
- Creation of relocation options of road freight transport to rail, by pooling and visualisation of main run traffic in the network.

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References

Apfelstädt A (2009) Begegnungsverkehre zur Steigerung der Wirtschaftlichkeit im euronationalen Ladungsverkehr. Master thesis, Hochschule Heilbronn

BAG Bundesamt für Güterverkehr (2013) Welche besonderen Rechtsvorschriften gelten für das Fahrpersonal? http://www.bag.bund.de/SharedDocs/FAQs/DE/Fahrpersonalrecht/Fahrpersonalrecht_01.html?nn=12826

Corsi T, Grimm C (1987) Changes in owner-operator use, 1977–1985: implications for management strategy. Transp J 26(3):4–16

Corsi T, Strowers J (1991) Effects of a deregulated environment on motor carriers: a systematic, multi-segment analysis. Transp J 30(3):4–28

Dashkovskiy S, Görges M, Naujok L (2012) Autonomous control methods in logistics—a mathematical perspective. Appl Math Model 36(7):2947–2960

Fraunhofer SCS (2011a) CARGO eXchange Abschlussbericht, Nürnberg

Fraunhofer SCS (2011b) SILK—Systemgestützte Intelligente Logistische Kooperation Abschlussbericht, Nürnberg

Gather M, Grothmaak A, Stangel C (2011) Nur heiße Luft in großen Bussen? Möglichkeiten und Grenzen einer flexiblen Flottengestaltung. In: Der Nahverkehr Heft 12/2011

Ickert L, Rommerskirchen S, Weyand E (2007) Abschätzung der langfristigen Entwicklung des Güterverkehrs in Deutschland bis 2050, Basel

Klaus P, Hartmann E, Kille C (2011) Die top 100 der Logistik. Hamburg

Müller S, Klaus P (2009) Die Zukunft des Ladungsverkehrs in Europa. Hamburg

Nieberding B, Dashkovskiy S (2014) Costs and travel times of cooperative networks in full truckload logistics. 4th international conference on dynamics in logistics (LDIC 2014), Bremen

Rakowski J, Southern N, Jarrel J (1993) The changing structure of the U.S. Trucking Industry. Implic Logist Managers J Bus Logist 1:111–130

Costs and Travel Times of Cooperative Networks in Full Truck Load Logistics

Sergey N. Dashkovskiy and Bernd Nieberding

Abstract Based on the actual situation of full truck load logistics in Germany and the idea of a reorganization of the transport routes using a cooperative network structure with encounter traffics at depots, we model one simple case to underline the expected advantages in costs and productivity. It turns out that the transport costs and unproductive time decreases drastically in the network structure and as positive side effect the job as truck driver may become more attractive.

Keywords Cooperative networks · Transportation costs · Transport time

Introduction

In the past decade, the truck transportation segment in Germany received a lot of transformations, for example new legal restrictions like tolls and rest times or new car sizes and the never ending procedure of higher prices for fossil energies. Beside this, the logistic branch is marked by high insolvency rates and low returns on sales with a high sensitivity to empty runs (Apfelstaedt 2009; Grill 2013).

At least the recruitment of new stuff is difficult through the situation of spending the working and rest time on the truck for often more than one day as opposed at home. All these problems are required for systematic analysis and optimization of the transport processes.

In this paper, we are focused on the full truck load segment. Several researches and studies in this field have been made by different authors. In (CARGO Exchange 2011), the attempt was made to establish the so-called ATLF model in Germany, which manages the driver-truck manning for large transport fleets and is very successful in the US markets. Another approach has been made in (SILK 2011),

S.N. Dashkovskiy · B. Nieberding (✉)
Erfurt University of Applied Sciences, Altonaerstrasse 25, 99085 Erfurt, Germany
e-mail: bernd.nieberding@fh-erfurt.de

S.N. Dashkovskiy
e-mail: sergey.dashkovskiy@fh-erfurt.de

H. Kotzab et al. (eds.), *Dynamics in Logistics*,
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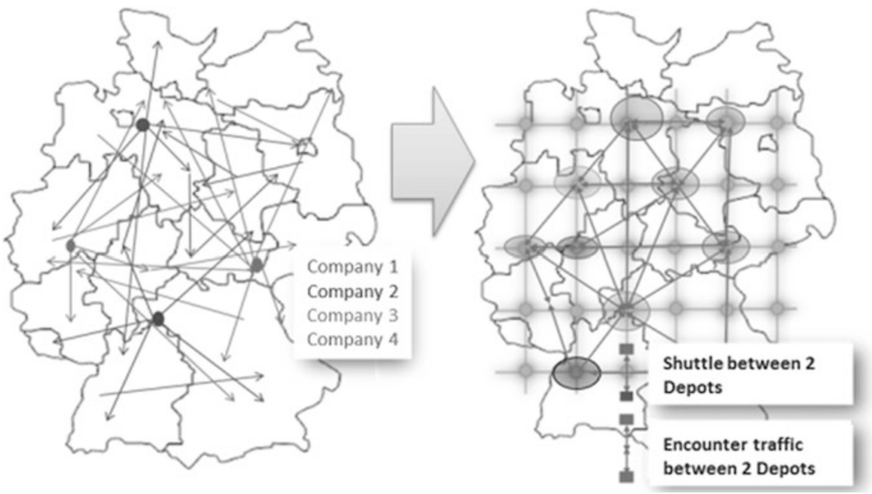

Fig. 1 Illustration of a carriage without an encounter traffic network (*left*) and with an encounter traffic network (*right*). *Source* Dashkovskiy and Gather (2012)

which tried to connect local dispositions to generate a bigger order pool with shared planning and executing of carriages. A standardization of processes and interfaces for encounter traffics has been derived in (Kunze et al. 2012).

In our project, we reorganize the transport routes of all carriages of the partner companies in a time period (Fig. 1). After the reorganization, we obtain a depot network so that transports with local distances will be shipped by one company and transports with longer distances will be shipped in the network as a cooperation of different companies using encounter traffics. Aim of this paper is to give a first view over the expected advantages of a cooperative network in cost and time.

This paper is organized as follows: In the next section, we give a short description about the investigated problem. In section "Main Results," we make simulations of the transport time and costs on one path in a network graph, with a various number of depot nodes on this path, to show the advantages of a cooperative network. In the last section, we will give conclusions and an outlook to further research steps.

Problem Description

A big lack of productivity in truck carriages is caused by the truck-driver coupling and therefore the parity of driver working time and truck operating time, i.e., a transport is managed by one single driver over the whole distance. As a consequence, the fraction of unproductive transport time increases drastically for long distance due to the legal rest time the driver takes in his truck. For example, the legal rest time in Germany in which the driver is not allowed to be in a moving truck is regularly 11 h which is the half of a day (BAG 2013). Combined with the average driving time of 7.5 h a day this leads to a truck workload of 30 % per day and person (Apfelstaedt 2009). Considering the fixed costs for driver and truck a day, this offers an optimizing potential of 280 € a day. For the whole transport this is up to 40 % compared to the total transport costs (c.f. section "Transport Costs").

To exhaust this potential, networks with encounter traffics must be created to decouple the driver from the truck, and with that the driver working time from the truck operating time. Because of the fact that more than 98.5 % of all carrier companies have less than 50 trucks of variety type in their transport fleet, a network can only be established as a cooperation of different companies (VWZ 2006). Beside legal and actuarial restrictions about the interchange of transport equipment between different companies there are emotional restrictions among the market players toward a cooperation with competitors. To demonstrate the advantages of a cooperative network structure, simulations and comparisons of the old and new model are needed to convince all participants of the win-win-situation. These simulations are the subject of the next section.

Main Results

We consider all carriages of different logistic companies at the same period of time, for example one day, as a mathematical graph with nodes and edges, where the nodes are the starting and end point of a carriage and the edges denote the existence and distance (or time) of a transport between two nodes.

The aim of the I-LAN project (Dashkovskiy and Gather 2012) is to add new nodes (depots or meeting points) to the transportation graph and to reorganize the transport paths along these nodes with encounter traffics, i.e., a truck moves not the complete distance from the starting point A to the destination point B. Instead, the truck moves from A to a depot N_1, where another driver moves this load to the next depot or the end point B. Meanwhile, the first driver moves another truck to his home depot A. To generate maximal productivity, the pairwise distance between two depots should be less than half of the average possible range a driver can reach with a pause of 0.75 h. This saves unproductiveness of the equipment during the legal rest time of the driver, and can make the drivers job more attractive due to its resting-at-home component. A more detailed description of the approach can be found in (Apfelstaedt and Gather 2014).

In this paper, we consider only a simple academic example to demonstrate the main idea and expected effects. Considerations of problems with quantity of nodes and network structure implied inefficiencies are postponed to future research steps. Also stochastic effects are considered actually as deterministic using average driving times or delays, and will be handled properly in the following research.

To give a quantitative and qualitative overview about the possible advantages we focus on a transport in one direction from point A to point B with a distance d and model the costs and time of the transport in dependence of the number of network depots. After reaching a depot the driver of the truck will be changed. To obtain realistic results, we assume the following parameters for a transport in Germany (Apfelstaedt 2009). The average driving time is set as $t_d = 7.5\,\mathrm{h}$ per day and driver. The fixed legal rest time is set as $t_r = 11\,\mathrm{h}$ a day per driver, the time for pauses is $t_p = 0.75\,\mathrm{h}$ a day, and the time spent in traffic jam is $t_{tr} = 0.5\,\mathrm{h}$ a day (Apfelstaedt 2009). The time for detouring, loading, and delays is $t_l = 1\,\mathrm{h}$ for every depot in the network. The difference time, in which a truck with only one driver has to rest due to legal restrictions (for more than one driver it is always zero):

$$t_{dif} = \begin{cases} 24 - t_d - t_l - t_r - t_p & \text{for } 24 - t_d - t_l - t_r - t_p > 0 \\ 0 & \text{else} \end{cases} \tag{1}$$

Further, we set the average velocity to $v_a = 65\,\mathrm{km/h}$. The variable costs are $c_v = 0.382$ €/km, the fixed costs are $c_f = 295$ € per day, and the business expenses are $c_e = 14$ € per day (Apfelstaedt 2009). The denotation of the number of depots in the network is N.

Encounter Traffics Increase Transport Equipment Productivity

Transport Time

In this section, we are focused only on a productive usage of the transport equipment. At first, we consider the transport time as function of the distance with the depot parameter N defined by

$$T_N(d) = \frac{d}{v_a} + \left\lfloor \frac{d}{(N+1)t_d v_a} \right\rfloor (t_r + t_{dif}) + \left\lfloor \frac{2d}{(N+1)t_d v_a} \right\rfloor \frac{t_p}{2} + \frac{d}{24 v_a} t_{tr} + (N+1)t_l, \tag{2}$$

where $\lfloor \cdot \rfloor$ denotes the floor function and d denotes the distance to destination.

In the top left picture in Fig. 2, we see that in the distance range less than 250 km a transport without depots is the optimal solution. In this range, the times caused by depot related tasks increase the transport time by 1.5 h (for one depot). Between 250 and 490 km, the difference in time decreases due to the pause of the driver in the transport without depots. In the last interval, from 490–500 km the jump occurs by the legal rest time, which the transport without depots has to take, while the transport with one network depot only has a small jump equal to the pause time of the driver.

The distance range of 1000 km is described in the top right picture in Fig. 2. In the range less than 750 km, the addition of a second depot reduces the transport

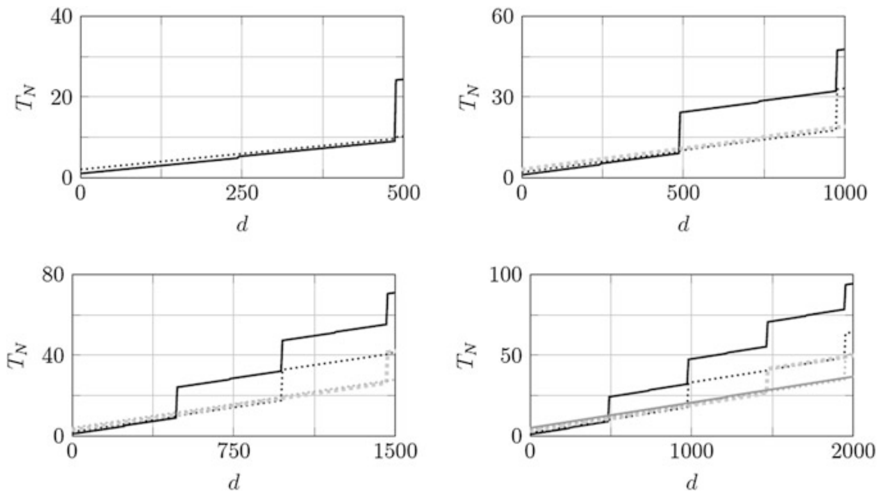

Fig. 2 Transport time T_N in h/km for the distances d = 500, 1000, 1500, and 2000 km with zero depots (—), one depot (· - -), two depots ( ), three depots ( ), and four depots ( )

time by the pause time, but obtains another 1.5 h for depot related tasks. Therefore, in the range of 500–980 km a network with one depot is the optimal solution. For distances around 980 km the transport without depots have a second jump equal to the rest time and the transport with one depot jumps also through the rest time. This behavior remains in greater distances (c.f. bottom of Fig. 2).

To underline the big advantage of the network structure, we consider the unproductive time (without traffic jam time). Therefore we remove from the time function T_N the productive component d/v_a and obtain:

$$T_N^{u}(d) = \left\lfloor \frac{d}{(N+1)t_d v_a} \right\rfloor (t_r + t_{dif}) + \left\lfloor \frac{2d}{(N+1)t_d v_a} \right\rfloor \frac{t_p}{2} + (N+1)t_l. \qquad (3)$$

It is obvious in Fig. 3 that the legal rest time involves the biggest potential of optimization and that the application of depots and the sequential multilayer operation transfers this to the productive time sector. If we compare the transport times in the range of distances greater than 490 km, the transport time without or insufficient numbers of depots is two times higher as the time of a transport with a depot every 490 km (c.f. Fig. 2).

Transport Costs

Now we investigate how the differences in time affect the transport costs. The costs as function of the distance with the depot parameter N is defined as the sum of variable costs, business expenses, and fixed costs:

$$C_N(d) = c_v d + \left\lfloor \frac{2d}{(N+1)t_d v_a} \right\rfloor c_e + c_f \left\lfloor \frac{\frac{d}{v_a} + \left\lfloor \frac{d}{(N+1)t_d v_a} \right\rfloor (t_r + t_{dif}) + \left\lfloor \frac{2d}{(N+1)t_d v_a} \right\rfloor \frac{t_p}{2} + \frac{d}{24 v_a} t_{tr} + (N+1)t_l}{24} + 1 \right\rfloor . \quad (4)$$

In the top left picture in Fig. 4, we see that in the distance range less than 250 km there is no difference in costs using a network structure or not. After 250 km, the driver of a transport without depots cannot return to his home depot with the truck and the costs jump by the value of business expenses, while the costs for a transport with one depot are equal to the variable costs plus the necessary fixed costs. For distances greater than 490 km, the driver of the transport without depots has to rest till the end of day and the costs jump by the value of fixed costs and business expenses, while the costs for a transport with one depot increases only by business expenses. The maximal distance before the costs must jump by the fixed costs, is around 1150 km (using two depots). This jump involves optimizing potential only in optimizing depot tasks times, which may increase costs due to required extra driving staff and is not related to unproductive transport times caused by legal rest time restrictions (c.f. bottom right picture in Figs. 3 and 4).

If we consider the bottom right picture in Fig. 4, we see that the fixed costs for a transport without depots increase the transport costs up to 40 % of the costs of a transport with four depots, which includes an optimization potential for profit and prices.

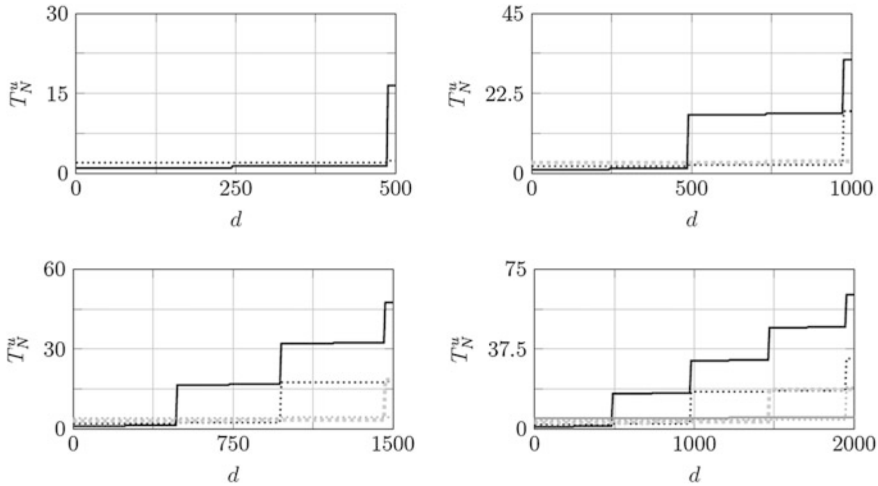

Fig. 3 Unproductive time T_N^u in h/km for the distances d = 500, 1000, 1500, and 2000 km with zero depots (—), one depot (· - -), two depots (▫ ▫), three depots (· ▫ ▫), and four depots (▬)

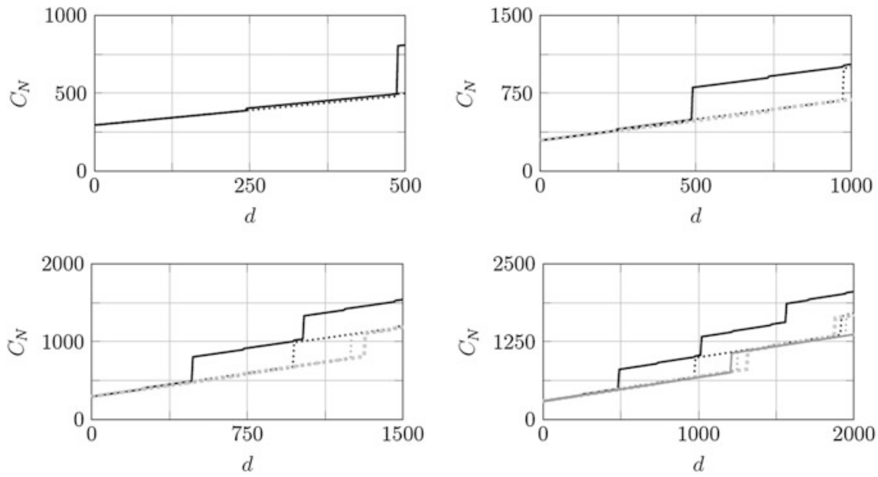

Fig. 4 Transportation costs C_N in €/km for the distances d = 500, 1000, 1500, and 2000 km with zero depots ( ), one depot ( ), two depots ( ), three depots ( ), and four depots ( )

Encounter Traffics Generate Lower Costs and Increase Job Attractiveness

In the previous section, we have not used the constraint of the pairwise depot distance less than half of the average maximal driving distance per day ($v_a \cdot t_d$). Now the depot number N must be chosen in dependence of the transport distance d as

$$N^* = \left\lfloor \frac{2d}{t_d v_a} \right\rfloor. \tag{5}$$

With this constraint, the maximum distance radius of one driver is around 240 km and the driver can return to his home depot without resting. To operate mathematically with the floor function $\lfloor \cdot \rfloor$, we chose $1 > \varepsilon \geq 0$ such that

$$\left\lfloor \frac{2d}{t_d v_a} \right\rfloor = \frac{2d}{v_a t_d} - \varepsilon, \tag{6}$$

holds. Then we obtain

$$\left\lfloor \frac{d}{\left(\left\lfloor \frac{2d}{t_d v_a} \right\rfloor + 1 \right) t_d v_a} \right\rfloor = \left\lfloor \frac{d}{2d + (1 - \varepsilon) t_d v_a} \right\rfloor = 0, \tag{7}$$

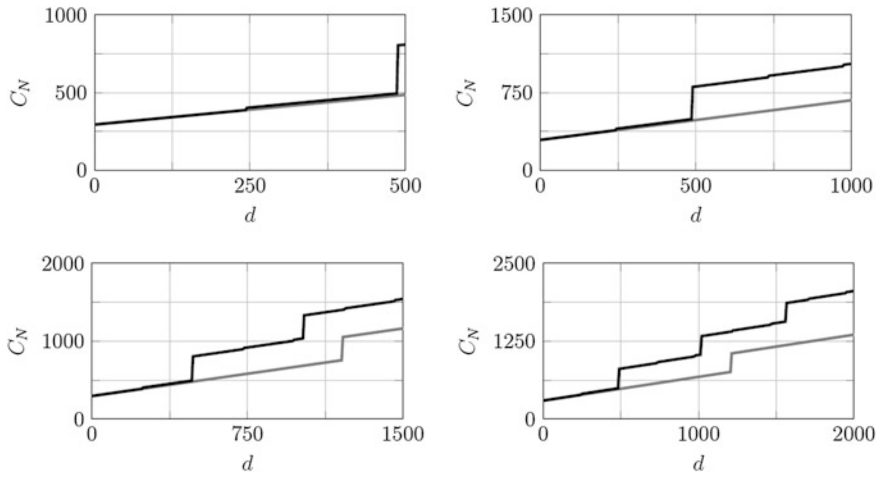

Fig. 5 Transportation costs C_N in €/km for the distances d = 500, 1000, 1500, and 2000 km with zero depots (—) and N^* depots (▬)

and

$$\left\lfloor \frac{2d}{\left(\left\lfloor \frac{2d}{t_\mathrm{d} v_\mathrm{a}} \right\rfloor + 1\right) t_\mathrm{d} v_\mathrm{a}} \right\rfloor = \left\lfloor \frac{2d}{2d + (1-\varepsilon) t_\mathrm{d} v_\mathrm{a}} \right\rfloor = 0. \tag{8}$$

With (7) and (8) our transport time function (2) is reduced to

$$T_{N^*}(d) = \frac{d}{v_\mathrm{a}} + \frac{d}{24 v_\mathrm{a}} t_\mathrm{tr} + (N^* + 1) t_\mathrm{l}, \tag{9}$$

and with that the cost function (4) becomes

$$C_{N^*}(d) = c_\mathrm{v} d + c_\mathrm{f} \left(1 + \left\lfloor \frac{\frac{d}{v_\mathrm{a}} + \frac{d}{24 v_\mathrm{a}} t_\mathrm{tr} + (N^* + 1) t_\mathrm{l}}{24} \right\rfloor \right). \tag{10}$$

As a consequence, we can save the business expenses of the driver and the driver can take his rest time at home. The transport costs using N^* depots compared to zero depots are illustrated in Fig. 5.

The description of Fig. 5 is analog to Fig. 4. Using a depot network, the costs can be reduced up to 40 %. Because of depot related times for loading, detouring, and delays, the cost function with N^* depots has optimizing potential correlated with extra costs, which has to be investigated and balanced in reality. On the other hand, better labor conditions through low transport distances prevent boosting labor costs for drivers and eases driving recruitment.

Conclusions and Future Work

We have shown that the usage of a cooperative network with encounter traffics increases the productivity of the transport equipment drastically (cf. Figs. 2 and 3). As a consequence, the transport costs can be reduced from 25 up to 40 % depending on the transport distance. Beside that a network structure with depot distances lower than half of the average maximal driving distance per day for one driver reduces the fixed costs to their minimum, and due to the transfer of the rest time from the truck to the drivers home the job can become more attractive.

Further, research steps are the establishing of a cooperative network in the real world with the founded parameters, and the comparison between theoretical and practical costs of a transport in this network. Especially, the required extra driving personal will have some effect on the cost reducing factors. A dynamical component to include carriages which are not directly related to the network and analysis of the network to guarantee stability and robustness are other research steps in the near future.

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References

Apfelstaedt A (2009) Begegnungsverkehre zur Steigerung der Wirtschaftlichkeit im euronationalen Ladungsverkehr. Master thesis, Hochschule Heilbronn

Apfelstaedt A, Gather M (2014) New design of a truck load network. In: Proceedings of 4th international conference on dynamics in logistics (LDIC 2014), Bremen

Bundesamt für Güterverkehr (BAG) (2013) Welche besonderen Vorschriften gelten für das Fahrpersonal?

Dashkovskiy S, Gather M (2012) Entwicklung und Erprobung produktivitäts- und effizienzsteigernder Lösungen zur intelligenten Vernetzung nationaler Ladungsverkehre. Forschungsantrag im Rahmen der Förderlinie "IngenieurNachwuchs" des Bundesministeriums für Bildung und Forschung (BMBF)

Fraunhofer SCS (2011) CARGO eXchange, Abschlussbericht

Fraunhofer SCS (2011) SILK—Systemgestützte Intelligente Logistische Kooperation, Abschlussbericht

Grill R (2013) Insolvenzprognose Deutschland: Etliche Branchen in 2013 insolvenzgefährdet. http://www.eulerhermes.de/mediacenter/Lists/mediacenterdocuments/euler-hermes-insolvenzprognose-deutschland-01-2013.pdf

Kunze O, Baumgärtel H, Neitmann A et al (2012) Dynamic truck meeting (DTM)—Ein Prozess- und Schnittstellenstandard zur Realisierung von dynamischen Begegnungsverkehren mit Hilfe von Dispositions- und Telematik-Systemen, Forschungsbericht

Verkehrswirtschaftliche Zahlen (VWZ) 2005/2006 (2006)

Optimizing Mixed Storage and Re-Marshalling Plans

Yeong Su Choi and Kap Hwan Kim

Abstract This study addresses the problem of optimizing the mixed storage and re-marshalling plans in a block stacking storage system with re-handling. Mixed storage is a storage method in which unit loads of different types are stored in the same bay. The re-marshalling is an activity of moving unit loads from mixed storage to other areas in which unit loads of different types are stored in a segregated way. This removes the need for re-handling during retrieval operations. The objectives of this study are to suggest methods for: (1) estimating the space requirement, including broken space, for mixed and segregated storage; and (2) determining the groups of unit load types to be placed in mixed storage, and the re-marshalling time for each group. Two uncertainties are considered: the types of unit loads to arrive and the times of arrival. A simulation model is used to estimate the space requirement for the two storage methods, and various load composition and arrival time distribution parameters are considered.

Keywords Block stacking · Storage system · Simulation · Re-marshalling

Introduction

This study addresses the logistics of mixed storage and re-marshalling. We assume that all the storage space units are the same, whether they are bays in a container yard, a block-stacking warehouse, or a drive-in/drive-through rack. A Set of Sequence-Exchangeable Unit (SSEU) loads is a set of unit loads whose sequence of retrieval is interchangeable. A Mixed Storage Unit load Group (MSUG) is a set

Y.S. Choi (✉) · K.H. Kim
Department of Industrial Engineering, Pusan National University, Busandaehak-Ro 63 Beon-Gil, Geumjeong-gu, Busan 609-735, Korea
e-mail: choipog@pusan.ac.kr

K.H. Kim
e-mail: kapkim@pusan.ac.kr

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of SSEUs that are stored at the same storage space, which is likely to necessitate some re-handling during the retrieval operation. A Space Supply Unit (SSU) is defined as the minimum unit of space allocation. Thus, when an MSUG is said to be stored in a space, the storage space corresponds to an SSU. An SSU may be a bay of a container storage block, a stack of steel plates, a bay of pallets, a bay of steel coils, or multiple deep lanes of pallet racks.

There are generally two storage policies: segregated storage, in which different types of unit loads are stored in separate areas, and mixed storage, in which unit loads of different types are stored in the same storage area.

Mixed storage requires less space than segregated storage for the same number of unit loads. However, additional re-handling operations will be required during the retrieval process, and this entails re-marshalling before the retrieval operation begins. Where space is limited, segregated storage is not possible. Thus, at the beginning of the storage period, loads are mixed in the same stacks, and then re-marshalled to other areas to reduce the number of relocations during the retrieval process. Minimizing the re-handling and relocation effort is the motivation of this study.

Similar storage problems have been addressed previously. For example, Marsh (1979) addressed the design problem of blocking storage systems, and later, Goetschalckx and Ratliff (1991) discussed the problem of determining the storage depth of bays for multiple SSEUs that are stored in segregated bays on the same floor. Jang (2012) proposed a method to design block stacking storage bays by considering the expected number of re-handling operations during the retrieval process. Although previous studies the design and operation of block stacking storage systems, no study has ever addressed the problem of grouping products for mixed storage and determining re-marshalling time.

Estimation of Space Required for Segregated Storage

This section analyses the space requirement for the segregated storage policy. Suppose that unit loads from multiple SSEUs arrive at a multiple SSU storage system in a random order. The arrival times of unit loads follow a probability distribution. The issue in this section is how the space requirements for accommodating all the arriving unit loads changes as the number of arrivals increases. The following notation is used:

Parameters

- n number of SSEUs considered
- U set of all the SSEUs
- s shape parameter of the distribution of the unit load duration-of-stay (DOS). This study assumes that the cumulative distribution function of the arrival time of unit loads at time X is $F(X) = X^S, 0 \leq X \leq 1$
- u_j total number of unit loads of type j that will arrive at the storage system until the end of the planning horizon

p_j percentage of unit loads of SSEU j, represented by $\frac{u_j}{\sum_{j \in G_j} u_j}$

b storage capacity of an SSU

c storage capacity allocated to all the SSEUs considered (SSU-unit times)

G_i the ith MSUG. The $G_i' s$ is a partition of U, that is, $\text{U}\{G_i\} = U$ and $G_i \cap G_j = \emptyset$ for all i and j ($\neq i$)

v_i total number of unit loads of G_i, which is $\sum_{j \in G_j} u_j$

X_i number of unit loads in the ith SSEU

Exact Expressions for the Required Number of SSUs

Let the number of SSUs required for storing $X_1, X_2, \ldots, X_n$ unit loads in a segregated policy be *S(X),* where $X = (X_1, X_2, \ldots, X_n)$. Let $Y = X_1 + X_2 + \cdots + X_n$. Then, the probability that $X_1 = x_1, X_2 = x_2, \ldots, X_n = x_n$ becomes

$$P(X_1 = x_1, X_2 = x_2, \ldots, X_n = x_n) = \frac{y!}{x_1!x_2!\ldots x_n!} p_1^{x_1} p_2^{x_2} \ldots p_n^{x_n} \tag{1}$$

where $y = x_1 + x_2 + \cdots + x_n$. Let the set of all possible $x_1, x_2 \ldots, x_n$ be U_y.

Let $M_i(y)$ and $S_i(y)$ be the expected number of SSUs required to store all y unit loads in G_i in the mixed and segregated storage methods, respectively. Then, $M_i(y)$ can be expressed as

$$M_i(y) = \sum_{X \in U_y} \left\{ \left\lceil \frac{\sum_{j \in G_i} x_j}{c} \right\rceil \frac{m!}{x_1!x_2!\ldots x_n!} p_1^{x_1} p_2^{x_2} \ldots p_n^{x_n} \right\} \tag{2}$$

Note that the total number of unit loads is $\sum_{j \in G_i} x_j$, and $\left\lceil \frac{\sum_{j \in G_i} x_j}{c} \right\rceil$ represents the number of SSUs required to store all unit loads that have arrived.

Let Y_i be $\sum_{j \in G_i} X_j$. Then, Y_i follows a binomial distribution with $p_{Y_i} = \sum_{j \in G_i} p_j$. Thus, the above expression is the same as

$$M_i(y) = \sum_{z=0}^{y} \left\{ \left\lceil \frac{z}{c} \right\rceil \frac{y!}{z!(y-z)!} p_{Y_i}^{z} (1 - p_{Y_i})^{y-z} \right\} \tag{3}$$

Similarly, $S_i(y)$ can be written as:

$$S_i(y) = \sum_{X \in U_y} \left\{ \left(\sum_{j \in G_i} \left\lceil \frac{x_j}{c} \right\rceil \right) \frac{m!}{x_1!x_2!\ldots x_n!} p_1^{x_1} p_2^{x_2} \ldots p_n^{x_n} \right\} \tag{4}$$

Note that $\sum_{j \in G_i} \left\lceil \frac{x_i}{c} \right\rceil$ represents the space required when all the SSEUs in G_i are stored in a segregated manner. Note also that it is difficult to evaluate expression (4) because of the number of compositions. Thus, in the next subsection, we conduct a simulation to evaluate (4).

Estimating the Required Number of SSUs

To generate p_j, which is the probability that an arriving unit load is from SSEU j, the SSEUs are ordered in decreasing order of p_j, and the following cumulative distribution function is used:

$$P\{j \le i\} = \left(\frac{i}{n}\right)^r, \quad \text{where } 1 \le i, j \le n \text{ and } 0 < r \le 1. \tag{5}$$

The parameter r determines the degree of uniformity of arrivals among different SSEUs. As r approaches 0, the probabilities concentrate toward SSEUs with lower indices, and as r tends to 1, the probabilities of different SSEUs become equal. In our numerical experiments, the following input parameters are used: b = 10, 20, 30, 40, 50, and 60; n = 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20; r = 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0. The simulation runs until $n \times b \times 5$ unit loads arrive at the storage system. When a unit load arrives, the corresponding SSEU is determined randomly according to the probability distribution given by (5), and separate SSUs are provided to different SSEUs. When an SSU has been filled by unit loads of an SSEU, a new empty SSU is provided. Once an SSU has been provided, it is included in the required number of SSUs.

Figure 1 shows the change in the average number of SSUs required to store various numbers of unit loads under mixed storage and segregated storage policies. The curves show the average over 100 simulation runs.

Note that in the segregated storage policy, the number of SSUs increases rapidly with the initial arrivals, but this rate of increase then declines. In the mixed storage policy, the SSU requirement increases in a stepwise manner whenever an SSU becomes full.

Figure 2 shows how the rate of increase in the average SSU requirement changes as unit loads arrive at the storage system. The rate of increase drops rapidly in the initial stages of the arrival process, and then becomes stable with random surges. The rate of increase drops more rapidly as the value of r becomes smaller. The average SSU requirement becomes larger when r approaches 1, as shown in Fig. 2.

Figure 3 shows the change in the total number of empty slots in broken space for various values of r. Broken space refers to the empty slots in partially filled stacks, which is effectively wasted space. The broken space is larger under a segregated storage policy than with mixed storage. For a larger value of r, the peak broken

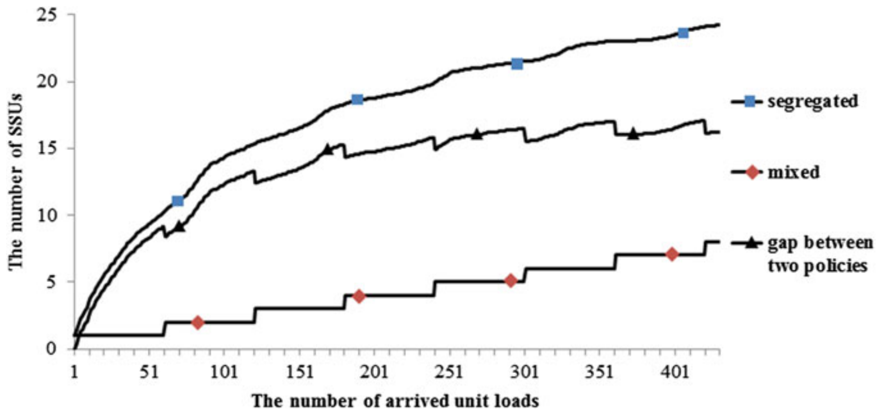

Fig. 1 Changes in the average SSU requirement ($S(y)$) for an increasing number of unit loads (y) (b = 60, n = 20, r = 0.1)

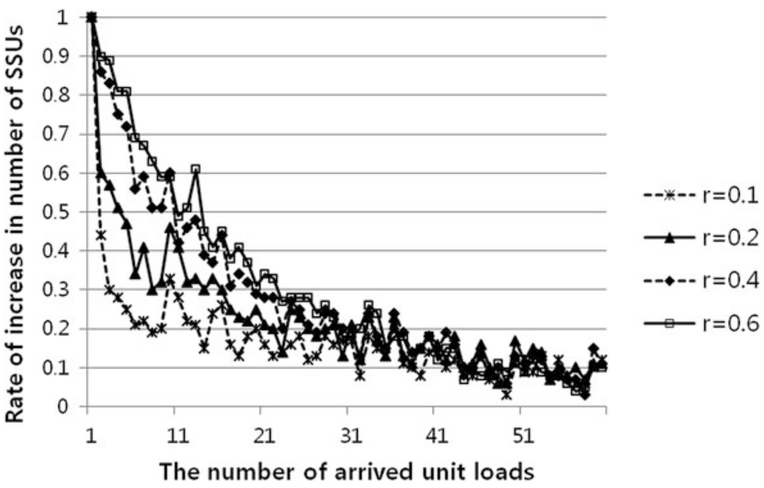

Fig. 2 Changes in the rate of increase of $S(y)$ for various values of r in the segregated storage policy (b = 60, n = 20)

space is higher, and occurs at an earlier point in time, than when the value of r is small. The dots in Fig. 4 represent the rate of increase in number of empty slots for broken space; this drops rapidly and approaches zero as the number of arrivals increases.

We attempted to derive an equation for the SSU requirement ($S(y)$) for a given number of unit load arrivals. Considering that the curve in Fig. 4 decreases exponentially, we propose expression (6) to represent the rate of increase in broken

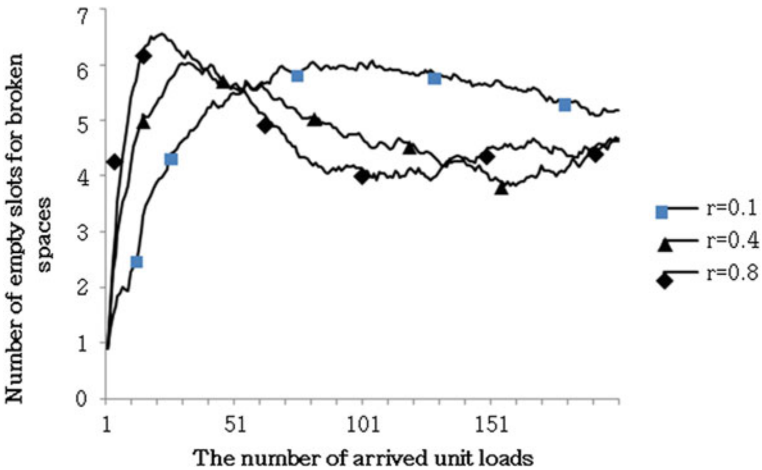

Fig. 3 Changes in the total number of empty slots for broken space for various values of r (b = 10, n = 6)

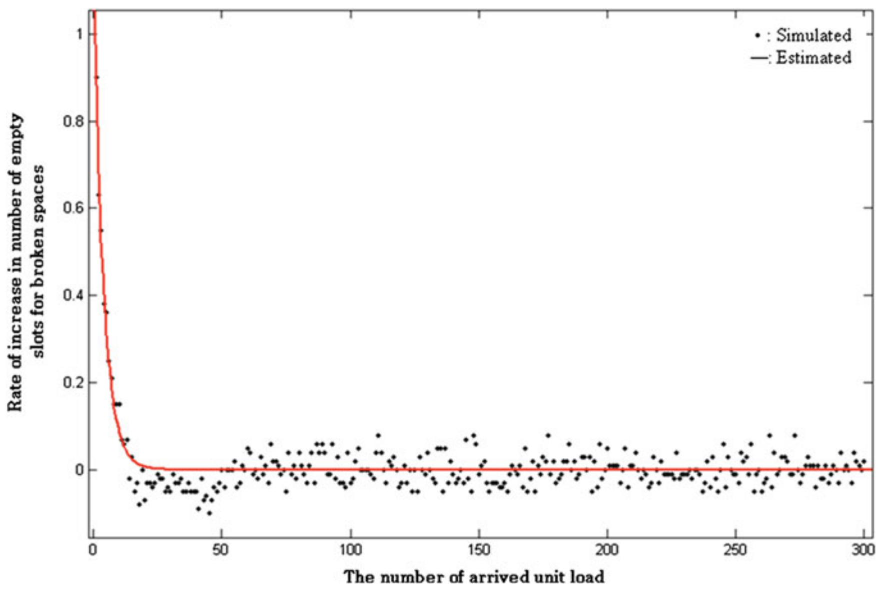

Fig. 4 Rate of increase in broken space as the number of unit loads increases (b = 10, n = 6, r = 0.6)

space. Note that the broken space (in units of SSUs) resulting from the arrival of the first unit load is $\frac{b-1}{b}$.

$$\frac{b-1}{b}\mathrm{e}^{-a(y-1)} \tag{6}$$

For the case in Fig. 4, the value of a was estimated to be 0.2573 by a regression analysis ($R^2 = 0.851$). Note that the solid line in Fig. 4 represents (6), and the average error between this and the simulation results was 2.7 % (standard deviation 2.06 %). Thus, the SSU requirement for storing y unit loads from an MSUG can be represented by adding the space occupied by unit loads and the broken space as follows:

$$\hat{S}(y) = \frac{y}{b} + \sum_{i=1}^{y}\frac{b-1}{b}\mathrm{e}^{-a(i-1)} \tag{7}$$

which can be approximated by

$$\begin{aligned}\hat{S}(y) &= \frac{y}{b} + \int\limits_{0.5}^{y+0.5}\frac{b-1}{b}\mathrm{e}^{-a(z-1)}dz \\ &= \frac{y}{b} + \frac{-(b-1)}{ab}\left[\mathrm{e}^{-a(z-1)}\right]_{0.5}^{y+0.5} \\ &= \frac{y}{b} - \frac{(b-1)}{ab}\mathrm{e}^{-a(y-0.5)} + \frac{(b-1)}{ab}\mathrm{e}^{0.5a}\end{aligned} \tag{8}$$

For the case in Fig. 4, the mean error of $\hat{S}(y)$ compared with the result of the simulation study was 7.54 %.

Finding the Optimal MSUGs and Their Re-Marshalling Time

As shown in Fig. 1, the segregated storage policy requires more space than the mixed strategy. Thus, for limited available space, re-marshalling is performed to reduce the space usage. When re-marshalling occurs at an earlier point in time, the amount of space used increases, but the number of re-marshalled unit loads is smaller. Note that the area below the curve corresponds to the amount of space used.

In this section, we attempt to find the optimal MSUGs and their re-marshalling time. This should minimize the expected number of re-marshalling operations under the constraint that the available storage space is limited. Thus, in addition to G_i, we consider the decision variable q_i, which represents the cumulative number of arrivals of unit loads from MSUG i. This will trigger the re-marshalling operation for MSUG i.

Let $\delta(G_i)$ be 1 if $|G_i| > 1$, and 0 otherwise. Let t_{ij} be the arrival time of the jth unit load of MSUG i. Then, the formulation of the problem in this section becomes

$$\mathrm{Min}_{G_i,q_i} \sum_{G_i \in G} \delta(G_i) q_i \tag{9}$$

such that

$$\sum_{G_i \in G} \delta(G_i) E\left[\sum_{j=1}^{q_i} M_i(j)\left\{t_{i(j+1)} - t_{ij}\right\}\right] + \sum_{G_i \in G} \delta(G_i) E\left[\sum_{j=q_i+1}^{v_i} S_i(j)\left\{t_{i(j+1)} - t_{ij}\right\}\right] + \sum_{G_i \in G} \{1 - \delta(G_i)\} E\left[\sum_{j=1}^{v_i} S_i(j)\left\{t_{i(j+1)} - t_{ij}\right\}\right] \le c \tag{10}$$

where $t_{i(v_i+1)}$ is the end of the storage period.

The optimal MSUGs were found from all the possible subsets of SSEUs, and the optimal re-marshalling time for each MSUG was determined by the total enumeration for the problems. Constraint (10) is applied during the total enumeration for the optimal MSUG and the optimal re-marshalling time. For these simulations, we used an Intel Core2 Duo CPU E8400 @3.00 GHz with 3 GB RAM. The following input parameters were used: b = 5, 10, 20, 30; n = 4, 6, 8; r = 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, 1.0; s = 2, 3, 4, 5.

Table 1 Optimal MSUGs and re-marshalling times for each MSUG for various values of r (b = 5, n = 6, s = 2, c = 11)

R	MSUG	q_i
0.1	{1}, {2, 3, 4}	29
0.2	{1}, {2, 3, 4}	46
0.4	{1}, {2, 3, 4}	79
0.6	{1, 2, 3, 4}	84
0.8	{1, 2, 3, 4}	85
1.0	{1, 2, 3, 4}	80

Table 2 Optimal MSUGs and re-marshalling times for various values of b (n = 4, s = 2)

R	b	c	MSUG	q_i
0.1	5	7.6	{1}, {2, 3, 4}	5
	10	7.6	{1}, {2, 3, 4}	29
	20	7.7	{1}, {2, 3, 4}	49
	30	7.8	{1}, {2, 3, 4}	56
0.6	5	7.6	{1, 2, 3, 4}	30
	10	7.6	{1, 2, 3, 4}	84
	20	7.7	{1, 2, 3, 4}	176
	30	7.8	{1, 2, 3, 4}	196

Table 3 Optimal MSUGs and re-marshalling times for various values of s_i

No.	s_i				r	c	MSUG	Re-marshalling amount	Re-marshalling time		Average space consumption
	s_1	s_2	s_3	s_4					p_1	p_2	
1	3	3	3	3	0.1	6.0	{1}, {2, 3, 4}	11	0	12	5.996
2	3	2	2	2	0.1	6.0	{1, 2, 3, 4}	92	93		5.917
3	3	2	2	2	0.1	6.3	{1}, {2, 3, 4}	15	0	16	6.283
4	3	3	2	2	0.1	6.3	{1}, {2, 3, 4}	9	0	10	6.298
5	2	3	4	5	1.0	6.0	{1, 2, 3, 4}	16	17		5.994
6	5	4	3	2	1.0	6.0	{1, 2, 3, 4}	14	15		5.997

Table 1 shows the optimal solutions for various values of *r*. All solutions have only one MSUG, and the optimal value of q_i increases as the value of *r* increases. For larger values of *r*, because the proportions among different SSEUs are mutually equivalent, all the SSEUs are included in the MSUG, whereas for smaller *r*, because there are large differences in the arrival rate among SSEUs, only those with low arrival rates are included in the MSUG. That is, when there are large differences in the arrival rate among SSEUs, it is more effective to store only SSEUs with low arrival rates, so that the amount of re-marshalling can be minimized for the same amount of storage space used. Table 2 illustrates optimal MSUGs and re-marshalling times for various values of *b*. Table 3 shows optimal MSUGs and re-marshalling times for various values of s_i, *r*, and *c*. Table 2 shows how the optimal solution changes as the value of *b* increases. As the value of *b* increases, the optimal value of q_i tends to increase.

Conclusion

This study investigated storage requirements under both segregated and mixed storage policies. For segregated storage, it was found that the rate of increase in space requirements in the early stages of arrival was higher than in later periods. The rate of increase slows sharply for smaller values of *r*, which represents the degree of uniformity in the distribution of unit load arrival types. When the number of types of unit loads (*n*) becomes larger, the required amount of space increases. It was also found that, as the size of the SSU becomes larger, the space requirements and the amount of broken space increase. As the number of arrivals increased, the amount of broken space reached a maximum, before stabilizing at a lower level. The amount of broken space reached an earlier and higher maximum for larger values of *r*. In addition, it was found that the amount of broken space is proportional to the size of the SSU (*b*). We derived an analytic expression for the space requirement using the simulation results, and found that the average error rate of this estimator is 6 %. The estimation fits well in the early stages of arrival, when the amount of broken space is increasing. We also considered how to group different types of unit loads in mixed storage, and determined the re-marshalling time needed to convert mixed storage to segregated storage. This study utilized simulations to derive various conclusions. However, some statistical methods may be applied for easier and more accurate analysis in future studies.

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References

Goetschalckx M, Ratliff HD (1991) Optimal lane depths for single and multiple products in block stacking storage systems. IIE Trans 23(3):245–257

Jang DW (2012) Optimal design and operation of block stacking systems considering relocations. Ph.D. Dissertation, Pusan National University

Marsh WH (1979) Elements of block storage design. Int J Prod Res 17(4):377–394

Container Flows and Truck Routes in Inland Container Transportation

Julia Funke and Herbert Kopfer

Abstract In the inland container transportation problem, one trucking company operating a homogeneous fleet of trucks has to move 40-ft. containers. The recent extension to this problem is to introduce two different commodities, namely 20- and 40-ft. containers, instead of only 40-ft. containers. Our objective is to minimize the total travel distance of the trucks for the extended problem. A model is shown and implemented in C++ using IBM ILOG CPLEX solver. Fifteen test instances are created to obtain computational results using our implementation.

Keywords Inland container transportation · Mixed-integer programming · Two commodities · Pickup and delivery

Introduction

The process of moving containers with different transportation modes in one transportation chain is referred to as *intermodal container transportation*. A typical transportation chain can be subdivided into three sections, whereby each of them is operated by the same transportation mode. In the first section (*pre-haulage*) containers are transported from the actual customers (shippers) to terminals by truck. The second section (*main-haulage*) consists of container transportation between terminals carried out by barge or rail. The last section (*end-haulage*) implies container transportation by truck from the terminals to customers (receivers). The trucking sections (*drayage*) of the transportation chain cause between 25–40 % of

J. Funke (✉) · H. Kopfer
University of Bremen, Wilhelm-Herbst-Str. 5, 28359 Bremen, Germany
e-mail: jfunke@uni-bremen.de
URL: http://www.logistik.uni-bremen.de

H. Kopfer
e-mail: kopfer@uni-bremen.de

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the total transportation costs (Macharis and Bontekoning 2004). That is why we address a problem arising in the pre- and end-haulage.

In the considered problem one trucking company has to transport 20- and 40-ft. containers. Several papers are dealing with modifications on problems considering transportation of 40-ft. containers only. But the considered modification is studied rarely in the literature. To find an optimal solution to the problem, it has to be simplified (Vidovic et al. 2011; Chung et al. 2007; Popovic et al. 2012). Schönberger et al. (2013) introduce a mixed-integer programming (MIP) formulation, but they conclude that a solution should be generated by a heuristic approach. Zhang et al. (2015) show an improved reactive tabu search algorithm and apply it to a real-world data set.

The remaining paper is organized as follows: Section "Problem Definition" defines the 2-Commodity Inland Container Transportation Problem (2-ICTP), before in Section "Mathematical Model" a mathematical formulation is presented, the computational results are shown in Section "Computational Results". Section "Conclusion" concludes the paper.

Problem Definition

We consider one trucking company that operates a homogeneous fleet of trucks and has to transport containers. We mainly differentiate between two types of transportation requests, whereby empty containers serve as transportation media for goods. In the case of *outbound full (OF)* transportation requests, trucks have to supply shippers with empty containers and afterwards transfer fully loaded containers to terminals. In the case of *inbound full (IF)* transportation requests, trucks have to transport fully loaded containers from terminals to receivers and afterwards collect empty containers at the receivers' place. As empty containers serve as transportation media, we additionally take two more types of transportation requests into consideration, which are especially important for export- or import-oriented areas that might have a lack or an overrun of empty containers. *Outbound empty (OE)* transportation requests involve a transportation of empty containers to terminals for onward transportations. *Inbound empty (IE)* transportation requests define a collection of arriving empty containers at terminals. Empty containers can be stored at a single depot that also serves as starting and ending point of truck routes. Thus, empty containers can be picked up at receivers' places, terminals, or the depot and analogously, they can be delivered to shippers' places, terminals, or the depot. We assume that each customer has the opportunity to lift a container from the truck, so that trucks have the possibility whether to accompany (un) loading operations or not. The objective is to minimize the total operating time of the fleet. For OF and IF transportation requests the solution space is restricted to contain only solutions, where a fully loaded container is moved directly from its origin to its destination.

Mathematical Model

Our approach to model the problem is to consider in a first step the two underlying subproblems of assigning empty containers to requests (Section "The Container Assignment") and building routes for trucks (Section "The Truck Routes") separately. We build two networks for the different problems that are defined on almost the same underlying graph (Section "The Graph"). Then, the two networks are coupled with constraints (Section "Coupling of the Models"), such that one model is obtained that simultaneously solves the complete problem.

The Graph

We construct a digraph $G = (V, A)$ reflecting the tasks occurring in the 2-ICTP. An instance of the 2-ICTP consists of a set L of locations, R of transportation requests, and T of trucks. The first set combines locations of customers, terminals, and the depot. The set R can be divided into $R := R^F \cup R^E$ whereupon R^F denotes the set of all requests referring to fully loaded containers (IF and OF requests) and R^E denotes the set of all requests referring to empty containers (IE and OE requests). The obtained division can be further partitioned into $R^F := R^F_O \cup R^F_I$ and $R^E := R^E_O \cup R^E_I$. Here, requests are classified in inbound (lower-I sets) or outbound requests (lower-O sets).

For each request $r \in R^E$ there is exactly one node r^s introduced. As a request $r \in R^F$, besides the collection and delivery of empty containers, consists of two tasks, three nodes r^s, r^m, r^e and two edges (r^s, r^m), (r^m, r^e) are introduced to represent it. In more detail, if r is an OF request the arc (r^s, r^m) is the representative of the operation where an empty container is loaded at the customer's place and the arc (r^m, r^e) is the representative of the operation where a fully loaded container is transported from the customer's place to the terminal. If r is an IF request the arc (r^s, r^m) is the representative of the operation where a fully loaded container is transported from the terminal to the customer's place and the arc (r^m, r^e) is the representative of the operation where a fully loaded container is unloaded at the customer's place. By definition, the nodes can be considered as being the representatives of the corresponding locations the tasks are performed at. Meaning, r^s corresponds to the shipper's place if $r \in R^F_O$ and to the terminal otherwise; r^m corresponds to the customer's place; r^e corresponds to the terminal if $r \in R^F_O$ and to the receiver's place if $r \in R^F_I$. To complete the definition of the node set, there are introduced two depot duplicates d_s and d_e representing the starting and ending location, respectively. V can be written as $V := \{d_s\} \cup \{d_e\} \cup \{r^s, r^m, r^e | r \in R^F\} \cup \{r^s | r \in R^E\}$.

We now address the arc set. d_s is considered to be the starting location, so there are only out-going edges. On the other hand, d_e represents the ending location, so there are only in-going edges. It is to ensure for an IF request $r \in R^F_I$ that the identity of the fully loaded container (transported by operation arc (r^s, r^m)) stays the same for

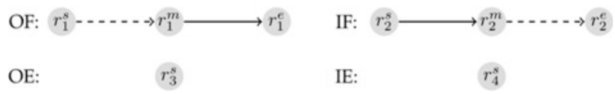

Fig. 1 Modeling the different types of transportation requests

the unloading operation (arc (r^m, r^e)). That is why the only in-going edge of node r^m is the edge (r^s, r^m). Analogously, it is to ensure that the container, which has been previously loaded at the customer's place (arc (r^s, r^m)), stays the same when it is transported to the terminal (arc (r^m, r^e)) for an OF request $r \in R_O^F$. Therefore, the only out-going edge of node r^m is the edge (r^m, r^e). The rest of G is a complete digraph, meaning that there is an arc between each pair of vertices, which defines its arc set as $A := \left\{(v, w)|v \in \vec{V} \cup \overleftrightarrow{V}, w \in \overleftarrow{V} \cup \overleftrightarrow{V}\right\} \cup \left\{(r^s, r^m)|r \in R_I^F\right\} \cup \left\{(r^m, r^e)|r \in R_O^F\right\}$, where $\vec{V} := \left\{r^m|r \in R_I^F\right\} \cup \{d_s\}, \overleftarrow{V} := \left\{r^m|r \in R_O^F\right\} \cup \{d_e\}, \overleftrightarrow{V} := V(\vec{V} \cup \overleftarrow{V})$.

An arc $a \in A$ has a cost of the corresponding time c_a that is needed to fulfill the symbolized task. That is, the arc representing an (un)loading operation of an OF or IF request has a cost equal to the time needed to (un)load the container; the costs of the other arcs arise from the travel distances between the corresponding locations. Figure 1 shows the modeling of the different types of requests. The dashed arcs represent (un)loading operations, while the consistent arcs represent moving operations. We have to distinguish between the different operation types, as we later want to minimize the total travel distance of the trucks and thus do not include arcs symbolizing (un)loading operations into the objective function. Thus, we distinguish between the set A_L of arcs representing (un)loading operations and A_T representing travel operations.

The Container Assignment

The aim of this section is to formulate the problem of assigning containers to requests as a multi-commodity flow problem (mCFP). We only formulate constraints and no objective function, as the objective of the coupled model only involves movement of the trucks. For a given digraph the mCFP is to route all amounts of flows indicated by nodes that have supply for different commodities to nodes that have demand for them. The nodes are associated with balance values b_{kv} indicating whether node v has supply ($b_{kv} > 0$), demand ($b_{kv} < 0$), or is a transshipment node ($b_{kv} = 0$) for commodity k. Additionally, capacities associated with the arcs limit the maximum amount of the flows that can traverse an arc. In the case of the 2-ICTP there are two commodities, 20- and 40-ft. containers. Even et al. (1976) show that producing integral flows is NP-complete even if there are only two commodities.

We add balance values and capacities to the graph G introduced in Section "The Graph". The two balance values on the nodes represent the supply/demand for an appropriate sized container needed by the node belonging to the request, while the capacity on an arc represents the capacity of a single truck as it has to carry the container through the arc.

For node $v \in V$ let b_{1v}/b_{2v} describe the demand/supply for 20-ft./40-ft. containers, respectively. Let $r \in R^E$ then b_{kr^s} is set to minus one, if r is an OE request requiring an empty container of size k TEU, and b_{kr^s} is set to one, if r is an IE request providing an empty container of size k TEU. If $r \in R^F$ is an OF request needing a container of size k TEU we want to achieve that a fully loaded container is delivered at the terminal at the end, therefore we set a minimum capacity on the arcs (r^s, r^m) and (r^m, r^e) and we further set b_{kr^e} to minus one. By definition of the arc set, the container loaded at (r^s, r^m) is the container transported at (r^m, r^e) and thus the demanded container of r^e. Analogously, if $r \in R^F$ is an IF request a fully loaded container of size k TEU is obtained at the terminal at the beginning, so b_{kr^s} is set to one, the corresponding arcs (r^s, r^m) and (r^m, r^e) get a minimum capacity symbolizing the container of the specified size which has to be transported and unloaded here. Again by definition of the arc set the container obtained at b_{kr^s} is the same one that is finally unloaded at (r^m, r^e). The other representative nodes of tasks of a request in the set R^F have a balance value of zero. The balance value of the starting depot node d_s should catch all demands obtained by the outbound transportation requests, i.e., $b_{kd_s} := -\sum_{r \in R_O^F \cup R_O^E} b_{kr}$, $k \in \{1, 2\}$ measuring the container size in TEU. Analogously, the balance value of the ending depot node d_e should be used for storage operations of containers obtained by inbound transportation requests, i.e., $b_{kd_e} := -\sum_{r \in R_I^F \cup R_I^E} b_{kr}$, $k \in \{1, 2\}$.

Measuring the container size in TEU, a truck has a capacity of two, so the capacity u_{vw} on arc $(v, w) \in A$ has to equal two in order to prohibit that more containers traverse an arc than a truck is able to transport. There is one exception: the arc (d_s, d_e) is an artificial edge catching up the surplus of containers, i.e., all containers stored at the beginning at the depot and are not needed by any of the outbound requests. Here we define $u_{d_s d_e} := b_{d_s}$.

For each arc $(v, w) \in A$ there are introduced two integral decision variables x_{1vw} and x_{2vw} indicating, whether there is a movement of containers of size k TEU between v and w. Constraints for the container assignment problem can be formulated as follows:

$$\sum_{w \in V} x_{kvw} - \sum_{w \in V} x_{kwv} = b_{kv} \quad \forall v \in V, \forall k \in \{1, 2\} \tag{1}$$

$$0 \leq x_{kvw} \quad \forall (v, w) \in A, \forall k \in \{1, 2\} \tag{2}$$

$$x_{1vw} + 2x_{2vw} \leq u_{vw} \quad \forall (v, w) \in A \tag{3}$$

$$x_{kr^s r^m} \geq \max\{|b_{kr^e}|, b_{kr^s}\} \quad \forall r \in R^F, \forall k \in \{1,2\} \tag{4}$$

$$x_{kr^m r^e} \geq \max\{|b_{kr^e}|, b_{kr^s}\} \quad \forall r \in R^F, \forall k \in \{1,2\} \tag{5}$$

$$x_{kvw} \in \mathbb{Z} \quad \forall (v,w) \in A, \forall k \in \{1,2\} \tag{6}$$

The decision variable x_{2vw} is weighted with a factor of two, as the size of transportation resources is measured in the TEU. Constraint (1) says that the supply/demand of all nodes is satisfied. Constraints (2) and (3) care for the adherence to the capacity on the arcs, i.e., there is positive flow, not exceeding the capacity function. As the movement of fully loaded containers and the (un)loading operations of IF and OF requests are completely determined, a minimum capacity on the arc incident to the representing nodes has to ensure that at least the container of the corresponding size traverses these locations, see Constraints (4) and (5).

The Truck Routes

When constructing the truck routes we use a modification of the multi-traveling salesman problem (mTSP). A given set of trucks has to visit nodes representing locations, trucks start and end their route at the node representing the depot. The objective is to minimize the total distance traveled. In our case, it can be distinguished between two sets of nodes. On the one hand, there are nodes referring to operations of the transportation requests. These nodes must be visited at least once. On the other hand, there are nodes representing storage operations that can be visited but do not need to.

For each node $v \in V$ the decision variables γ_v define the number of vehicles leaving node v. Decision variables t_v indicate the point in time when a vehicle arrives at v. For each arc $(v,w) \in A$ there are introduced decision variables δ_{vw}, so that each arc is associated with the number of vehicles traversing it. Because the depot can be visited more than once in a route of a vehicle, G has to be modified. For each request a depot duplicate has to be inserted into the node set that can, but does not need to be visited for container collecting/parking operations. We refer to the obtained graph as $\tilde{G} = (\tilde{V}, \tilde{A})$, where $\tilde{V} := V \cup \{v_r^d | r \in R\}$ and $\tilde{V} := \{(v,w) | v,w \in R \times R\}$. The problem can be modeled as follows

$$\min \sum_{(v,w) \in \tilde{A} \setminus A_L} c_{vw} \delta_{vw} \tag{7}$$

subject to

$$\sum_{w\in\tilde{V}}\delta_{vw}=\sum_{w\in\tilde{V}}\delta_{wv}=\gamma_v\quad\forall v\in\tilde{V}\backslash\{d_s,d_e\}\tag{8}$$

$$1\leq\gamma_v\quad\forall v\in\tilde{V}\backslash(\{v_r^d|r\in R\}\cup\{d_s,d_e\})\tag{9}$$

$$\gamma_d^s\leq|T|\tag{10}$$

$$\sum_{v\in\tilde{V}}\delta_{d_sv}=\sum_{v\in\tilde{V}}\delta_{vd_e}=\gamma_{d^s}\tag{11}$$

$$\delta_{vw}=1\Rightarrow t_v+c_{vw}\leq t_w\quad\forall(v,w)\in\tilde{A}\tag{12}$$

$$\delta_{vw}\in\{0,1\}\quad\forall(v,w)\in\tilde{A}\tag{13}$$

$$\gamma_v\in\mathbb{Z}\quad\forall v\in\tilde{V}\tag{14}$$

$$t_v\in\mathbb{R}\quad\forall v\in\tilde{V}\tag{15}$$

The objective function (7) minimizes the costs of only those arcs, which indicate a truck movement: if a truck stays at the container, while the container is (un) loaded, i.e., it uses an arc in A_L, it is not penalized. Constraint (8) represents the flow conservation. Constraint (9) defines that all nodes representing requests have to be visited and vertices representing the depot need not. Constraints (10) and (11) ensure that there are no more trucks in use than specified by the instance and that all vehicles leaving the depot also return to it. Finally, a truck arrives at the nodes on its route respecting the duration between them [Constraint (12)].

Using this formulation, nodes can be reached by a truck more than one time, but not within the same route. In other words, locations can be visited by more than one truck, but it is not possible that such locations are visited by the same truck two times. Trucks start their routes at node d_s and end it at node d_e, the other depot duplicates can be visited, but need not and all nodes belonging to transportation requests have to be covered by at least one truck. Finally, an arc can be traversed by at most one truck. This limitation can be accepted when the costs satisfy the triangle inequality. An optimal solution does not contain a solution where an arc is used by a vehicle more than one time.

Coupling of the Models

In this section are defined the coupling constraints that connect the model for the container assignment (Section "The Container Assignment") with the model for the truck routes (Section "The Truck Routes"). The coupling constraints have to satisfy two aspects: First, as containers have to be moved by trucks, each arc representing a container movement in the container network has to be covered in the truck network. Second, the order in which nodes are processed in the container network has to be considered in the coupled model. The first condition states that arcs representing (un)loading operations, i.e., arcs of the set A_L that are covered in the container network, can be covered by a solution of the truck network, but do not need to.

The graph $\tilde{G}$ of the truck network is an extension of G that is used by the container network: each request has its own depot duplicate in $\tilde{G}$. Let $v \in V \backslash \{d_s, d_e\}$ be a representative node of request $r \in R$, we define *req*: $V \backslash \{d_s, d_e\} \rightarrow R$ with $req(v) := r$. If an arc is covered in the container network including v and one of the nodes d_s or d_e, in the truck network the arc incident to v and v_r^d has to be covered. The extension affects the set $A_D := A_{d_s} \cup A_{d_e}$, with $A_{d_s} := \{(d_s, v) | v \in V\}$, $A_{d_e} := \{(v, d_e) | v \in V\}$. For each arc $(v, w) \in A$ an integral decision variable z_{vw} is introduced that should help to determine the starting times of the trucks at the locations. If a container traverses (v, w) in the container network, i.e., $x_{1vw} + 2x_{2vw} \in \{1, 2\}$, z_{vw} is set to one. z_{vw} is set to zero, if there is no container movement on (v, w).

$$x_{1vw} + 2x_{2vw} \leq 2\delta_{vw} \quad \forall (v, w) \in A \backslash (A_D \cup A_L) \tag{16}$$

$$x_{1d_s v} + 2x_{2d_s v} \leq 2\delta_{v^d_{req(v)} v} \quad \forall v \in V \backslash \{d_e\} \tag{17}$$

$$x_{1vd_e} + 2x_{2vd_e} \leq 2\delta_{v v^d_{req(v)}} \quad \forall v \in V \backslash \{d_s\} \tag{18}$$

$$\frac{x_{1vw} + 2x_{2vw}}{2} \leq z_{vw} \leq x_{1vw} + 2x_{2vw} \quad \forall v, w \in V \backslash \{d_s, d_e\} \tag{19}$$

$$\frac{x_{1d_s v} + 2x_{2d_s v}}{2} \leq z_{v^d_{req(v)} v} \leq x_{1d_s v} + 2x_{2d_s v} \quad \forall v \in V \backslash \{d_e\} \tag{20}$$

$$\frac{x_{1vd_e} + 2x_{2vd_e}}{2} \leq z_{v v^d_{req(v)}} \leq x_{1vd_e} + 2x_{2vd_e} \quad \forall v \in V \backslash \{d_s\} \tag{21}$$

$$z_{vw} = 1 \Rightarrow t_v + c_{vw} \leq t_w \quad \forall (v, w) \in \tilde{A} \tag{22}$$

$$z_{vw} \in \{0, 1\} \quad \forall (v, w) \in \tilde{A} \tag{23}$$

Constraints (16)–(18) ensure that each arc including a movement of a container is covered by a truck, where Constraints (17) and (18) ensure that, if a container is moved in the container network on an arc including the depot, in the truck network it is used the arc that contains the corresponding depot duplicate. Analogously, Constraints (19)–(21) set z_{vw} to one, if there is a container traversing arc (v, w) and zero otherwise. Finally, Constraint (22) ensures that requests using the same container allow to start only one after another.

For each node $v \in V$ we introduce exactly one decision variable t_v representing the point in time v is visited. By determining the sequence of points in time containers and trucks arrive at nodes, we determine implicitly an underlying sequence in that all nodes are visited. Considering this model, one is not able to minimize operating times of the truck: if two trucks visit the same node v, then the first truck has to wait for the second truck, because there is only one decision variable t_v for the node's starting time. t_v is set by the latest truck arriving at v. For computing final solutions, we had to set correct starting times in a post-processing step, i.e., starting times where one truck does not have to wait for another truck.

Computational Results

To test our model, we created 15 randomly chosen test instances. We built three different sets with six, eight, and ten transportation requests, respectively. Each set consists of twice as much locations and half as much trucks as number of requests. The locations are placed in the square $[0, 20] \times [0, 20]$, the distance between them is the Euclidean distance (kilometers), where we cut after three decimal places. We implemented our model in C++ using IBM ILOG CPLEX Optimization Studio version 12.5.1 and tested it on an Intel Core i5-3230 M 2.6 GHz machine, where we use the default settings of CPLEX and set the time limit to solve a single instance to one hour.

Tables 1, 2, and 3 show the results. All but one instances can be solved to optimality within one hour. In the second row there are two comma separated numbers, the first number gives the cardinality of R^F and the second the cardinality of R^E. It is distinguished between six different values: The third row shows the objective value, i.e., the total travel distance of trucks, while the fourth row represents the total distance of transporting 20-ft. containers plus twice-penalized the total distance of 40-ft. containers, i.e., the ton-kilometers which are measured here in "TEU-kilometers". Then, in row five the number of used trucks is shown. After that, the sixth row shows the kilometers which a truck averagely has to travel for providing one TEU-kilometer; while its inverse, which is shown in row seven, indicates the TEU-kilometers which are averagely achieved by a single kilometer of

Table 1 Results small instances

Results	Six requests		
	(6, 0)	(3, 3)	(0, 6)
Obj.	102.378	72.908	70.779
Dist. TEU	141.750	111.691	70.676
#Trucks	3	3	3
TEU-km	1.385	1.532	0.999
Km-TEU	0.722	0.653	1.001
Time	25.19	4.38	1.69

Table 2 Results middle-sized instances

Results	Eight requests				
	(8, 0)	(6, 2)	(4, 4)	(2, 6)	(0, 8)
Obj.	126.966	103.437	102.457	79.996	70.951
Dist. TEU	164.747	125.647	127.922	102.666	40.428
#Trucks	4	4	4	2	2
TEU-km	1.298	1.215	1.249	1.283	0.570
Km-TEU	0.771	0.823	0.801	0.779	1.755
Time	72.30	20.19	46.04	8.08	2.39

Table 3 Results large instances

Results	Ten requests						
	(10, 0)	(8, 2)	(6, 4)	(5, 5)	(4, 6)	(2, 8)	(0, 10)
Obj.	155.738	159.024	136.872	–	130.658	117.813	124.679
Dist. TEU	243.751	232.866	202.604	–	178.295	150.433	141.349
#Trucks	3	4	3	–	4	3	3
TEU-km	1.565	1.464	1.481	–	1.365	1.277	1.134
Km-TEU	0.640	0.683	0.675	–	0.733	0.783	0.882
Time	698.04	38.01	28.22	–	51.19	4.09	16.16

a vehicle. This value is a meaningful key figure for the efficiency of container transportation, which by definition has to be within the interval [0, 2]. Finally, the eighth row gives the time in seconds needed to compute the former shown results.

The results show that the container transport efficiency reaches the highest values when only OF and IF requests are considered; i.e., $R^E = \emptyset$. That is because the edges (r^m, r^e) for OF requests and (r^s, r^m) for IF requests have been assigned a minimum capacity, i.e., one fully loaded container to be transported. However, the values of Tables 1, 2, and 3 imply a trend indicating that the transportation of empty containers causes a decrease of the total container transport efficiency. This should be investigated in detail by analyzing a large number of different test sets in future research. If this trend proves true in exhausting tests, this would be very crucial since empty containers not only lead to the inefficiency of the transportation of goods but also decrease the container transport efficiency itself.

The values for the computing time in Tables 1, 2, and 3 show that the model is sensitive in terms of the structure of an instance. There are large instances like (8, 0), (8, 2), and (6, 4), which can be solved to optimality in a few seconds. And there is one instance (5, 5), where not even a feasible solution can be obtained after one hour. In case of TEU-km there are two outliers, given by instances (0, 6) and (0, 8). While instance (0, 6) only contains inbound transportation requests, the container sizes and the inbound/outbound requests of instance (0, 8) form a uniform distribution.

Conclusion

A recent problem and a modeling are shown. New test instances are created and, except for one instance, are solved to optimality within one hour. Future research should concentrate to add more degrees of freedom to the model. It should be able for a truck to pick up fully loaded containers at their origin, carry them to some places, and afterwards discharge them at their destination. Also locations should be approached by trucks in different orders. Each truck should get its own point in time where it arrives at a location, such that the use of time windows can be integrated. Time needed for coupling and decoupling containers and trucks has to be penalized. A larger set of instances has to be built in order to analyze the decrease of the container transport efficiency. Finally, different objectives should be integrated in the model and their effect on the solutions should be compared.

References

Chung KH, Ko CS, Shin JY, Hwang H, Kim KH (2007) Development of mathematical models for the container road transportation in korean trucking industries. Comput Ind Eng 53(2):252–262

Even S, Itai A, Shamir A (1976) On the complexity of timetable and multicommodity flow problems. SIAM J Comput 5:691–703

Macharis C, Bontekoning YM (2004) Opportunities for OR in intermodal freight transport research: a review. Eur J Oper Res 153:400–416

Popovic D, Vidovic M, Nikolic M (2012) The variable neighborhood search heuristic for the con-tainers drayage problem with time windows. In: 2012 online conference on soft computing in industrial applications, pp 1–10

Schönberger J, Buer T, Kopfer H (2013) A model for the coordination of 20-foot and 40-foot container movements in the hinterland of a container terminal. In: Pacino D, Voß S, Jensen RM (eds) ICCL 2013, LNCS 8197. Springer, Berlin, pp 113–127

Vidovic M, Radivojevic G, Rakovic B (2011) Vehicle routing in containers pickup up and delivery processes. Procedia—Social Behav Sci 20:335–343

Zhang R, Yun WY, Kopfer H (2015) Multi-size container transportation by truck: modeling and optimization. Flexible Serv Manuf J. 27(2-3): 403–430

Application of Semi-Markov Drift Processes to Logistical Systems Modeling and Optimization

Mykhaylo Ya Postan

Abstract In our paper, a general scheme for modeling different logistical systems functioning under uncertainty is presented. It is defined in the terms of so-called semi-Markov drift processes with several continuous components (random walks in non-negative orthant of Eucleadean space). Some examples of this scheme application for modeling and optimization of logistical systems are given: optimal lot sizing taking into account the irregularity of product delivery from a vendor to wholesaler in the multi-echelon distribution system under fixed demand; optimal distribution of a manufactured product to a set of retailers under random demand.

Keywords Logistical systems modeling · Uncertainty and risk · Semi-Markov drift process · Stationary probabilistic distribution · Storage level · Irregular supply · Optimal lot sizing · Random demand · Optimal distribution of product

Introduction

It is well known that inventory control models play an important role in the theory of logistics and its applications (Bramel and Simchi-Levi 1997; Brandimarte and Zotteri 2007). This is explained by the wide proliferation of different kinds of inventory in production, transportation, and logistical systems. Production and inventory planning, for example, is an area, where difficult mathematical problems appear in day-to-day logistics operations. Stochastic inventory/storage models have attracted considerable attention for modeling and analysis of transportation/logistical systems during the last three decades (Prabhu 1998; Gnedenko and Kovalenko 2005; Postan 2006b, 2008). They allow us to take into account the factors of uncertainty existing in exchangeable external environment of

M.Y. Postan (✉)
Department Economy and Management, Odessa National Maritime University,
Mechnikov Str. 34, 65029 Odessa, Ukraine
e-mail: postan@ukr.net

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any logistical system and inside it. The above factors are the significant obstacles for a logistic manager, when he makes decision concerning material/information flows control. In contrast to classical deterministic approaches, application of stochastic models gives the possibility to model, investigate, and optimize a much bigger variety of inventory control systems functioning under uncertainty. In many practical situations it is possible to apply the theory of Markov and/or semi-Markov drift processes for modeling (Davis 1984; Mitra 1988; Postan 2006a). This class of stochastic processes includes simultaneous description of discrete and continuous variables describing the dynamics of a logistical system's behavior (e.g., inventory level's dynamics). Therefore, it is a flexible mathematical apparatus for many logistical systems analysis and optimization. The efficiency of such an approach was shown in our previous works (Postan 2006b, 2008).

In this paper, the semi-Markov drift process application is demonstrated for solving the problems related to: (a) optimal lot sizing for a distribution system assuming that lead time (i.e., time that elapses between the placement of an order and receipt of ordered product) is random variable with known distribution function; (b) optimal distribution of product among a set of retailers under random demand.

The mathematical definition and some properties of a type of semi-Markov drift processes are given in the Appendix.

Optimal Lot Sizing Model of Multi-echelon Logistical System with Irregular Supply

Consider a distribution system with a single warehouse (e.g., belonging to wholesaler), denoted by the index 0, and R retailers indexed from 1 to R. The orders come from an outside vendor with unlimited stock and they are received by the wholesaler that replenishes the retailers (see Fig. 1). Our model assumes the following:

- An order is placed at that moment when inventory at warehouse is zero.
- Order quantities (lot sizes) are the independent identically distributed (i.i.d.) random variables $\delta_1, \delta_2, \ldots$ with the distribution function (d.f.) $G(x) = \mathbf{P}\{\delta_1 \le x\}$.
- The lead times are i.i.d. random variables $\theta_1, \theta_2, \ldots$ with the d.f. $A(t) = \mathbf{P}\{\theta_1 \le t\}$ and independent of the random variables $\delta_1, \delta_2, \ldots$
- The planning horizon is infinite (i.e., we consider the functioning of our distribution system in equilibrium).
- The product comes from the warehouse to the rth retailer with the constant rate W_r (if the warehouse is not empty).
- The rth retailer faces the given demand with the constant rate $U_r < W_r,\ r = 1, 2, \ldots, R$.

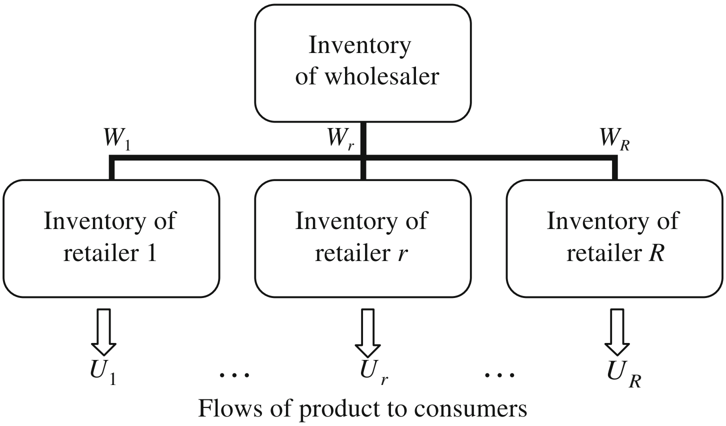

Fig. 1 Scheme of multi-echelon logistical system with irregular supply and given demand

- The capacities of all retailers' warehouses are sufficiently large (i.e., we ignore the probability that they will be filled up at any moment of time).
  - It is quite clear that, because of irregularity of product supply from a vendor to wholesaler the supply of retailers will be irregular, as well.
  - Note that under the suppositions mentioned above, the warehouse's behavior is described by the model of one-server queueing system of GI/G/1/1 type (with one customer) in which service time d.f. is $B(t) = G(Wt), W = W_1 + \cdots + W_R$.
  - Let $\xi_0(t)$ be the inventory level at the warehouse of the wholesaler at moment t, and $\xi_r(t)$ be the inventory level of the rth retailer at moment t. Let us introduce the semi-Markov process $Y(t)$ with two states: 0 and 1 and with the d.f. $A(t)$ and $B(t)$ of sojourn-times in these states correspondingly. Let $\theta_0(t)$ be a period of time from moment t till a moment of the next lot arrival and $\theta_1(t)$ be a period of time from moment t until a moment when the warehouse will be empty. It is obvious that $\xi_0(t) = W\theta_1(t)$. Thus we arrived to the general scheme described in the Appendix for which

- $M = R$, $\mathbf{D} = \{0, 1\}$, $\mathbf{D}_r^+ = \{1\}, \mathbf{D}_r^- = \{0\}, \mathbf{D}_r^0 = \emptyset$,
- $A_0(t) = A(t)$, $A_1(t) = B(t)$, $\pi_{01} = \pi_{10} = 1, p_0^* = p_1^* = 1/2$.

Therefore we can immediately apply the results of the Appendix concerning the determination of d.f. $\Phi_i(x_1, \ldots, x_R), F_i(x_1, \ldots, x_R), i = 0, 1,$ i.e., stationary distribution of the random vector $(\xi_1(t), \ldots, \xi_R(t))$, i.e., in other words, the inventory level's distribution of each retailer.

The stationary distribution of process $(Y(t), \xi_0(t))$ may be found by the methods of renewal theory (Smith 1958; Gnedenko and Kovalenko 2005) and it is given by

$$H_0(\tau) = \frac{p_0}{\alpha} \int_0^{\tau} (1 - A(u))\mathrm{d}u, \quad \tau \geq 0; \quad H_1(\tau) = \frac{Wp_1}{g} \int_0^{\tau} (1 - G(Wu))\mathrm{d}u, \quad \tau \geq 0, \tag{1}$$

where

$$H_i(\tau) = \lim_{t\to\infty} P\{Y(t) = i, \theta_i(t) \leq \tau\}, \quad i = 0, 1;$$
$$p_i = \lim_{t\to\infty} P\{Y(t) = i\}, \quad i = 0, 1; \quad p_1 = \frac{g}{\alpha W} \Big/ \left(1 + \frac{g}{\alpha W}\right), \quad p_0 = 1 - p_1;$$
$$\alpha = \int_0^{\infty} (1 - A(y))\mathrm{d}y < \infty, g = \int_0^{\infty} (1 - G(x))\mathrm{d}x < \infty.$$

From (1), it follows that stationary mean inventory level at wholesaler's warehouse is

$$\mathbf{E}\xi_0 = p_1 \int_0^{\infty} x(1 - G(x))\mathrm{d}x = (g^{(2)}/2g)p_1, \tag{2}$$

where $g^{(2)} = \int_0^{\infty} x^2 \mathrm{d}G(x) < \infty$. Our next target is determination of the mean inventory levels

$\mathbf{E}\xi_r = \int_0^{\infty} x\, \mathrm{d}(F_{0r}(x) + F_{1r}(x)),\ r = 1, 2, \ldots, R$, where [see (25)]

$$F_{0r}(x) = \sigma \int_0^{\infty} \Phi_{0r}(x + U_r y)(1 - A(y))\mathrm{d}y,$$
$$F_{1r}(x) = \sigma \int_0^{x/V_r} \Phi_{1r}(x - V_r y)(1 - B(y))\mathrm{d}y, \quad \sigma = 2 \Big/ \left(\alpha + \frac{g}{W}\right), \ \ V_r = W_r - U_r. \tag{3}$$

Here$F_{ir}(x) = F_{ir}(\underbrace{\infty, \ldots, \infty,}_{r-1} x, \underbrace{\infty, \ldots, \infty}_{R-r}),$

$$\Phi_{ir}(x) = \Phi_{ir}(\underbrace{\infty, \ldots, \infty,}_{r-1} x, \underbrace{\infty, \ldots, \infty}_{R-r}), \quad i = 0, 1.$$

From (24), we obtain the following system of integral equations for the functions' $\Phi_{ir}(x), i = 0, 1$, determination:

$$\Phi_{0r}(x) = \int_0^{x/V_r} \Phi_{1r}(x - V_r t)\mathrm{d}B(t), \quad \Phi_{1r}(x) = \int_0^{\infty} \Phi_{0r}(x + U_r t)\mathrm{d}A(t), \quad x \geq 0. \quad (4)$$

Particularly, if $A(t) = 1 - \mathrm{e}^{-\lambda t}, \quad t \geq 0$, then the solution of Eq. (4) in terms of the Laplace transform is given by

$$\begin{aligned} \varphi_{1r}(s) &\equiv \int_0^{\infty} \mathrm{e}^{-sx}\mathrm{d}\Phi_{1r}(x) = \varphi_0(\lambda/U_r)/[1 - (\lambda/sU_r)(1 - g(sV_r/W))], \\ \varphi_{0r}(s) &\equiv \int_0^{\infty} \mathrm{e}^{-sx}\mathrm{d}\Phi_{0r}(x) = \varphi_{1r}(s)g(sV_r/W), \quad \mathrm{Re}\, s > 0, \end{aligned} \quad (5)$$

where $g(s)$ is the Laplace–Stieltjes transform of d.f. $G(x)$. Since $\varphi_{1r}(0) = p_1^* = 1/2$, passing s to 0 in relation (5), we find

$$\varphi_{0r}(\lambda/U_r) = \frac{1}{2}\left(1 - \frac{\lambda g V_r}{W U_r}\right).$$

Taking into account (3), after some transformations we obtain

$$\begin{aligned} f_r(s) &= \int_{-0}^{\infty} \mathrm{e}^{-sx} d(F_{0r}(x) + F_{1r}(x)) \\ &= F_{0r}(0)\frac{1 + (\lambda/sV_r)(1 - g(sV_r/W))}{1 - (\lambda/sU_r)(1 - g(sV_r/W))}, \quad \mathrm{Re}\, s > 0, \end{aligned} \quad (6)$$

where $F_{0r}(0)$ is stationary probability that warehouse at the rth retailer is empty at arbitrary moment of time and

$$F_{0r}(0) = \left(1 - \frac{\lambda g V_r}{W U_r}\right) \Big/ \left(1 + \frac{\lambda g}{W}\right), \quad (7)$$

From (6), it follows that mean inventory level at the rth retailer is

$$\mathbf{E}\xi_r = -f_r'(0) = \frac{\lambda g^{(2)} V_r W_r}{2(W + \lambda g)(W U_r - \lambda g V_r)}. \quad (8)$$

Note that results (5)–(8) are valid only under conditions (equilibrium conditions)

$$\lambda g V_r < W U_r, \quad r = 1, 2, \ldots, R. \quad (9)$$

Now we assume that lot size is fixed and equals Q. It means that $G(x) = \begin{cases} 0, & x < Q \\ 1, & x \geq Q, \end{cases}$ $g = Q, g^{(2)} = Q^2$, and [see (1) and (2)]

$$p_0 = W/(W + \lambda Q),\ p_1 = \lambda Q/(W + \lambda Q), \mathbf{E}\xi_0 = \lambda Q^2/2(W + \lambda Q). \tag{10}$$

Similarly, the relations (7) and (8) will take the form

$$\mathbf{E}\xi_r = \frac{\lambda Q^2 V_r W_r}{2(W + \lambda Q)(U_r W - \lambda V_r Q)}, \quad F_{0r}(0) = \left(1 - \frac{\lambda Q V_r}{W U_r}\right) \Big/ \left(1 + \frac{\lambda Q}{W}\right), \tag{11}$$

$$\lambda V_r Q < W U_r, \quad r = 1, 2, \ldots, R. \tag{12}$$

Let us formulate the optimal lot sizing problem, i.e., the problem of optimal value Q determination. Using the relations (10)–(12) we can compose the following objective function

$$\begin{aligned} \bar{P}(Q) = &\sum_{r=1}^{R} \pi_r U_r (1 - F_{0r}(0)) \\ &- \left[\lambda(e_0 + cQ)p_0 + h_0 \mathbf{E}\xi_0 + \sum_{r=1}^{R} h_r \mathbf{E}\xi_r + \sum_{r=1}^{R} e_r W_r p_1\right], \end{aligned} \tag{13}$$

where e_0 is the transportation cost for delivery of a lot of product from supplier to warehouse; c is per unit order cost; h_0 is the per time unit holding cost per unit of the product for its storage at wholesaler's warehouse; e_r is the transportation cost for delivery of the unit of product from the warehouse to the rth retailer; h_r is the per time unit holding cost per unit of product for its storage at the rth retailer; π_r is the sale unit price for the product of the rth retailer $(\pi_r > e_r + c, r = 1, 2, \ldots, R)$. The first term in the right-hand side of the formula (13) is the mean rate of logistical system's income, the expression in the square brackets is the mean rate of logistical costs. Thus, the expression (13) is the mean profit of logistical system under consideration per unit of time. We obtained the following optimization problem: It is required to find out the value Q (lot size) maximizing the function (13) under condition (12). Using the results (2), (7), (8), and (10) the expression in the right-hand side of (13) may be written in the explicit form

$$\bar{P}(Q) = \frac{\lambda}{W + \lambda Q}\left[Q \sum_{r=1}^{R} (\pi_r - e_r - c) W_r - W e_0 - \frac{Q^2}{2}\left(h_0 + \sum_{r=1}^{R} \frac{h_r V_r W_r}{W U_r - \lambda Q V_r}\right)\right].$$

Elementary analysis shows that equation $\bar{P}'(Q) = 0$ has exactly one root in the interval $(0, (W/\lambda) \min_{1 \leq r \leq R}(U_r/V_r))$.

Optimal Distribution of Product Among a Set of Retailers Under Random Demand

The modeling scheme stated in the Appendix and used in the previous section allows us to formulate the optimization problems for other logistical systems, as well. In particular, it may be used for the analysis of similar logistical systems taking into account the random fluctuation of demand for a product. Consider, for example, a distribution system including an enterprise, which produces and sells a homogeneous product to R retailers. From an enterprise the product comes to the rth retailer by pipeline with constant processing rate W_r $r = 1, 2, \ldots, R$. It may be, for example, any oil product or liquefied gas. Each retailer has his own warehouse for the storage of the product. The demand per time unit at the rth retailer is modulated by semi-Markov process $Y_r(t)$ with a finite set of states **D**. We will assume that semi-Markov processes $Y_1(t)$, $Y_2(t)$, …, $Y_R(t)$ are stochastically mutually independent and process $Y_r(t)$ is defined by semi-Markov matrix $\|\pi_{ikr}A_{ir}(t)\|$. It is supposed that demand at the rth retailer has the random rate $U_r(Y_r(t))$. The problem is to determine the optimal (in definite sense) values W_r, $r = 1, 2, \ldots, R$. To solve this problem let us refer to the modeling scheme from the Appendix once again. For the sake of simplicity we will study a more simple case when $\mathbf{D} = \{0, 1\}, \pi_{10r} = \pi_{01r} = 1, r = 1, 2, \ldots, R$.

Denote $U_{ir} = U_r(Y(t))$ if $Y_r(t) = i, i = 0, 1$. We also assume that $0 \le U_{1r} < W_r < U_{0r}$, $r = 1, 2, \ldots, R$, and consequently $\mathbf{D}_r^+ = \{0\}, \mathbf{D}_r^- = \{1\}$. Preserving the designations of the previous section we denote $\xi_r(t)$ the inventory level of the product at the rth retailer. Due to above suppositions $(Y_r(t), \xi_r(t))$ will be the semi-Markov drift process. Therefore, to determine the stationary distribution of this process we can use Eqs. (7) and (8) with a simple modification. In particular, for determination of the functions $\Phi_{ir}(x), i = 0, 1$, the following system of integral equations is valid [see (24)]:

$$\Phi_{0r}(x) = \int_0^{x/V_{1r}} \Phi_{1r}(x - V_{1r}\tau)\mathrm{d}A_{1r}(\tau), \quad \Phi_{1r}(x) = \int_0^{\infty} \Phi_{0r}(x + V_{0r}\tau)\mathrm{d}A_{0r}(\tau), \quad x \ge 0, \tag{14}$$

where $V_{0r} = U_{0r} - W_r > 0, V_{1r} = W_r - U_{1r} > 0$. Correspondingly, relations (25) take the form

$$F_{0r}(x) = \sigma_r \int_0^\infty \Phi_{0r}(x + V_{0r}y)(1 - A_{0r}(y))\mathrm{d}y,$$

$$F_{1r}(x) = \sigma_r \int_0^{x/V_{1r}} \Phi_{1r}(x - V_{1r}y)(1 - A_{1r}(y))\mathrm{d}y, \tag{15}$$

$$\sigma_r = 2/(\alpha_{0r} + \alpha_{1r}); \quad \alpha_{ir} = \int_0^\infty (1 - A_{ir}(y))\mathrm{d}y < \infty, \quad i = 0, 1.$$

For example, put $A_{0r}(t) = 1 - \exp(-\lambda_r t), t \geq 0$. Then the solution of system (14) is determined by the relations [see (5)]

$$\varphi_{1r}(s) \equiv \int_0^\infty \mathrm{e}^{-sx}\mathrm{d}\Phi_{1r}(x) = \varphi_{0r}(\lambda_r/V_{0r})/[1 - (\lambda_r/sV_{0r})(1 - \alpha_{1r}(sV_{1r}))]$$

$$\varphi_{0r}(s) \equiv \int_0^\infty \mathrm{e}^{-sx}\mathrm{d}\Phi_{0r}(x) = \varphi_{1r}(s)\alpha_{1r}(sV_{1r}), \quad \mathrm{Re}\, s > 0, \tag{16}$$

and the Laplace–Stieltjes transform of stationary d.f. of process $\xi_r(t)$ is

$$f_r(s) = \int_{-0}^\infty e^{-sx}d(F_{0r}(x) + F_{1r}(x)) = F_{0r}(0)\frac{1 + (\lambda/sV_{1r})(1 - \alpha_{1r}(sV_{1r}))}{1 - (\lambda/sV_{0r})(1 - \alpha_{1r}(sV_{1r}))}, \tag{17}$$

where $\alpha_{ir}(z) \equiv \int_0^\infty \mathrm{e}^{-zt}\mathrm{d}A_{ir}(t), \mathrm{Re}\, z > 0; \mathrm{Re}\, s > 0$. Probability $F_{0r}(0)$ may be determined from relation (17) by the condition $\lim_{s\to+0} f_r(0) = 1$:

$$F_{0r}(0) = \left(1 - \frac{\lambda_r\alpha_{1r}V_{1r}}{V_{0r}}\right)\Big/(1 + \lambda_r\alpha_{1r}). \tag{18}$$

From (17), it follows that the stationary mean inventory level at the rth retailer is equal to [see (11)]

$$\mathbf{E}\xi_r = -f_r'(0) = \frac{\lambda_r\alpha_{1r}^{(2)}V_{1r}(U_{0r} - U_{1r})}{2(1 + \lambda_r\alpha_{1r})(V_{0r} - \lambda_r\alpha_{1r}V_{1r})}, \tag{19}$$

where $\alpha_{1r}^{(2)} = \int_0^\infty t^2\mathrm{d}A_{1r}(t)) < \infty$. The relations (18) and (19) are valid only if

$$V_{1r}\lambda_r\alpha_{1r} < V_{0r} \quad \text{or} \quad W_r < (U_{0r} + U_{1r}\lambda_r\alpha_{1r})/(1 + \lambda_r\alpha_r). \tag{20}$$

Let us evaluate the mean profit of all retailers per unit of time $\bar{P}$:

$$\begin{aligned}\bar{P} &= \sum_{r=1}^{R} [(\pi_r - c_r - e_r)W_r - h_r \mathbf{E}\xi_r] \\ &= \sum_{r=1}^{R} \left[(\pi_r - c_r - e_r)W_r - \frac{1}{2} h_r \frac{\lambda_r \alpha_{1r}^{(2)} V_{1r}(U_{0r} - U_{1r})}{(1 + \lambda_r \alpha_{1r})(V_{0r} - \lambda_r \alpha_{1r} V_{1r})} \right],\end{aligned} \tag{21}$$

where parameters π_r, c_r, e_r, h_r have the same meaning as in the formula (13). The production capacity of enterprise is the finite value W_0, therefore the following condition must be fulfilled

$$\sum_{r=1}^{R} W_r \leq W_0. \tag{22}$$

The problem of optimal distribution of products among retailers is reduced to one-stage stochastic optimization problem: It is required to find out the positive variables $W_r, r = 1, 2, \ldots R$, maximizing the objective function (21) under conditions (20), (22). Since $\partial^2 \bar{P} / \partial W_r^2 < 0$ due to the condition (20), the function (21) is concave.

Conclusion

In the logistic management practices it is very important to take into account different kinds of uncertainty. In such situations the logistical managers may apply the theory of Markov and the semi-Markov drift processes, which are very suitable mathematical apparatuses to model and optimize sufficiently complicated logistical systems including suppliers, industrial enterprises, transportation systems, traders, etc. The type of stochastic processes mentioned above allows a simultaneous description of many kinds of inventories under fluctuation of demand, random delay in supply, etc. In our paper, the examples are given, which demonstrate the usefulness of such an approach. It may also be applied for modeling and analyzing more general logistical systems, e.g., optimal lot sizing of multi-item product, different types of distribution systems, a port's terminal functioning (Postan 2006a).

Appendix: Definition of Semi-Markov Drift Process and Its Properties

Consider the stochastic process $(Y(t), \xi_1(t), \ldots, \xi_M(t))$ with the phase space $\mathbf{\Omega} = \mathbf{D} \times \mathbf{R}_M^+$ where $\mathbf{D}$ is a finite set, R_M^+ is the non-negative orthant of M-dimensional Euclidean space. Here $Y(t)$ is the semi-Markov process with the phase space $\mathbf{D}$ and semi-Markov matrix $\left\|\pi_{ij}A_i(t)\right\|, i,j \in \mathbf{D}$, where π_{ij} are transition probabilities of embedded Markov chain, $A_i(t)$ is d.f. of sojourn-time of $Y(t)$ in the state $i \in \mathbf{D}$. Let us assume that continuous components $\xi_m(t)$, $m = 1,2,\ldots, M$ satisfy the following differential equations (with probability 1):

$$\xi'_m(t) = \sum_{i\in\mathbf{D}} v_{im} I(Y(t) = i) - \sum_{i\in\mathbf{D}_m^-} v_{im} I(Y(t) = i, \xi_m(t) = 0), \quad t \geq 0, \qquad (23)$$

where $I(A)$ is the indicator of an event A; $v_{im}, i \in \mathbf{D}$, are the given values (velocities); $\mathbf{D}_m^- = \{i : \; v_{im} < 0, i \in \mathbf{D}\} \; \neq \emptyset, m = 1, 2, \ldots, M$. In accordance with Eq. (23) $\vec{\xi}(t) = (\xi_1(t), \ldots, \xi_M(t))$ is M-dimensional random walk in non-negative orthant $\mathbf{R}_M^+$ with the sticky bounds. The stochastic process $(Y(t), \vec{\xi}(t))$ defined above is a kind of semi-Markov drift process (Postan 2006a). Let $\{t_n\}, n \geq 1$ be the sequence of moments, when $Y(t)$ changes its state. Denote $\langle \Phi_i(\vec{x}), i \in \mathrm{D}, \vec{x} \in \mathbf{R}_M^+ \rangle$ and $\langle F_i(\vec{x}), i \in \mathbf{D}, \vec{x} \in \mathbf{R}_M^+ \rangle$ the stationary probabilistic measures of homogeneous Markov chain $(Y(t_n), \vec{\xi}(t_n))$ and process $(Y(t), \vec{\xi}(t))$ correspondingly. Taking into account Eq. (23), it may be proven (Postan 2006a) that functions $\Phi_i(\vec{x})$ satisfy the following system of convolution type integral equations

$$\Phi_i(\vec{x}) = \sum_{k\in\mathbf{D}} \pi_{ki} \int_0^{T_k(\vec{x})} \Phi_k(\vec{x} - \vec{v}_i\tau)\mathrm{d}A_k(\tau), \quad i \in \mathbf{D}, \quad \vec{x} \in \mathbf{R}_M^+, \qquad (24)$$

where $T_k(\vec{x}) = \min_{1\leq m\leq M}(x_m/v_{km}^+), v_{km}^+ = \max(0, v_{km})$. From the semi-Markov processes theory of (Korolyuk and Turbin 1976; Gnedenko and Kovalenko 2005), it follows that

$$F_i(\vec{x}) = \sigma \int_0^{T_i(\vec{x})} (1 - A_i(\tau))\Phi_i(\vec{x} - \vec{v}_i\tau)\mathrm{d}\tau, \quad i \in \mathbf{D}, \quad \vec{x} \in \mathbf{R}_M^+, \qquad (25)$$

where $\sigma = \left(\sum_{i\in\mathbf{D}} \alpha_i p_i^*\right)^{-1}; \alpha_i = \int_0^\infty (1 - A_i(\tau))\mathrm{d}\tau < \infty$; and $p_i^* = \Phi_i(\infty), i \in \mathrm{D}$, are the stationary probabilities of the Markov chain $Y(t_n)$.

References

Bramel J, Simchi-Levi D (1997) The logic of logistics: theory, algorithms, and applications for logistics management. Springer, Berlin

Brandimarte P, Zotteri G (2007) Introduction to distribution logistics. Wiley, NY

Devis MHA (1984) Piecwise-deterministic Markov process: a general class of non-diffusion stochastic models. J Royal Statist Soc 3:353–388

Gnedenko BV, Kovalenko IN (2005) An introduction to queueing theory. KomKniga, Moscow (in Russian)

Korolyuk VS, Turbin AF (1976) Semi-Markov processes and their applications. Kyiv, Naukova Dumka (in Russian)

Mitra D (1988) Stochastic theory of a fluid model of producers and consumers coupled by a buffer. Adv Appl Prob 20:646–676

Postan MY (2006a) Modeling complex systems on the basis of semi-Markov drift processes. In: Proceedings of the 5th international conference on system identification and control problems SICPRO'06, Moscow (in Russian)

Postan MY (2006b) Economic-mathematical models of multimodal transport. Astroprint, Odessa (in Russian)

Postan MY (2008) Application of Markov drift processes to logistical systems modeling. In: Haasis HD et al (eds) Dynamics in logistics. Proceedings of first international conference, LDIC 2007. Springer, Berlin

Prabhu NU (1998) Stochastic storage processes: queues, insurance risk, dams, and data communications, 2nd edn. Springer, Berlin

Smith WL (1958) Renewal theory and its ramifications. J Royal Statist Soc B 20:2

An Agent-Based Approach to Multi-criteria Process Optimization in In-House Logistics

Christoph Greulich

Abstract One of the crucial enablers of the fourth industrial revolution is the implementation of autonomy in supply chains. Increased autonomy in logistics adds flexibility and robustness to supply chains. However, decentralized local decision making also creates new challenges since optimization problems now have to be solved in a decentralized manner. This research project proposes to apply agent technology to solve optimization problems in a distributed way in order to maintain efficiency while benifitting from the advantages of decentralization.

Keywords Multi-Agent Systems · Intralogistics · Decentralization

Introduction

Since it was first introduced (Davis 1987), the concept of mass customization has turned into a widespread research area. It is defined as an approach to manufacture customized products for individual consumers without significantly increasing production costs or selling prices (Kaplan and Haenlein 2006).

Within the last decade, the number of publications regarding successful implementation of mass customization increased significantly (Fogliatto et al. 2012). However, the implementation of mass customization in the real world is still restrained by the limits of assembly segmentation and lack of autonomy in supply chains (Günthner et al. 2006). Hence, future project industry 4.0 suggests that loosening those limitations and implementing autonomy in supply chains by applying cyber-physical systems (CPS) (Broy 2010) and the Internet of things (Fleisch and Mattern 2005) will be the key enabler for the fourth industrial revolution (Kagermann et al. 2013).

C. Greulich (✉)
University of Bremen, Am Fallturm 1, 28359 Bremen, Germany
e-mail: greulich@cs.uni-bremen.de

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Before autonomy can be implemented in production facilities and in-house logistics, several aspects have to be taken into consideration. Some authors have already emphasized that a trade-off between costs and benefits has to be managed (Piller et al. 2004). Other authors suggest the consideration of energy consumption (Liu et al. 2013). Another factor is the speed and synchronization of each production step. It is likely that parameters and their weights vary between different facilities. Additionally, synergetic effects may emerge between the various factors. It has to be determined which factors can be generalized and which factors depend on the given facility. In any case, a multi-criteria optimization problem must be solved to maintain and improve efficiency.

Currently, computer-aided production planning (CAPP) is considered a valid solution to realize mass customization efficiently (Yao et al. 2007; Zäh and Rudolf 2003). However, centralized CAPP does not allow autonomy of any machine during the overall production process. When decentralizing the planning process, decisions will be made locally by the various machines. To further maintain efficiency, the multi-criteria optimization problem must be solved in a decentralized way. Therefore, this research project proposes an agent-based approach.

Multi-agent Systems

In the context of artificial intelligence (AI), an agent is a software program which is defined as an autonomous entity with the capability of reacting upon changes in its environment (Wooldridge and Jennings 1995). For a more detailed definition of a specific agent, four components have to be considered: performance, environment, actuators, sensors (PEAS) (Russell and Norvig 2004). Performance describes the goals the agent wants to reach and the rules he has to follow. Environment describes the surroundings of the agent, including static and dynamic factors, which may include other agents. Additionally, every agent has two sets of interfaces: one set to perceive the environment (sensors) and one set to manipulate and interact with the environment (actuators). Additionally, agents can be divided into four different classes: simple reflex agents which only react upon recent events without a concurrent world model or any knowledge of previous decisions; model-based reflex agents which have an internal model of the current state of the environment; goal-based agents which are working toward reaching specific goals; utility-based agents which apply a utility function to choose the most efficient way to reach their goals. Furthermore, machine learning methods can be applied to refine the decision-making process of an agent.

Multi-agent systems (MAS) are suitable for real-world application and simulation of systems where local decision-making and dynamic reactions on events are focused (Parunak et al. 1998). During the last decade, MAS have been used to solve various problems of the logistics domain in simulation and practice (Greulich et al. 2013; Schwarz et al. 2012; Tu et al. 2009).

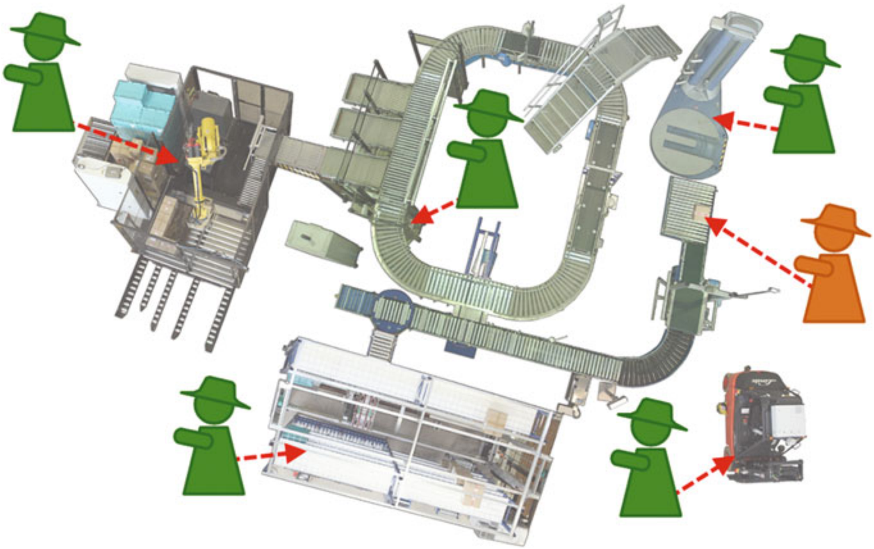

Fig. 1 Agents representing stakeholders of in-house logistics

Application to In-House Logistics

As stated above, the purpose of this research project is to derive a multi-criteria optimization problem from scenarios of in-house logistics and to find a decentralized solution for this problem. By representing every machine and/or every product within a given facility by a dedicated agent (See Fig. 1), the stakeholders of the scenario will be able to act autonomously and optimize their performance locally. Hence, the optimization problem will be solved in a decentralized way. Even though the agent model will be developed for simulation purposes, it has to be applicable to real-world systems like the LogDynamics Lab (Brieber and Szymanski 2012).

Each agent will be able to react upon recent events, which may include short-term changes, varying priority of the given products, and occurring problems such as bottlenecks, resource shortages, and machine failures. Possible reactions by an agent representing a machine are, e.g., to reschedule the production order or to reconfigure the given machine to handle new conditions.

Different strategies for decision making can be applied, because decisions can be made by machines, products, or both of them. It has to be determined which approach is the most promising. While interaction with the environment strongly depends on the type of machine, all interactions between agents will be handled by exchanging messages using the Foundation for Intelligent Physical Agents (FIPA) Communication Language.[1]

[1] http://www.fipa.org/specs/fipa00061/index.html.

Considering that solving the multi-criteria optimization problem is a global goal within the facility, all agents should be at least utility based. The application of machine learning is not necessarily required but should be considered.

Conclusion

By deriving multi-criteria optimization problems from scenarios of in-house logistics and determining the stakeholders of the given facilities, MAS can be developed to solve the problems in a decentralized way and therefore increase autonomy in in-house logistics. It has to be considered that stakeholders and optimization problems can hardly be generalized due to the wide variety of facilities. Therefore, analyzing a specific scenario and developing a MAS to represent the stakeholders of this scenario are a promising approach.

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References

Brieber B, Szymanski L (2012) Autonomous logistics—potentials of multiagent-systems and advanced scenarios for virtual logistics lab 2.0. In: Warden T, Werthmann D, Uckelmann D, Lawo M (eds) Technical report 65. Technologie-Zentrum Informatik (TZI), Universität Bremen, Bremen, Germany

Broy M (2010) Cyber-physical systems. Springer, Berlin

Davis SM (1987) Future perfect. Addison Wesley

FIPA ACL Message Structure Specification (Standard 00061G) (2002) Foundation for intelligent physical agents

Fleisch E, Mattern F (eds) (2005) Das Internet der Dinge – Ubiquitous Computing und RFID in der Praxis. Springer, Berlin

Fogliatto FS, da Silveira GJC, Borenstein D (2012) The mass customization decade: an updated review of the literature. Int J Prod Econ 138(1):14–25. doi:10.1016/j.ijpe.2012.03.002

Greulich C, Edelkamp S, Gath M (2013) Agent-based multimodal transport planning in dynamic environments. In: KI 2013: advances in artificial intelligence, pp 74–85

Günthner WA, Wilke M, Zäh MF, Rudolf H (2006) Planung von Produktionsprozessen und Materialflusssteuerung. In: Lindemann U, Reichwald R, Zäh MF (eds) Individualisierte Produkte - Komplexität beherrschen in Entwicklung und Produktion. Springer, Berlin, pp 151–161

Kagermann H, Wahlster W, Helbig J (2013) Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0. Abschlussbericht Des Arbeitskreises Industrie (April)

Kaplan AM, Haenlein M (2006) Toward a Parsimonious definition of traditional and electronic mass customization. J Prod Innov Manage 23(2):168–182

Liu H, Zhao Q, Huang N, Zhao X (2013) A simulation-based tool for energy efficient building design for a class of manufacturing plants. IEEE Trans Autom Sci Eng 10(1):117–123. doi:10.1109/TASE.2012.2203595

Parunak HVD, Savit R, Riolo RL (1998) Agent-based modeling vs. equation-based modeling: a case study and users' guide. In: Multi-agent systems and agent-based simulation, first international workshop (MABS), vol 1534. Springer, Berlin, pp 10–25

Piller FT, Moeslein K, Stotko CM (2004) Does mass customization pay? An economic approach to evaluate customer integration. Prod Plann Control 15(4):435–444
Russell S, Norvig P (2004) Künstliche Intelligenz: Ein moderner Ansatz, 2nd edn. Pearson Studium, London
Schwarz C, Hahn A, Sauer J (2012) Multi agent simulation of a warehouse. In: Proceedings of the 2012 international conference on logistics and maritime systems (LOGMS), pp 487–496
Tu M, Lin J-H, Chen R-S, Chen K-Y, Jwo J-S (2009) Agent-based control framework for mass customization manufacturing with UHF RFID technology. Syst J IEEE 3(3):343–359
Wooldridge M, Jennings NR (1995) Intelligent agents: theory and practice. Knowl Eng Rev 10(02):115–152. doi:10.1017/S0269888900008122
Yao S, Han X, Yang Y, Rong (Kevin) Y, Huang SH, Yen DW, Zhang G (2007) Computer aided manufacturing planning for mass customization: part 2, automated setup planning. Int J Adv Manuf Technol 32(1–2):205–217
Zäh MF, Rudolf H (2003) Computer aided process planning as an enabler for mass customization: state of the art and future areas for research. In: Reichwald R, Piller F, Tseng M (eds) Leading Mass Customization and Personalization from an Emerging Stage to a Mainstream Business Model. Proceedings of the MCPC 03: 2nd Interdisciplinary World Congress on Mass Customization and Personalization

Part III
Technology Application in Logistics

Machine-to-Machine Sensor Data Multiplexing Using LTE-Advanced Relay Node for Logistics

Farhan Ahmad, Safdar Nawaz Khan Marwat, Yasir Zaki, Yasir Mehmood and Carmelita Görg

Abstract Machine-to-Machine (M2M) communication is one of the emerging fields today and expected to play a major role in interconnecting various types of devices for different applications, such as logistics. Mobile communication standards, such as Long Term Evolution Advanced (LTE-A), have high data rate capability and are designed to provide broadband services to the human-based communication. M2M devices in logistics usually transmit small amount of data depending on the application scenario. LTE-A can be optimized to provide better performance of M2M devices in logistics. This paper studies a Relay Node (RN) based solution in LTE-A to integrate M2M devices in mobile cellular networks. Different M2M scenarios are developed for logistics along with normal LTE-A users in our LTE-A simulation model implemented in OPNET Modeler. The simulation results show that the data traffic performance of LTE-A network improves significantly if RN is utilized for aggregation and multiplexing of M2M data traffic in logistics.

Keywords M2M · Logistics · LTE-A · Relay node · Aggregation

F. Ahmad (✉) · S.N.K. Marwat · Y. Mehmood · C. Görg
Communication Networks (ComNets), University of Bremen,
Otto-Hahn-Allee NW1, 28359 Bremen, Germany
e-mail: farhan@comnets.uni-bremen.de

S.N.K. Marwat
e-mail: safdar@comnets.uni-bremen.de

Y. Mehmood
e-mail: ym@comnets.uni-bremen.de

C. Görg
e-mail: cg@comnets.uni-bremen.de

Y. Zaki
Computer Science Department, New York University Abu Dhabi (NYUAD),
Abu Dhabi, United Arab Emirates (UAE)
e-mail: yasir.zaki@nyu.edu

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Introduction

Machine-to-Machine (M2M) communication is one of the recent research areas today. This offers the devices, the so called machines to communicate with each other without or with minor human involvement. With the increase in number of M2M devices in future, the mobile data traffic is also expected to grow significantly, i.e., 13 folds until 2017 in future communication networks (Cisco Systems Inc. 2013).

The existing wireless communication technologies like Global System for Mobile Communication/General Packet Radio Service (GSM/GPRS) are currently providing services to facilitate M2M communication. Because of the tremendous expected growth in M2M communication, the numbers of devices are increasing and the resulting M2M traffic is growing exponentially. The current mobile communication systems like GSM and GPRS may no longer be able to handle this rapid hike of M2M traffic. As a result, Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are considered as potential candidates to incorporate future M2M traffic. M2M communication has a different impact on the network performance as compared to normal communication, because of the nature of M2M devices of transmitting small data packets with low data rates. The integration of a high number of M2M devices can reduce the overall LTE and LTE-A network performance as in Pötsch et al. (2013), Marwat et al. (2013a, b).

This paper specifically focuses on the degradation of network performance, when integrating the M2M traffic in LTE-A. The main goal of this paper is to highlight the network related issues pertaining to the dynamics in logistics and presents the concept of a practical solution for managing the traffic generated by the logistic devices in LTE-A network. We elaborate a Relay Node (RN) based solution for the efficient network resource utilization to serve the M2M devices utilized in logistics.

M2M Data Communication in Logistics

Logistics is considered to be a leader in the use of M2M devices (Vodafone 2013) and M2M communication has a great impact on the logistics process. Sensors used in the logistics container usually transmit useful information including temperature, humidity, pressure, location, and light intensity. The logistics goods are usually expensive and require proper monitoring right from its departure until the successful delivery of goods at the destination (Pötsch et al. 2013). The successful delivery of goods at the destination on assured time is of great importance in logistics. By monitoring with sensor readings, the delivery of goods in time and in good condition can be facilitated. Hence, M2M can be seen very important in the context of logistics and with the increase in number of the M2M devices for logistics, the role of M2M communication is expected to increase in near future.

The most important challenge for M2M communication is the large number of messages generated by M2M devices. All the sensors deployed with M2M devices in factories, logistics container, or storage facilities would produce a huge number of messages. The size of these messages could vary too. It could be very small in case of light intensity sensors and it could be very large in case of video surveillance of M2M device. M2M traffic is quite different from the normal human-generated traffic. The data generated by the M2M devices is usually very small sized with infrequent transmissions, and the number of devices can be quite huge as compared to human-based traffic. In logistics, the data transmitted by sensors for remote monitoring of goods contains the measurements and the protocol overhead is kept as small as possible.

Relaying in LTE-A

The Third Generation Partnership Project (3GPP) has been investigating new methods to increase the data volume requirement of cellular mobile users. LTE-A is the recent standard of wireless communication proposed by 3GPP. LTE-A is designed to serve the cellular devices with data rates up to1 Gbits/s in downlink. The access network of LTE-A consists of two main nodes, i.e., a base station called eNodeB (eNB) and the user known as User Equipment (UE). One of the main objectives of LTE-A is the throughput enhancement of the cell-edge UE. The 3GPP has addressed this issue by putting forward some solutions such as the low power heterogeneous nodes with both micro and macro base stations as well as low cost and low power RNs. The focus of this paper is to propose a scheme for exploiting the RN for efficient spectrum utilization to enhance bandwidth efficiency and offer better service to the M2M traffic for logistics.

RN is a low power device which is used for coverage extension of the cell, especially, where fixed-line backhaul links are difficult to deploy (Nagata et al. 2011). RN is connected wirelessly over the air interface to the donor eNB (DeNB) and the communication between the DeNB and the cell-edge UE takes place through RN. The link between DeNB and RN is called backhaul link (Un Interface), while the link between RN and UE is called access link (Uu Interface). Using relaying, a better throughput and better signal-to-noise ratio performance can be achieved. The locations with poor channel conditions or coverage holes can be improved by RN.

Relaying user plane protocol stack is shown in Fig. 1. Based on the protocol stack, RN can be categorized into three types. Layer 1 RN, also called amplify-and-forward type of relay, which receives the downlink signal from DeNB and amplifies the signal. The amplified signal is forwarded to the UE. This is the simplest solution but the main drawback of this kind of relaying is that the intercell interference and noise are amplified as well along with the desired signal. This ultimately reduces the throughput enhancement (Nagata et al. 2011). Layer 2 relay is a decode-and-forward type of relay. RF downlink signal received at the relay is

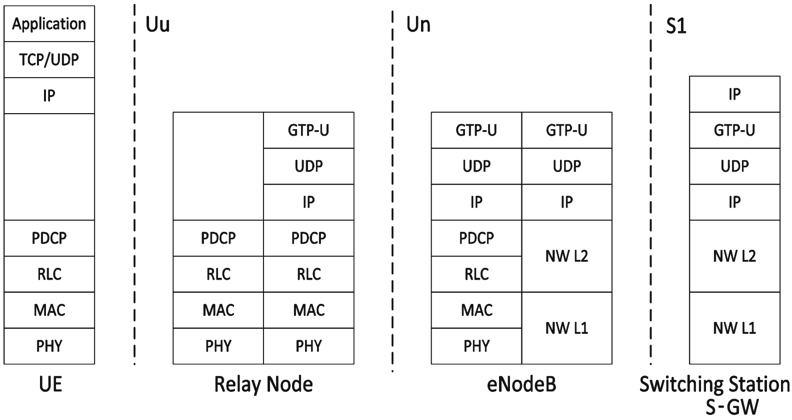

Fig. 1 Relay node protocol stack

decoded and encoded again, which is forwarded to the UE. This decoding and encoding of signal overcomes the drawback of the layer 1 relay, i.e., it has better SINR and better throughput (Ghafar et al. 2011). Layer 3 RN uses normal wireless air interface instead of expensive microwave links. Layer 3 RN is also decode-and-forward type of relay as Layer 2 RN. Signal received on the downlink performs the decoding and goes further to the higher layers to process user data by ciphering, combining, and encoding again to forward the signal to UE. Using this relay, best throughput enhancement can be achieved as compared to other relay types but this relay introduces a large processing delay as compared to Layer 2 relay (Ghafar et al. 2011).

The 3GPP supports two types of relays based on the usage of spectrum (3GPP TR 36.814 V9.0.0 2010). The Inband relaying is achieved using the same carrier frequency on backhaul link and access link, while the Outband relaying uses a different carrier frequency on both backhaul and access links. Downlink and uplink communications can be achieved in Inband relaying by time multiplexing both the links, i.e., backhaul link and access link. Outband relaying could not be a feasible alternative, since it requires a different frequency carrier. Figure 2 shows the architecture of LTE-A network highlighting the RN along with some M2M devices.

Problem Statement and Proposed Solution

In LTE-A, the smallest resource unit that can be allocated by the eNB to a UE is a Physical Resource Block (PRB) as standardized by the 3GPP. A PRB is capable of transmitting large data in favorable channel conditions. The LTE-A frequency spectrum is a scarce resource and the vendor pays huge investment capital to obtain it. As the M2M device usually transmits small data at a particular time, the allocation of the entire PRB to a single M2M device degrades the spectrum efficiency.

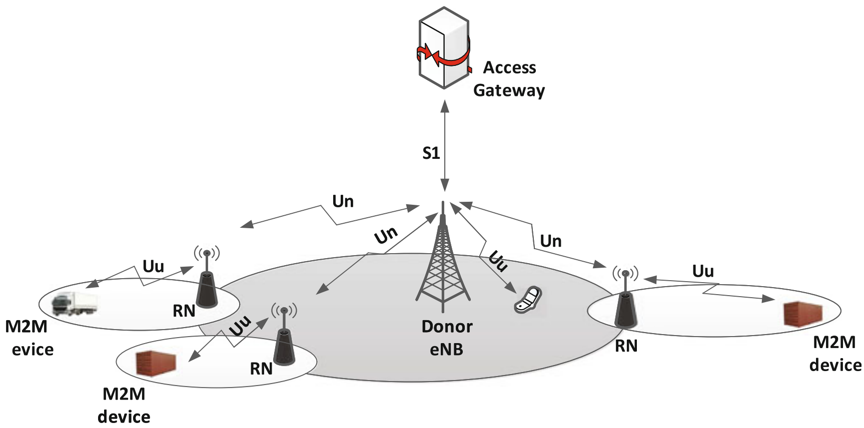

Fig. 2 M2M-LTE-A architecture with focus on relay node

Since, the numbers of machines are growing and in the context of large-scale network, the idea of allocating whole PRB to each machine can reduce the overall efficiency. Therefore, to enhance spectral efficiency and to ensure the same Quality of Service (QoS) provision to M2M and normal traffic, it is preeminent that architectural changes in LTE/LTE-A are required. The authors in (Marwat et al. 2013a, b) have proposed a solution to address this problem, where the data of the M2M users is multiplexed at the packet data convergence protocol (PDCP) layer of the RN. Consequently, the RN disguises the requests for radio resources (PRBs) from the eNB as a single user requesting for resources. Hence, several M2M devices could share a single PRB. Using this strategy, the spectrum efficiency can be increased significantly as compared to normal M2M communication, where one PRB is assigned to one M2M user as shown in Fig. 3.

The multiplexing of M2M users on the RN can be accomplished by modifying the RN. It needs the designing of efficient PDCP layer algorithm where M2M users

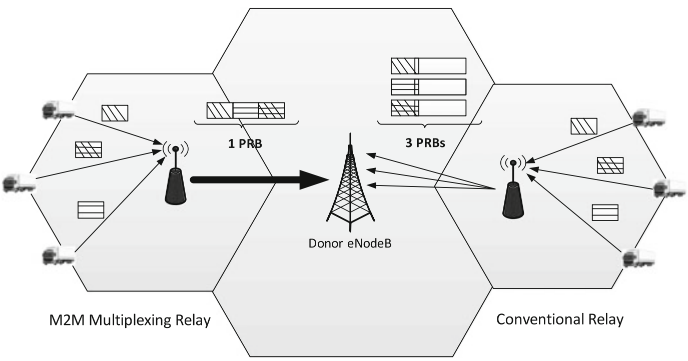

Fig. 3 M2M multiplexing relay node (Marwat et al. 2013a, b)

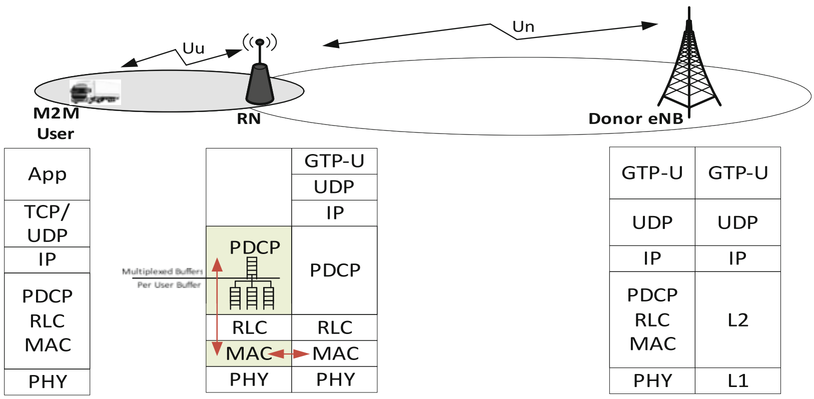

Fig. 4 M2M user multiplexing algorithm (Marwat et al. 2013a, b)

can be multiplexed and this multiplexing algorithm should be able to interact actively with the RN scheduler at the MAC layer of RN as shown in Fig. 4. The RN scheduler is responsible for the scheduling over the access link of the RN.

In case of emergency, i.e., fire, accident, or natural disaster, the performance of LTE-A network can degrade as it has to deal with the simultaneous transmission of emergency messages (Marwat et al. 2012). The sensors in the logistics container would trigger the M2M devices to transmit the emergency M2M messages, which requests simultaneous resources to deal with the situation.

Simulation Settings

The implementation of a simulation model is achieved using an LTE-A model in the OPNET simulation environment. The OPNET Modeler (OPNET Modeler 2013) is used as the primary modeling, simulation, and analysis tool of this paper. The OPNET Modeler provides solutions for network research and development, as well as, application and network performance management. The designed LTE-A simulation model (Zaki et al. 2011) consists of several nodes with LTE-A functionalities and protocols shown in Fig. 5.

The remote server node supports user applications in all the cells and acts as a sink for the uplink data. The remote server and the Access Gateway (aGW in Fig. 5) nodes are interconnected via an Ethernet link of 20 ms average delay. The Access Gateway node consists of peer-to-peer protocols like User Datagram Protocol (UDP), Internet Protocol (IP), and Ethernet toward the Transport Network (TN); and the other part toward the remote server. The Access Gateway and the eNB nodes (eNB1, eNB2, …) are connected through the TN of IP routers (that is R1 and R2), which are configured according to the standard OPNET Differentiated Service (diffserv) model and routing protocols. The QoS parameters for the traffic differentiation at the TN are

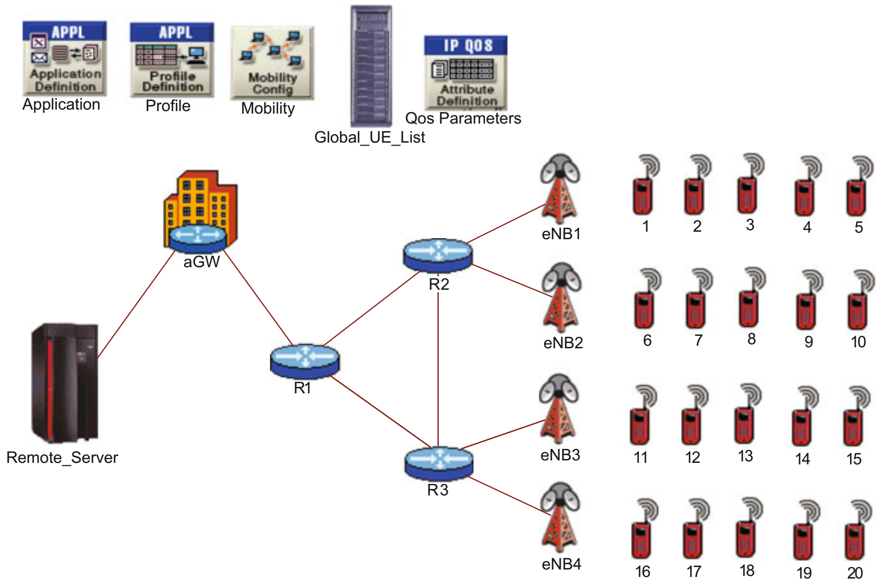

Fig. 5 OPNET project editor

configured at the QoS parameters node. The mobility node consists of the mobility and channel models. The mobility model emulates the user movement in a cell and updates the user location at every sampling interval. The user mobility information is stored in the global user database (Global_UE_List in Fig. 5) and is accessible from every node in the system at any given time. The channel models include path loss, slow fading, and fast fading models. The mobility of the UEs is modeled with Random Mobility Model and Random Waypoint. The simulation parameters are given in Table 1, while traffic models are given in Table 2.

Results and Analysis

In the simulations, we illustrate the feasibility of our proposed scheme for the RN. Since RN has yet to be implemented into our LTE-A model; we utilize an efficient way to simulate the aggregation and multiplexing of data from the sensor nodes. We simulate four scenarios for this purpose with varying M2M traffic load in the network. 10 FTP users are deployed in all the scenarios. However, the number of trailers is varied in the scenarios to evaluate the network performance. The number of trailers with a single sensor under study is 60, 90, 120, and 150 in these scenarios. We, then, consider two sub-scenarios for each scenario. In one sub-scenario, each sensor node is communicating individually with the network. While, in second sub-scenario, data for each set of five sensor nodes is aggregated, before sending it to the network.

Table 1 Simulation parameters

Parameter	Value
Simulation length	1000 s
eNB coverage radius	350 m
Min. eNB−UE distance	35 m
Max terminal power	23 dBm
Terminal velocity	120 km/h
Mobility model	Random way point (RWP)
Frequency reuse factor	1
Transmission bandwidth	5 MHz (for downlink and uplink each)
No. of PRBs	25 (for downlink and uplink each)
MCS	QPSK, 16QAM, 64QAM,
Path loss	128.1 + 37.6 log10(R), R = distance in kilometers
Slow fading	Lognormal shadowing, 8 dB standard deviation, correlation 1
Fast fading	Jakes-like method
UE buffer size	Infinite
Power control, α	0.6
Power control, P_0	−58 dBm

Table 2 Traffic models

Parameter	Setting
FTP traffic model (low priority)	
File size	20 Mbyte
File inter-request time	Uniform distribution (80–100 s)
M2M traffic model (high priority)	
Message size	6 bytes
Message interarrival time	60 ms

Thus, the network views a set of five nodes as a single terminal transmitting data. For instance, for the second sub-scenario of the first scenario, the network considers 12 terminals requesting network resources instead of 60. The relay transmission delay and machine delays are not taken into account for these scenarios.

Figure 6 shows that by increasing the number of unaggregated M2M devices, the upload time increases. But for the aggregated and multiplexed devices, the average file upload time of FTP users increases very marginally. The network assigns more resources to the M2M devices having high priority traffic as compared to FTP users. The average end-to-end delay for the M2M devices shown in Fig. 7 for the case of data aggregation does not increase drastically with the increase in number of the M2M devices. However, in the unaggregated case, the packet end-to-end delay increases significantly with the increase in cell load. Also, throughput can be enhanced when the data of M2M devices are aggregated.

Fig. 6 Average FTP file upload time

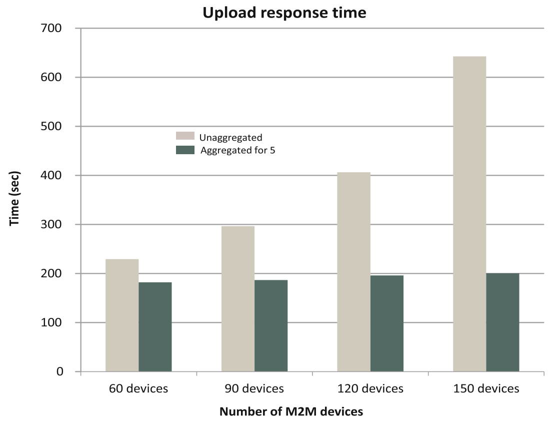

Fig. 7 Average M2M packet end-to-end delay

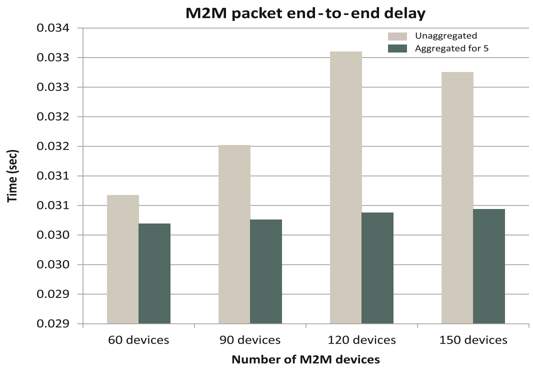

Fig. 8 Average cell throughput

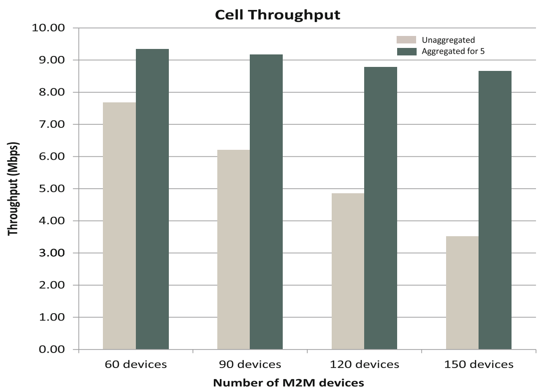

Figure 8 illustrates that the performance of the network is significantly improved for the aggregated M2M data traffic as compared to the unaggregated traffic. The reason for this improvement is that the aggregation of M2M data ensures the usage of a minor number of PRBs for the same amount of data transmission. Hence, it ultimately increases the efficiency of the network.

Conclusion and Future Work

In this paper, we proposed a methodology for facilitation of logistic processes by exploiting the RN functionality for aggregation and multiplexing of M2M data traffic. As LTE-A is designed specifically for broadband applications, thus the integration of large-scale deployment of narrowband, M2M devices can have a negative effect on the performance of LTE-A network as described in the results. We illustrated that by integrating the data of several M2M devices, the system performance can be enhanced considerably with reduced packet end-to-end delays and higher throughput as compared to the case of unaggregated data in the network.

In our future work, we are planning to implement fully functional RN with aggregation and multiplexing capabilities in our LTE-A model using OPNET modeler. The RN implementation can help in improving the LTE-A network performance, when huge amount of M2M devices are deployed along with normal LTE-A users.

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References

3GPP TR 36.814 V9.0.0 (2010) Evolved universal terrestrial radio access (E-UTRA), further advancements for E-UTRA physical layer aspects. http://www.3gpp.org/DynaReport/36814.htm. Accessed 15 Sept 2013

Cisco Systems Inc. (2013) Cisco visual networking index: global mobile data traffic forecast update, 2012–2017. http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf. Accessed 28 Aug 2013

Ghafar ASA, Satiman NFN, Maharum SMM, Saparudin FA, Rashid RA, Yusof SKS, Katiran N (2011) Communications in computer and information science: techniques on relaying for LTE-advanced network. In: The international conference on informatics engineering & information science (ICIEIS2011), Kuala Lampur, Malaysia, 14–16 Nov 2011

Marwat SNK, Weerawardane T, Perera R, Goerg C, Timm-Giel A (2012) Impact of machine-to-machine (M2M) communications on disaster management in future mobile networks. In: General Sir John Kotelawala Defense University Annual Symposium, Ratmalana, Sri Lanka

Marwat SNK, Pötsch T, Zaki Y, Weerawardane T, Goerg C (2013a) Addressing the challenges of E-healthcare in future mobile networks. In: 19th EUNICE workshop on advances in communication networking, Chemnitz, Germany, 28–30 Aug 2013

Marwat SNK, Zaki Y, Chen J, Timm-Giel A, Görg C (2013b) A novel machine-to-machine traffic multiplexing in LTE-A system using wireless in-band relaying. In: 5th International conference on mobile networks and management (MONAMI), Cork, Republic of Ireland

Nagata S, Yan Y, Gao X, Li A, Kayama H, Ab T (2011) Investigation on system performance of L1/L3 relays. In: Vehicular technology conference (VTC Spring), Yokohama

OPNET Modeler (2013) http://www.opnet.com. Accessed 27 Oct 2013

Pötsch T, Marwat SNK, Zaki Y, Goerg C (2013) Influence of future M2M communication on the LTE system. In: Wireless and mobile networking conference (WMNC), Dubai, United Arab Emirates

Vodafone (2013) The state of M2M in transport and logistics, Key findings from the 2013 Vodafone M2M adoption barometer. http://m2m.vodafone.com/discoverm2m/industries/transport-and-logistics/. Accessed 11 Sept 2013

Zaki Y, Weerawardane T, Goerg C, Timm-Giel A (2011) Long term evolution (LTE) model development within OPNET simulation environment. OPNET Workshop, Washington, D.C., USA, 12–14 Nov 2011

Impact of Machine-to-Machine Traffic on LTE Data Traffic Performance

Yasir Mehmood, Thomas Pötsch, Safdar Nawaz Khan Marwat, Farhan Ahmad, Carmelita Görg and Imran Rashid

Abstract Machine-to-machine (M2M) communication is an emerging paradigm in which trillions of intelligent devices are expected to communicate without or with small human intervention. The increasing M2M devices have severe impact on long-term evolution (LTE) data traffics. Moreover, the behavior of M2M traffic also differs from traditional mobile traffic. In future, logistics and transportations are considered to be the main M2M application areas. These applications disparately demand more efficient M2M traffic modeling to reduce end-to-end (E2E) delay between various interconnected machines. This paper investigates several traffic models and highlights the impact of M2M traffic in logistics and transportation on LTE data traffic. We evaluate the overall LTE network performance in terms of E2E delays for file transfer, voice, and video users.

Keywords M2M · LTE · Traffic modeling · LTE data traffic

Y. Mehmood (✉) · T. Pötsch · S.N.K. Marwat · F. Ahmad · C. Görg
Communication Networks, TZI, University of Bremen, Bremen, Germany
e-mail: ym@comnets.uni-bremen.de

T. Pötsch
e-mail: thp@comnets.uni-bremen.de

S.N.K. Marwat
e-mail: safdar@comnets.uni-bremen.de

F. Ahmad
e-mail: farhan@comnets.uni-bremen.de

C. Görg
e-mail: cg@comnets.uni-bremen.de

I. Rashid
National University of Sciences and Technology (NUST), Islamabad, Pakistan
e-mail: irashid@mcs.edu.pk

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Introduction

Machine-to-machine (M2M) communication is a pattern which identifies the evolving paradigm of interconnected machine devices that communicate without or with minor human interaction. M2M communication is enabling a pervasive computing environment toward the "Internet of Things" vision. The recent market analysts predict more than 500 million M2M connections by 2014 (Cox 2010; TS 23.888 V11.0.0 2012; Cisco 2012). The M2M applications include logistics, smart metering, e-healthcare, surveillance and security, intelligent transportation, city automation, and smart monitoring (Exalted 2013). The features of M2M communication include a large number of M2M devices connected concurrently. Moreover, M2M machines usually transmit data of small size as compared to traditional human-type communication. M2M communication is mainly based on wireless sensors, cellular networks, and the Internet. Low cost and high coverage of cellular networks like Global System for Mobiles (GSM), Universal Mobile Telecommunications System (UMTS), and long-term evolution (LTE) are the key motivations for increasing the number of M2M devices worldwide. To cope with massive growth in M2M machines, the international standard bodies are developing new standards to support future M2M traffic. The third-generation partnership project (3GPP) has been considered the support for increasing number of M2M communication in LTE networks (Stasiak et al. 2010). In this paper, we investigate the performance of M2M traffic models in logistics using LTE model developed in OPNET Modeler.

M2M Communication in Logistics

Transportation and logistics are considered the major M2M communication users worldwide. Tracking and monitoring vehicle with M2M devices and actuators are the main application areas of M2M in transportation and logistics. The major application of automotive M2M communication is fleet management in logistics (3GPP TR 102.898 2013). M2M applications enable the tracking of vehicles and cargo containers to collect data about location, vehicle speed, temperature, distribution progress, fuel consumption to ensure efficient logistics management, and in time goods delivery. With information and control provided by M2M technology in the logistics, better resource management, operations, and cost efficiency are highly possible (3GPP TR 102.888 2013). M2M communication system consists of three fundamental components: The M2M domain, network domain, and application domain as shown in Fig. 1.

The M2M domain comprised smart machine sensors and actuators which are used to collect information (e.g., heartbeat, temperature, humidity, etc.). M2M gateways communicate between M2M device domain and communication networks. Information collected by sensors reaches to the application domain (M2M

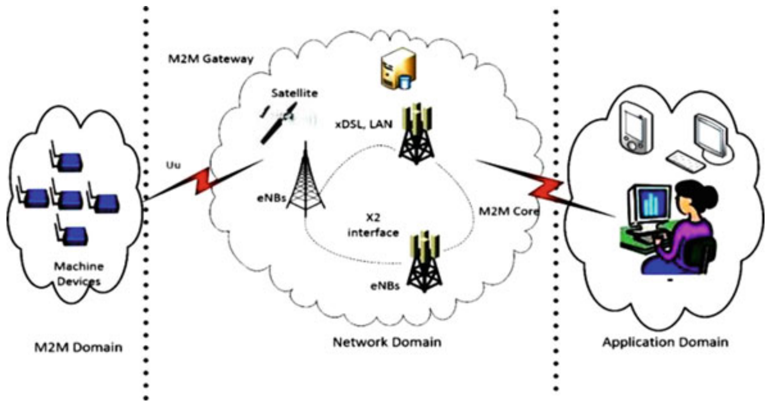

Fig. 1 High-level architecture for M2M communication system

management servers) through the network domain. The network domain comprises either wired or wireless networks. The reliability of the wireless networks has made this technology a vital concept in M2M applications for logistics and transport. The M2M communication addresses the following main issues in logistics:

Global Connectivity: the monitored cargo moves across various countries; hence, it is essential to be globally connected to network to stay updated.
Reporting: it is also important in logistics and is provided by the M2M technology through which the precise location of the freight, movements, and the conditions of the objects can be easily monitored.
Alarming: the third main emphasis of M2M technology is based on alarming. Several types of goods are temperature sensitive and the quality may be adversely affected in case of drastic variations in temperature and humidity.

It is essential to monitor the internal temperature of the container, carrying temperature-sensitive goods, using temperature sensors, so that in case of any adverse situation, measures could be taken to retain the desirable quality of the goods.

In response to the expected rapid growth in M2M devices in the near future, the cellular operators worldwide are expanding and updating the existing cellular networks with new introduced cellular technologies. The 3GPP continues to discover ways to enable operators with features for more capable, economic, and energy-efficient networks.

LTE standard is introduced by the 3GPP in its Release 8 document series, with minor enhancements described in Release 9 (ETSI TS 136.213 2008; Tran et al. 2012). It is a standard for wireless communication of high-speed data for mobile phones and data terminals. LTE networks are aimed to be installed worldwide. These new network installments (LTE, LTE-Advanced, Massive MIMO, etc.) will largely improve mobile communication as well as emerging M2M communication (Mehmood et al. 2013a, b). Table 1 describes the various standardization development

Table 1 Scope of M2M standard development organizations (SDO)

3GPP	Network improvements between M2M machines
ETSI	Functional and behavioral architecture for M2M networks
IEEE	Optimization of existing standards for M2M communication, i.e., IEEE 802.16p, IEEE 802.11ah
TIA	Telecommunication Industry Association new M2M standards, i.e., TR 50 TIA 4940.02 and TR 50 TIA 4940.000
OMA	Open Mobile Alliance (OMA) for M2M device management and personal network services

organizations for wireless communication to support human-based communication as well as M2M communications.

Long-Term Evolution Role in Logistics

LTE is a wireless communication standard developed by 3GPP with documentation in Release 8 and some modifications in Release 9 (ETSI TS136 213 2008; Tran et al. 2012). LTE brings complete IP network system with improved system capacity, increased uplink and downlink peak data rate, and scalable bandwidth (Holma and Toskala 2009). The peak data rates exceed 300 Mbps, delays below 10 ms, and noticeable spectrum efficiency gains over early 3G system releases. Further, LTE can be deployed in new and existing frequency bands, has a flat architecture, and facilitates simple operation and maintenance. While targeting a smooth evolution from legacy 3GPP and 3GPP2 systems, LTE includes many of the features originally considered for future fourth-generation system (Dahlman et al. 2008). The use of LTE, LTE-Advanced networks, is necessary, because besides the growth in M2M devices, it is also expected a rapid growth in mobile devices (Cisco 2012).

The basic LTE architecture comprises three components, i.e., user equipment (UE), the evolved UMTS terrestrial radio access network (E-UTRAN), and evolved packet core (EPC) as shown in Fig. 2. The EPC is connected to the external environment, i.e., Internet through packet data networks (PDNs) gateways. The E-UTRAN mainly consists of eNBs (base stations) that transmit and receive all the

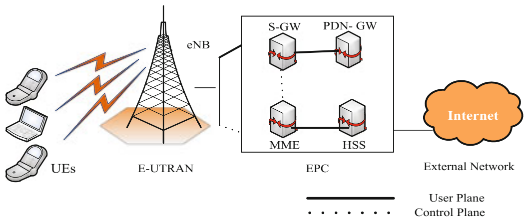

Fig. 2 High-level LTE architecture

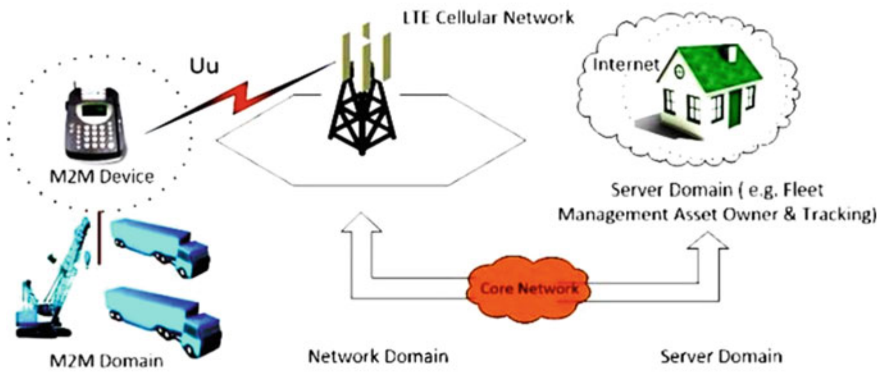

Fig. 3 LTE-based M2M communication for logistics

radio transmission from UEs to EPC using LTE air interface processing techniques. The eNBs also control the handling procedures within the same cell and also from one cell to another. Figure 3 depicts the high-level architecture of LTE-based M2M communication for logistics.

In logistics, the growths of M2M communication from the earliest M2M devices that tracked vehicle locations to today's sophisticated load sensors and driving behavior monitoring systems have made logistics one of the leading consumers of M2M devices. For instance, during transportation, if any unfavorable event occurs, the sensors can transmit information to the company's monitoring station through cellular network, and instructions can be sent to the vehicle for possible remedies.

There are more than 15 million containers at any particular time, which are monitored through M2M devices (Vodafone 2013). This number is still far below the expected future deployment (Paiva et al. 2011). This increasing M2M data traffic in logistics and other services might exceed the system capacity of current cellular systems. The data size in M2M is small, order of few bytes or kilo bytes, but a huge number of devices randomly accessing the network will influence the regular LTE traffic. Also, a larger number of M2M devices cannot be connected to these conventional cellular networks, which will downsize the future M2M market. Launching 3GPP's new standard LTE-advanced will greatly improve the M2M market and the quality of service (QoS) for the M2M customers.

Investigated M2M Traffic Models

The concept of traffic modeling is designing of stochastic processes so that they match the behavior of physical quantities of measured data traffics (Laner et al. 2013). The major differences between M2M communication and human-based communication are described as follows: In M2M communication, all machines behave similarly, while running the same application, i.e., M2M machines are

Table 2 M2M traffic models in logistics

Model	Average message size (bytes)	Message inter-transmission time (s)	Data rate (bits/s)
1	6000	60	800
2	128	60	17.07
3	1	60	0.134

homogenous. Moreover, the synchronization between M2M devices has made M2M traffic more coordinated while human-based traffic is uncoordinated (Laner et al. 2013). Therefore, some changes are required in conventional human-based traffic models for applicability in M2M communications. In most cases of M2M communication, a device transmits the measured data in periodical intervals to a remote end-point. Although those intervals range from several minutes to hours (Shafiq et al. 2012), the massive number of distributed M2M devices within a certain cellular network may create a considerable dense scenario. However, also other devices with network connectivity are present at the same time. In this paper, some of the M2M traffic models are investigated which are listed in Table 2.

Simulations Setup

The simulation model implementation is achieved using an LTE model in the OPNET simulation environment. We use OPNET Modeler as the primary modeling, simulation, and analysis tool in this work. The LTE model consists of several nodes with LTE functionalities and protocols implemented as shown in Fig. 4.

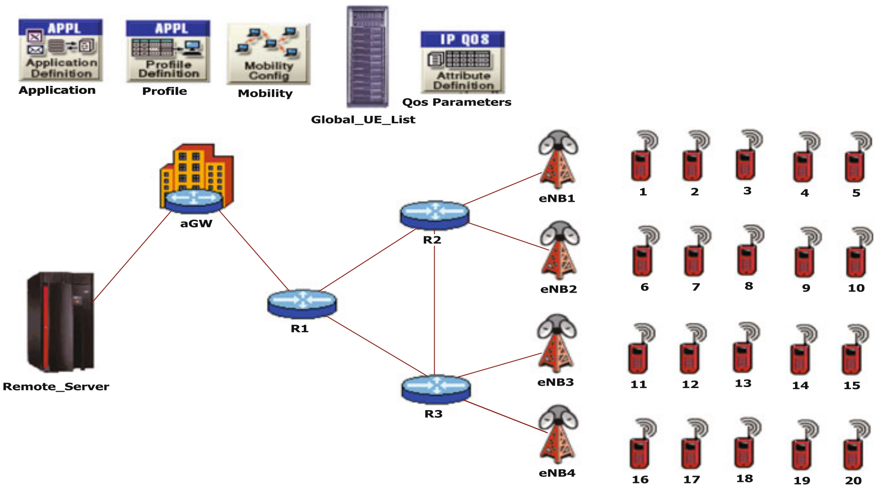

Fig. 4 OPNET project editor

The remote server supports various services like voice over internet protocol (VoIP), file transfer protocol (FTP), web browsing, etc. It also acts as a sink for the uplink data. The remote server and the access gateway (aGW in Fig. 4) nodes are interconnected with an ethernet link having an average delay of 20 ms. The access gateway node comprises peer-to-peer protocols such as user datagram protocol (UDP), internet protocol (IP), and ethernet; both toward the transport network (TN) and the remote server. The access gateway and eNB nodes (eNB1, eNB2, etc.) are connected through the TN of IP routers (R1 and R2 in Fig. 4), configured according to the standard OPNET differentiated service (diffserv) model and routing protocols. The QoS parameter node is responsible for the QoS parameterization and traffic differentiation at the TN. The mobility and channel models are implemented in the mobility node. The user movement in a cell is emulated by the mobility model by updating the user location at every sampling interval. The user mobility information is stored in the global user database (Global_UE_List in Fig. 4). This information is accessible from every node in the system at any given time. In the air interface, the channel models comprise path loss, slow fading, and fast fading models.

In this paper, the simulation modeling mainly focuses on the user plane, so as to be able to perform end-to-end (E2E) performance evaluations. The model was developed using the OPNET simulation environment (OPNET Modeler 2013). A comprehensive explanation of the LTE simulation model and details about the protocol stacks are in Zaki et al. (2011a, b). The OPNET simulations are performed for various traffic models proposed in (IEEE 802.16p 2010; Pötsch et al. 2013) under the parameter settings illustrated in Pötsch et al. (2013) and given in Table 3.

The M2M traffic models have been listed in Table 2. The LTE uplink scheduler proposed in Marwat et al. (2012) is used for uplink resource allocation in M2M communication. The various M2M traffic load performance scenarios are compared by analyzing the QoS performance of mobile devices with regular LTE uplink

Table 3 Simulation parameters

Parameter	Value
Simulation length	1000 s
eNB coverage radius	350 m
Min. eNB—UE distance	35 m
Max terminal power	23 dBm
Terminal velocity	120 km/h
Mobility model	Random way point (RWP)
Frequency reuse factor	1
Transmission bandwidth	5 MHz (for downlink and uplink each)
No. of PRBs	25 (for downlink and uplink each)

traffic. The LTE traffic for simulations includes voice, video, and file transfer as shown in Table 3. The regular LTE traffic load is kept constant and the M2M traffic load is varied in the scenarios for all the traffic models listed in Table 2. In all scenarios, the number of voice, video, and file transfer users is 10 each. In the first scenario, 300 devices are deployed in the cell. The number of devices reaches 450 in second scenario and 600 in the third scenario. For each traffic model, the velocity of mobile devices is kept constant, i.e., 120 km/h for all scenarios.

Results and Analysis

In the simulations, we illustrate the performance of various traffic models investigated by analyzing the impact of these models on the network performance in terms of QoS and throughput. 10 FTP users, 10 VoIP users, and 10 video users are deployed in all the scenarios. However, the number of trailers, facilitating M2M devices, is varied in the scenarios to evaluate the network performance. A number of trailers in the scenarios are 300, 450, and 600. The impact of varying M2M traffic load in the scenarios on LTE services is illustrated with parameter such as the file upload time, voice, and video packet E2E delay.

Figure 5 depicts the performance of FTP traffic in terms of file average upload time. The results in all the models clearly reflect the considerable amount of delay in file transfer users. By increasing the number of M2M traffic, i.e., from 300 to 450 and then to 600, the average upload time for FTP users increases. Figures 6 and 7 depict the performance of voice and video users in terms of voice packet E2E delay. All the three models show no major impact of M2M devices on LTE voice and video traffic (Table 4).

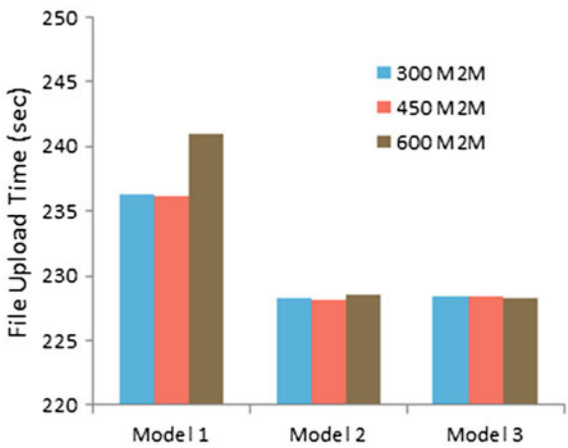

Fig. 5 Files upload time for model 1, model 2, and model 3

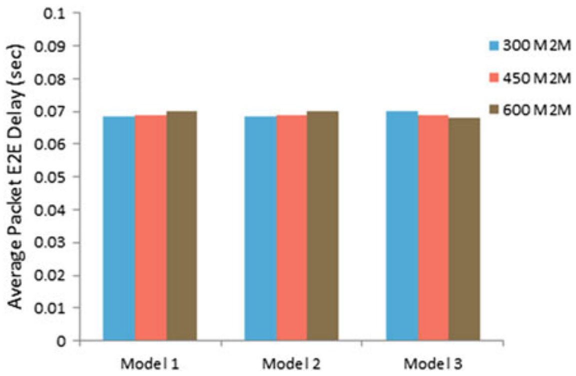

Fig. 6 Voice average packet end-to-end delay for model 1, model 2, and model 3

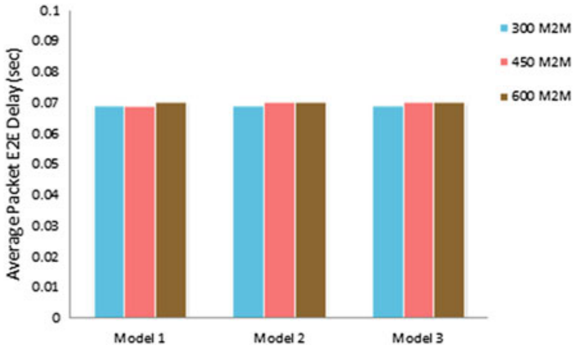

Fig. 7 Video average packet end-to-end delay for model 1, model 2, and model 3

Table 4 LTE traffic models

Parameter	Setting
VoIP traffic Model	
Silence length	Exponential distribution, 3 s mean
Talk spurt length	Exponential distribution, 3 s mean
Encoder scheme	GSM EFR (enhanced full rate)
FTP traffic model	
File size	20 Mbyte
File inter-request time	Uniform distribution (80–100 s)
Video traffic model	
Frame size	100 Kbyte
Frame inter-arrival time	75 ms
VoIP traffic Model	
Silence length	Exponential distribution, 3 s mean

Conclusion and Future Outlook

In this paper, we investigated several M2M traffic models for logistics. Moreover, we evaluate performance of these models and their impact on LTE regular traffic. The FTP users suffer large delay in file upload time due to low priority as compared to M2M devices. While voice and video users show no major influence because of M2M traffic, the priority of voice and video users is more than the M2M devices.

In future work, we have planned to introduce the aggregated traffic modeling approach in our LTE-advanced model using OPNET modeler in order to improve the network performance. Relay node is one of the significant features of LTE-advanced that can be best utilized as an intermediate terminal between M2M devices and eNB for data aggregation.

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References

Cisco Knowledge Network (2012) Cisco visual networking index: global mobile data traffic forecast update, 2011–2016

Cox A (2010) M2M—rise of the machines. Juniper Research, Hampshire

Dahlman E, Parkvall S, Sköld J, Beming P (2008) 3G evolution: HSPA and LTE for mobile broadband, 2nd edn. Academic Press, Waltham

Exalted (2013) http://www.ict-exalted.eu/fileadmin/documents/EXALTED_WP2_D2.1.pdf. Accessed 20 Sept 2013

Holma H, Toskala A (2009) LTE for UMTS—OFDMA and SC-FDMA based radio access, Illustrated edition. Wiley, Chichester

IEEE 802.16p-11/0014 (2010) Machine to machine (M2M), evaluation methodology document (EMD)

Laner M, Svoboda P, Nikaein N, Rupp M (2013) Traffic models for machine type communications. In: Tenth international symposium on wireless communication systems (ISWCS 2013), Ilmenau, Germany, pp 1–5

Marwat SNK, Weerawardane T, Zaki Y, Goerg C, Timm-Giel A (2012) Performance evaluation of bandwidth and QoS aware LTE uplink scheduler. In: 10th international conference on wired/wireless internet communications, Santorini, Greece, pp 298–306

Mehmood Y, Afzal W, Ahmad F, Younas U, Rashid I, Mehmood I (2013a) Large scaled multi-user MIMO system so called massive MIMO systems for future wireless communication networks. In: IEEE 19th international conference on automation and computing, pp 1–4

Mehmood Y, Haider N, Afzal W, Younas U, Rashid I, Imran M (2013b) Impact of massive MIMO systems on future M2M communication. In: IEEE 11th Malaysia international conference on communication (MICC), Kuala Lumpur, Malaysia (In Press)

OPNET Modeler (2013) http://www.opnet.com. Accessed 15 May 2013

Paiva RCD, Vieira RD, Saily M (2011) Random access capacity evaluation with synchronized MTC users over wireless networks. In: IEEE 73rd vehicular technology conference, Yokohama, Japan, pp 1–5

Pötsch T, Marwat SNK, Zaki Y, Goerg C (2013) Influence of future M2M communication on the LTE system. In: Wireless and mobile networking conference, Dubai, UAE

Shafiq MZ, Ji L, Liu AX, Pang J, Wang J (2012) A first look at cellular machine-to-machine traffic: large scale measurement and characterization. ACM SIGMETRICS Perform Eval Rev 40(1):65–76

Stasiak M, Glabowski M, Wisniewski A, Zwierzykowski P (2010) Modelling and dimensioning of mobile wireless networks: from GSM to LTE. Wiley, Hoboken

Technical Report 102.898 V1.1.1 ETSI (2013) Machine to machine communications (M2M); use cases of automotive applications in M2M capable networks. http://www.etsi.org/deliver/etsi_tr/102800_102899/102898/01.01.01_60/tr_102898v010101p.pdf. Accessed 20 Sept 2013

Technical Specification 136 213 V8.4.0 ETSI (2008) LTE, Evolved Universal Terrestrial Radio (E-UTRA), Physical layer procedures. http://www.etsi.org/deliver/etsi_ts/136200_136299/136213/08.04.00_60/ts_136213v080400p.pdf. Accessed 20 June 2013

Technical Specification 23.888 V11.0.0 3GPP (2012) System improvements for machine-type communications. http://www.qtc.jp/3GPP/Specs/23888-b00.pdf. Accessed 11 June 2013

Tran T-T, Shin Y, Shin O-S (2012) Overview of enabling technologies for 3GPP LTE-advanced. EURASIP J Wirel Commun Networking 1:1–12

Vodafone (2013) Vodafone machine-to-machine transport and logistics. http://m2m.vodafone.com/discover-m2m/industries/transport-and-logistics/. Accessed 10 Sept 2013

Zaki Y, Weerawardane T, Goerg C, Timm-Giel A (2011a) Long term evolution (LTE) model development within OPNET simulation environment. OPNET Workshop, Washington, D.C., USA, 12–14 Nov 2011

Zaki Y, Weerawardane T, Goerg C, Timm-Giel A (2011b) Optimized service aware LTE MAC scheduler: design, implementation. OPNET Workshop, Washington, D.C., USA

Dynamic Temperature Control in the Distribution of Perishable Food

Antonio G.N. Novaes, Orlando F. Lima Jr, Carolina C. Carvalho and Edson T. Bez

Abstract The temperature of chilled and frozen products along the distribution phase must be maintained within close limits to ensure optimum food safety levels. The temperature variation along the vehicle routing sequence is represented by nonlinear functions which depend on the process stage (line haul, unloading at customer's premises, local displacements, etc.). The usual vehicle routing optimization strategy is generally based on a traveling salesman problem (TSP) sequence, with the objective of minimizing travel distance or time. It is shown in the paper that in order to maintain the temperature variability within adequate restriction limits, other routing strategies, apart from the TSP criterion, should be considered.

Keywords Cold chain · Perishable cargo · TTI · PCI · Vehicle routing

Introduction

Lifestyle changes over the past decades led to increasing consumption of refrigerated and frozen foods, which are easier and quicker to prepare than the traditional types of food. In order to ensure product quality and health safety, the control of temperature throughout the cold chain is necessary. In fact, in addition to temperature, a number of factors affect the maintenance of quality and the incidence of

A.G.N. Novaes (✉)
Federal University of S.Catarina, Florianópolis, Santa Catarina, Brazil
e-mail: antonio.novaes@ufsc.br

O.F. Lima Jr · C.C. Carvalho
UNICAMP, University of Campinas, Campinas, São Paulo, Brazil
e-mail: oflimaj.fec@gmail.com

E.T. Bez
Univali – Itajaí Valley University, São José, Santa Catarina, Brazil
e-mail: edsonbez@gmail.com

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losses in fresh food products, but since temperature largely determines the rate of microbial activity, which is the main cause of spoilage of most fresh food products, continuous monitoring of the full-time temperature history usually allows for an adequate control of the process along the short- and medium-distance distribution segments (Giannakourou and Taoukis 2003). The quality of these products may change rapidly because they are submitted to a variety of risks during transport that are responsible for material quality losses. In practical terms, the maintenance of an optimal temperature throughout the postproduction handling chain is one of the most difficult tasks. In short- or medium-distance delivery runs, the chilled or frozen product can be subjected to many door openings, where there is heat ingress directly from outside air and from personnel entering to select and remove product (James et al. 2006; Pereira et al. 2010). Frequent door openings can also lead to increased evaporator frosting, resulting in a reduction of the evaporator's performance and an increase in the need for defrosts, particularly in humid weather conditions (Estrada-Flores and Eddy 2006). Additionally, the design of the vehicle refrigeration system has to allow for extensive variation in load distribution, which is a function of different delivery rounds, days of the week, and the removal of product during a delivery run. As a result, there are substantial difficulties in maintaining the temperature of refrigerated products transported in small- and medium-size refrigerated vehicles that perform multidrop deliveries to retail stores and caterers (James et al. 2006).

This paper reports a time–temperature indicator (TTI) analysis of a distribution of refrigerated products along a route containing a number of retail outlets with different demand levels. TTIs are tools used to monitor the time/temperature impacts on product quality, offering a cost-effective way to detect problematic points in the chill chain. TTI can furnish time- and temperature-dependent changes that cumulatively indicate the thermal history of the product from the point of origin to its destination (Giannakourou et al. 2005; Estrada-Flores and Eddy 2006; Sahin et al. 2007; Simpson et al. 2012; Novaes et al. 2013). Process capability indices (PCI), on the other hand, are additionally calculated to yield easily computed coefficients with dimensionless functions on TTI parameters and specifications (Chang and Bai 2001; Chang et al. 2002; Gonçalez and Werner 2009). This kind of TTI application helps to reveal undesired thermal conditions that may impair the compliance of product quality requirements along the supply chain.

The paper analyses alternative vehicle routing strategies intended to minimize travel cost, but at same time keeping thermal PCI performance indicators within the required levels. It is shown that the standard traveling salesman problem (TSP) approach, used to solve classical routing problems where vehicle travel distance or time is minimized, may lead to temperature restriction violations. Thus, instead of using a standard heuristic to get the optimized TSP vehicle routing sequence, such as the largely employed 2-opt and 3-opt improvement routines (Syslo et al. 2006), other routing strategies, apart from the TSP criterion, are considered. In addition, fault occurrences along the distribution process as, for example, exceptional delays in discharging the product at specific retailer premises, will trigger dynamic corrective measures intended to maintain temperature within the prescribed levels.

Thermal Characteristics of Refrigerated Transport

Road transport refrigeration equipment is required to operate reliably in much harsher environments than stationary refrigeration equipment. Due to the wide range of operating conditions and constraints imposed by variable cargo space and weight, transport refrigeration equipment has lower efficiency levels than stationary systems. The thermal performance of refrigerated vehicles is also dependent of age, since insulation materials deteriorates with time due to the inherent foam characteristics. Recent data show a typical loss of insulation value of between 3 and 5 % per year which can lead to considerable rise in the thermal conductivity after a few years (Tassou et al. 2009, 2012). The effects of door openings are another important concern in refrigerated cargo transport (Estrada-Flores and Eddy 2006; Pereira et al. 2010).

Generally, models that address the prediction of heat and mass transfer during transport can be divided into those that consider the environment within the transport unit (usually in regard to airflow), and those that concentrate only on the temperature of the product (James et al. 2006), which is the case of this work.

Time–Temperature Indicators (TTI) Associated with Route Simulation

TTIs are defined as specific measures that can show time- and temperature-dependent changes that cumulatively indicate the thermal history of the product from the point of origin to its destination (Estrada-Flores and Eddy 2006; Sahin et al. 2007). A number of papers on refrigerated food transport address the TTI evaluation along the cold chain process (James and Scholfield 1998; Giannakourou et al. 2005; Estrada-Flores and Eddy 2006). In order to gather TTI data, field tests and/or laboratory measurements are frequently performed. Such procedures are costly and take time. One alternative is to rely on computer simulation based on previous research endeavors, as the CoolVan research program developed to predict the temperature of refrigerated food during multi-drop deliveries. CoolVan is a simulation software developed by the Food Refrigeration and Process Engineering Research Center at the University of Bristol, UK. The brief description set forth was extracted from two works (Gigiel et al. 1998; CoolVan Manual 2000).

The objective of CoolVan is to aid the design and operation of small- and medium-delivery vehicles intended to distribute refrigerated food products (Gigiel et al. 1998; James and Scholfield 1998; James et al. 2006; CoolVan Manual 2000). The software contains a mathematical model that predicts food temperatures inside a refrigerated vehicle, analyzing the temperature changes that take place during a delivery journey, as well as the energy used by the refrigeration equipment. The model is solved using an implicit finite difference method. The heart of the CoolVan program is the temperature inside the vehicle. The internal air exchanges heat with the outside environment by the movement of air into and out of the truck, while the doors are either opened or closed. Inside the van the racking, fittings, trays, and food exchange heat with the van air. Evaporator coils or eutectic plates cool the inside air to maintain its temperature. The usual food distribution scheme starts with the vehicle being loaded at the distributor's premises and traveling to a series of retail outlets, where the individual lots are discharged in sequence. The program puts the results into an output file that can be saved. Vehicle data are fed into the CoolVan program: the thermal properties of the insulation system, the year of the van manufacture, the aging rate which depends on the vehicle maintenance characteristics, etc. Data were measured empirically in several vans, allowing for the fitting of appropriate equations and parameters into the model.

Thermal Performance Evaluation with Process Capability Indices

A PCI is a numerical element that compares the characteristics of a production or servicing process to engineering specifications (Chang and Bai 2001; Chang et al. 2002; Czarski 2008). A value of such an index equal or larger than a pre-established level indicates that the current process is capable of producing results that, in all likelihood, we will meet or exceed the predefined requirements. A capability index of this sort is convenient because it reduces complex information about the quality of the process to a single number. Thus, PCI can be defined as measurements of the ability of the production and servicing processes to meet the specifications. In our application, the analysis of the temperature variability inside a refrigerated vehicle is performed by means of PCI estimation applied to TTI values, showing the temperature distribution on the data collected along a typical distribution journey.

Usually, capability indices are employed to relate the process parameters to engineering specifications that may include unilateral or bilateral tolerances, with or without a target value (nominal value). In this application, the monitored variable is the temperature θ inside the vehicle along a typical distribution journey of refrigerated food products, with mean μ and standard deviation σ. In this case, there are two-sided specification limits for θ, respectively the upper value USL and the lower value LSL. Clearly, the aim of process control is to make C_p as large as possible. When the TTI distribution of θ is not normal (Czarski 2008), the standard PCI coefficient is C_{pk} defined as (Chang et al. 2002)

$$C_{pk} = \min\left\{\frac{\text{USL} - \mu}{3\sigma}, \frac{\mu - \text{LSL}}{3\sigma}\right\}. \tag{1}$$

If $C_{pk} > 1$ it indicates that the temperature variation fits within the specified temperature limits. As a rule of thumb, a $C_{pk} = 1.33$ or higher is indicative of a capable process with a safety margin. Gonçalez and Werner (2009) compared a number of approximate methods to evaluate non-normal situations and suggested that the method of Chang and Bai (2001) reflects with accuracy the number of non-conforming items in the evaluated sample, being superior to the other analyzed methods. Such method adjusts the values of PCIs in accordance to the degree of skewness of the underlying population by using specific factors in computing the deviations above and below the variable mean. The method, employed in this application, is based on the idea that σ can be divided into upper and lower deviations, σ_U and σ_L, which represent the dispersions of the upper and lower sides around the mean μ, respectively (Chang and Bai 2001; Estrada-Flores and Eddy 2006; Novaes et al. 2013).

The Static Approach

The objective of this research is to analyze a regional distribution of ready-to-eat refrigerated meat products (ham, turkey and chicken breasts, salami, sausage). The urban distribution district is located 84 km from the base depot. The served urban district has an approximated area of 73 km^2, where are located 12 retail shops and supermarkets to be attended, as shown in Fig. 1. Traditionally, the optimal sequence of points to be visited is the one obtained with a TSP algorithm, which yields the shortest Hamiltonian cycle that includes, in this application, all the retail outlets, plus the depot. Figure 1a depicts the TSP route, obtained with a 3-opt local search heuristic (Syslo et al. 2006), with a total extension of 204.1 km. The search for an optimal vehicle routing sequence requires quite a number of combinatory evaluations. On the other hand, the process for obtaining accurate TTI data is not a simple

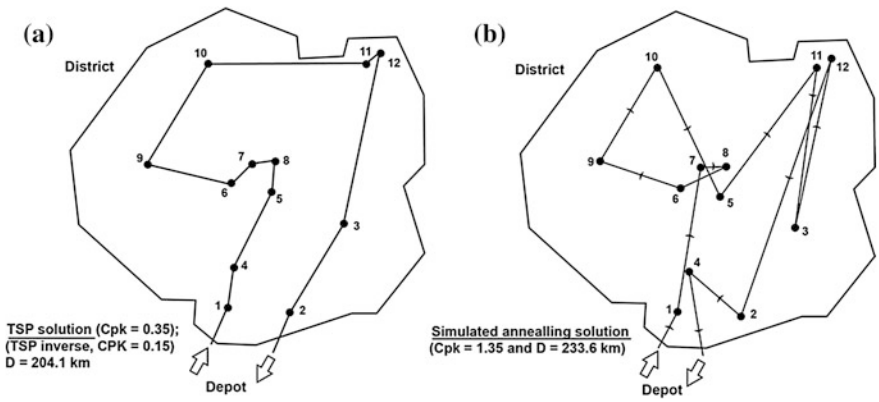

Fig. 1 Two alternative delivery routes

task, since it requires special laboratory settings (Moureh and Derens 2000; Tso et al. 2002; Estrada-Flores and Eddy 2006; Garcia 2008) and/or elaborate field tests (Pereira et al. 2010; Simpson et al. 2012). One possibility is to apply the simulation approach, such as the CoolVan software, in order to gather basic TTI data to be used in a computer-aided routing analysis.

In this application a hybrid approach was devised. It involves a combination of methods divided into three steps. First, the CoolVan software was used to simulate the thermal characteristics of the basic routing scheme represented by the TSP formulation as shown in Fig. 1a. Next, taking the CoolVan simulation results, the operating stages that compose the temperature evolution along the distribution journey is analyzed individually in order to define mathematical functions that relate temperature to the explaining variables. Third, a computer program was developed to estimate temperature levels step by step along the route, considering different delivering sequences and forming TTI sets. PCI coefficients are then computed in order to analyze the thermal performance of the different delivery sequences, leading to the optimal solution that minimizes traveled distance, but at the same time maintaining temperature levels within predefined limits.

A total of 12,000 kg of assorted refrigerated meat products are distributed in one daily round, with two retailers receiving larger quantities (7000 and 2000 kg respectively), while the other ten clients get 300 kg each. The average discharging times are 9.8, 23.3, and 62.7 min for clients receiving 300, 2000, and 7000 kg of refrigerated cargo per visit. The vehicle is a 143 HP, diesel-powered Volkswagen model 8150, with an internal compartment of 25.3 m^3. The simulation starts with the line-haul phase, which goes from the depot to the first client in the district, and takes 84.3 min. The distribution process is composed of four stage types: (1) line-haul segments linking the depot to the first client and, inversely, connecting the last visit to the depot; (2) delivering stages when the vehicle crew discharges the product, with the engine turned off and the doors opened; (3) local travel, with the vehicle going from one client to the next; and (4) occasional insertion of corrective refrigeration stops, with the vehicle parked, the doors closed and the refrigeration unit turned on (see section "Inserting Corrective Refrigerating Stops"). The temperature variation inside the vehicle can be expressed as (Hoang et al. 2012)

$$\theta(\tau) = \theta_0 \exp\left[\beta \frac{H\tau}{mC}\right], \tag{2}$$

where $\theta(\tau)$ is the air temperature (°C) inside the vehicle at time τ, θ_0 is the initial temperature, m is the total mass of the product contained in the vehicle, H is the heat transfer conductance (W K^{-1}), C is the thermal capacity (J kg^{-1} K^{-1}), and β is a coefficient. In the application, m is expressed as a fraction of the total load carried by the vehicle. The value of β depends on the process stage, being negative for stages (1), (3), and (4), and positive for stage (2). Equation (2) shows that the

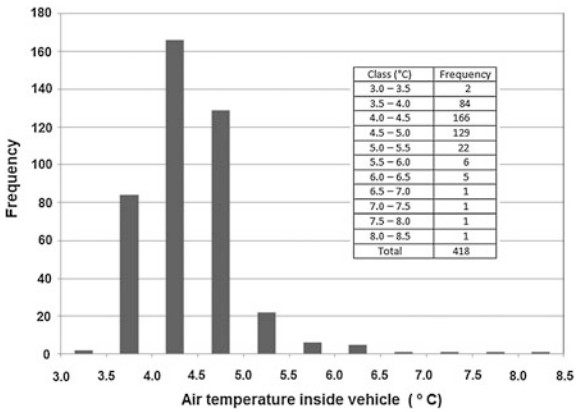

Fig. 2 Histogram of TTI data along a typical delivery journey

temperature does not vary linearly with time. In addition, the CoolVan simulator also considers the influence of the external temperature in the vehicle thermal process, which is more relevant in the discharging stage because of door openings. Departing from the CoolVan simulation results and adjusting the β coefficient values for each stage with regression analysis, different delivering sequences are analyzed to generate TTI series, to which the corresponding PCI values are computed.

Applying the PCI evaluation method to the TSP route depicted in Fig. 1a, it resulted a total traveled distance $D = 204.1$ km, with an unsatisfactory $C_{pk} = 0.35$. A simulated annealing procedure was developed to get the shortest route, but respecting the restriction $C_{pk} \geq 1.33$. The resulting optimal route is 1–7–8–6–9–10–5–11–3–12–2–4, as shown in Fig. 1b, with a total travel distance $D = 223.6$ km and $C_{pk} = 1.35$, showing a 9.5 % increase in the traveled distance as compared to the TSP solution, but keeping the temperature variation within the required range. Figure 2 shows the histogram of the 418 TTI values generated by the simulation of the optimal solution. The probability distribution is skewed to the right, justifying the use of the C_{pk} coefficient.

It has been observed that the C_{pk} values are very sensitive with time, mainly the discharging times at retailer's premises. The first conclusion, still in the static decision framework, is that the discharging times should be reduced substantially, with extensive field personnel training, and the need to perform campaigns directed to retailers, who sometimes are responsible for unexpected delays in the process.

The Dynamic Approach

In order to avoid drawbacks in product quality control, three dynamic fault detection and countermeasure actions are analyzed forth.

Reprogramming Visits

Let us take the optimal visiting sequence of Fig. 1b. Suppose that cargo discharge in outlet 8 has shown a 10 min delay. Running the TTI program again, it produced $C_{pk} = 1.10$, which is not satisfactory. When this delay happens, clients 1, 7, and 8 have already been visited. Keeping unaltered these visits, the program applies the simulated annealing routine again to re-organize the remaining nine visits. The resulting optimum forward sequence is 9–3–2–10–11–4–12–5–6, with $C_{pk} = 1.33$ and $D = 239.3$ km. Although the reprogramming of deliveries might not generate a satisfactory scheme sometimes, this dynamic countermeasure should always be analyzed by the monitoring system, since it is a lower cost option.

Inserting Corrective Refrigerating Stops

Vehicle door openings, even with protection such as air or plastic strip curtains, show expressive temperature raises during refrigerated cargo deliveries. When an expressive delay is observed in a delivering visit, it may be convenient to keep the vehicle standing along the curb with the doors closed and the refrigeration equipment turned on. Let us reconsider the optimal visiting sequence of Fig. 1b with an unexpected discharging delay of 10 min at retailer #8. For this situation one has an unsatisfactory $C_{pk} = 1.10$ value. Stopping the vehicle for 5 min just after this delivery, with doors closed and the refrigeration running, the TTI program estimated $C_{pk} = 1.56$, a quite satisfactory level. Depending on the necessary stopping time to improve the C_{pk} value, the planned delivery chronogram to the remaining outlets may turn problematic and therefore, the impacts of this action upon the service level and costs must be evaluated accordingly.

Seeking External Help

Novaes et al. (2012) analyzed a dynamic OEM pickingup (milk-run) routing problem in which tasks that will exceed the time limit in a route are assigned to supplementary vehicles, thus forming auxiliary dynamic routes. The results have shown that this dynamic formulation considerably improves the service level when compared with the static version. In the case of delivering refrigerated food, however, the eventual transference of cargo to other vehicle is more complex because it requires a rendezvous of both vehicles in an established point and time along the journey, with the physical transference of the product between the two trucks. One alternative is not to deliver the cargo with unsatisfactory C_{pk} levels, but take them back to the depot, and charge the responsible retailer for the corresponding product loss and additional operating costs.

Conclusions and Research Prospects

In this paper, we described a dynamic model for the real-time management of a vehicle performing a sequence of delivery visits of refrigerated food. It is shown that, in order to maintain the temperature variability within predefined restriction limits, other routing strategies, apart from the TSP criterion, should be considered. Since the vehicle routing time is composed by quite a number of independent random variables with expressive variances, and since the resulting TTI elements are nonlinear functions of time (section "The Static Approach"), the C_{pk} evaluation factors are very sensitive to differences between the planned and the actual routing chronograms. Because of that, we performed sensibility analyses to define previous countermeasures in order to avoid product losses and delivery postponements. A new project already in course in our research group is intended to setup a dynamic control system to evaluate the routing sequence step by step, indicating which countermeasures should be taken in advance as to improve service level and reduce costs and product losses.

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References

Chang YS, Bai DS (2001) Control charts for positively-skewed populations with weighted standard deviations. Qual Reliab Eng Int 17:397–406

Chang YS, Choi IS, Bai DS (2002) Process capability indices for skewed populations. Qual Reliab Eng Int 18:383–393

CoolVan Manual (2000) Food refrigeration and process engineering research centre, version 3.0. University of Bristol, UK

Czarski A (2008) Estimation of process capability indices in case of distribution unlike the normal one. Arch Mater Sci Eng 34(1):39–42

Estrada-Flores S, Eddy A (2006) Thermal performance indicators for refrigerated road vehicles. Int J Refrig 29:889–898

Garcia LR (2008) Development of monitoring applications for refrigerated perishable goods transportation. PhD thesis, Universidad Politécnica de Madrid

Giannakourou MC, Taoukis PS (2003) Application of a TTI-based distribution management system for quality optimization of frozen vegetables at the consumer end. J Food Sci 68 (1):201–209

Giannakourou MC, Koutsoumanis K, Nychas GJ, Taoukis PS (2005) Field evaluation of the application of time temperature integrators for monitoring fish quality in the chill chain. Int J Food Microbiol 102:323–336

Gigiel AJ, James SJ, Evans JA (1998) Controlling temperature during distribution and retail. In: Proceedings of 3rd Karlsruhe nutrition symposium. Karlsruhe, Germany, pp 284–292

Gonçalez PU, Werner L (2009) Comparison of process capability indices for non-normal distribution. Gestão e Produção 16:121–132 (in Portuguese)

Hoang MH, Flick D, Derens E, Alvarez G, Laguerre O (2012) Combined deterministic and stochastic approaches for modelling the evolution of food products along the cold chain. Part II: a case study. Int J Refrig 35:915–926

James SJ, Scholfield I (1998) Modelling of food refrigeration systems. In: Proceedings of 3rd Karlsruhe Nutrition Symposium. Karlsruhe, Germany, pp 293–301

James SJ, James C, Evans JA (2006) Modelling of food transportation systems—a review. Int J Refrig 29:947–957

Moureth J, Derens E (2000) Numerical modelling of the temperature increase in frozen food packaged in pallets. Int J Refrig 23:540–552

Novaes AG, Bez ET, Burin PJ, Souza JC (2012) Dynamic vehicle routing under abnormal

Novaes AG, Lima Jr OF, Carvalho CC, Takebayashi F (2013) Process capability indices to evaluate thermal performance of refrigerated vehicles. In: Proceedings 22nd international conference on production research. Iguassu Falls, Brazil, 28th July–1st August 2013

Pereira VF, Dória EC, Carvalho BC Jr, Neves LC Jr, Silveira V Jr (2010) Evaluation of temperatures in a refrigerated container for chilled and frozen food transport. Ciência e Tecnologia de Alimentos, Campinas 30(1):158–165 (in Portuguese)

Sahin E, Babaï MZ, Dallery Y, Vaillant R (2007) Ensuring supply chain safety through time temperature integrators. Int J Logistics Manag 18(1):102–124

Simpson R, Almonacid S, Nuñez H, Pinto M, Abakarov A, Teixeira A (2012) Time-temperature indicator to monitor cold chain distribution of fresh salmon (salmo salar). J Food Process Eng 35(5):742–750

Syslo MM, Deo N, Kowalik JS (2006) Discrete optimization algorithms with Pascal programs. Dover, Mineola, NY

Tassou SA, De-Lille G, Ge YT (2009) Food transport refrigeration—approaches to reduce energy consumption and environmental impacts of road transport. Appl Therm Eng 29:1467–1477

Tassou SA, De-Lille G, Lewis J (2012) Food transport refrigeration. Centre for Energy and Built Environment Research, Brunel University, UK

Traffic Conditions in Congested Urban Areas. PANAM 2012 Conference, The Pan American Society of Transportation Research, Santiago, Chile, September 2012

Tso CP, Yu SC, Poh HJ, Jolly PG (2002) Experimental study of the heat and mass transfer characteristics in a refrigerated truck. Int J Refrig 25:340–350

RFID-Enabled Real-Time Dynamic Operations and Material Flow Control in Lean Manufacturing

Muawia Ramadan, Mohammed Alnahhal and Bernd Noche

Abstract Over the past decade, due to its superior characteristics over other data capturing systems, the trend toward implementing radio frequency identification (RFID) technology in real-time production is increasing. However, RFID adoption is still not mature enough to cover today's production environments' aspects and needs. This research addresses the significant role of RFID in smart lean manufacturing sustainability and lean digital factories. This paper focuses on expanding the utilization of RFID system beyond tracking to include intelligent real-time control of production operations from the value stream point of view. Therefore a real-time RFID-based dynamic value stream mapping (DVSM) is developed to overcome the limitations of snapshot VSM in order to live monitor the dynamic behavior of production shop-floor (PSF). DVSM is used as a real-time computer-based lean tool that contains different real-time operations control modules, and if-analysis functions to sustain LM practices and to achieve lean aims. An example of the real-time module which runs through DVSM to support LM aims is developed. It is called real-time dispatching priority generator (RT-DPG) module. RT-DPG contains different material flow control rules to live prioritize the material flow in unpredictable dynamic production environments, and thereby real-time jobs dispatching priorities will be more practical and precisely generated to match load-leveling schedule which is based on "Takt-time" and enhance production smoothing to reduce the total cycle time.

Keywords Radio frequency identification · Lean manufacturing · Dynamic value stream mapping · Dispatching rules · Production shop-floor

M. Ramadan (✉) · M. Alnahhal · B. Noche
Transport Systems and Logistics Engineering Institute, Mechanical Engineering Department, Duisburg-Essen University, 47058 Duisburg, Germany
e-mail: muawia.ramadan@uni-due.de

M. Alnahhal
e-mail: mohammed.alnahhal@uni-due.de

B. Noche
e-mail: bernd.noche@uni-due.de

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Introduction

The increasing product customization in global markets is creating more job shop environments in the manufacturing world (Velaga 2012; Zhong et al. 2013). In any job shop, the high customized products pass through a sequence of workstations as specified in their routing and they may wait for the required resources at those workstations. The total waiting time of the products in the entire value stream usually constitutes a major part of production lead time which plays a critical role in the leanness level (Velaga 2012). Within LM context, comparing this undesirable time to value added or processing time gives a shock, particularly for job shops with high-mix and low-volume production (Rother and Shook 2003).

In this regard, poor visibility of the current PSF status and frequent disturbances during production (e.g. machine breakdown, unexpected defective parts) make it difficult to accurately predict job progress. These disturbances cause additional wastes such as customer orders delays, logistics errors, and high level of work-in-progress (WIP) inventories which hinder the manufacturers to achieve lean goals. Furthermore, many experts in LM implementation agree that a common reason for lean failure lies in the tendency to apply the wrong solution based on old status to the current problems (Pavnaskar et al. 2003) which refers to a serious time-gap between the physical activities on PSF and the associated information flow, that is caused also due to snapshot VSM and the poor real-time visibility (Zhong et al. 2013). To overcome these challenges, radio frequency identification (RFID) has been proposed to support automatic/smart real-time data capturing, aiming to fill the time-gap between the material flow and operations progress on PSF, and the associated information flow (Günther et al. 2008; Chongwatpol and Sharda 2012; Baudin and Rao 2005; Blanchard 2009). Here, RFID replaces barcode and other paper-based data capturing systems to eliminate the associated human errors and the scanning time.

Focusing on the value stream aspects, this paper discusses how LM goals (e.g. minimum WIP level, zero lead time to customer, no late orders, full utilization, zero defect, etc.) (Hopp and Spearman 2008) can be achieved through DVSM-based RFID which increases the PSF real-time visibility and supply the decision makers with full, accurate, and real-time information about the actual status. Furthermore, this paper describes through one example module (i.e. RT-DPG) how DVSM could be utilized not just as a tracking tool but as a real-time decision-making tool where several real-time control modules can be constructed to generate real-time decisions. The RT-DPG module is developed to set the optimal dispatching rule [e.g. first in-first out (FIFO)] during normal status or to generate an optimal dispatching sequence during disruptions to prioritize the waiting WIPs at the preceding supermarket or a queue, and will be processed at the next workstation. This will enhance the real-time Kanban control to meet load-leveling schedule, and thereby meet customers demand. The working logic of the module depends on checking actual PSF status, and accordingly generates the optimal dispatching sequence based on the constructed control rules. In this way, the impacts of the disturbances and their consequences can be avoided in advance. Through using RT-DPG, it is expected to reduce the WIPs inventory level along the value stream and eliminate the resulting wastes, where the manufacturing lead time will be significantly reduced and the resources will be optimally utilized.

Literature Review

Dispatching rules play a critical role in reducing the total lead time and meeting the production planning and scheduling (Zhong et al. 2012). The importance of dispatching priorities lies in decreasing the line variability, reducing the jobs waiting time before workstations, increasing the utilization of resources, and improving the production smoothness (Bohnen et al. 2013). But in reality, due to the continuous changes in production; no specific dispatching rule works well all the time (Hopp and Spearman 2008).

Typically, the scheduling in LM uses the load-leveling box based on "Takt time" to support the working of Kanban and to enhance the "one piece flow" to achieve "a smoothed production" and to meet the customers demand. However, load-leveling schedule practice becomes difficult to be meet in today's high dynamic and customized production environment, because it is not relevant to such production environments that simultaneously produce high-mix and low-volume orders with different due dates, priorities, routings, process times, and resource and material requirements (Velaga 2012). One of the major difficulties in managing such environment's operations may be a lack of accurate and comprehensive, time-sensitive data and information (Chongwatpol and Sharda 2012).

Over the past decade, RFID technology has gained significant interests in many industrial areas due to its special characteristics and superior capabilities (e.g. no direct line-of-sight operability, fast reading rate, high data storage capacity, etc.) over other Auto-ID technologies especially the barcode technology to eliminate the associated human errors that result in incomplete, inaccurate, and untimely information which is considered as a misleading information (Huang et al. 2009; Visich et al. 2009). The adoption of RFID in logistic, supply chain, manufacturing, warehouse management, quality, maintenance, and other fields has been investigated by (Mueller and Tinnefeld 2008; Chen et al. 2009; Shi et al. 2009; Sabbaghi and Vaidyanathan 2008; Attaran 2007). For increasing data granularity and effectiveness of the real-time automatic data capturing systems; several studies (Jiang et al. 2010; Brintrup et al. 2010; Ruhanen et al. 2008; Zhekun et al. 2004) investigated the possibility of RFID-sensors integration such as velocity, force, vibration, displacement sensors, etc., to collect equipment-related data, measuring tools, and WIP-related quality data. However, most of previous researches are supply chain-oriented while none of these researches have focused on the methodology of how RFID can be integrated with LM practices to serve for achieving lean goals and targets.

In dynamic production scheduling, few studies (Zhong et al. 2012, 2013; Hozak and Collier 2008) expanded the powerful features of RFID in dispatching priority methods for better production scheduling. For instance, (Zhong et al. 2012) presented a holistic data-mining approach for generating dispatching rules depending on RFID real-time PSF data. However, these studies lack the focus on the core of the value stream and pull production concepts to enhance other LM tools and practices. Therefore, this work introduces a new approach to improve the flexibility of LM through tackling the dynamic behavior of production environments which helps to achieve lean targets. The next section, describes the DVSM as a real-time LM-enabler and sustainability tool with dynamic aspects helps to enhance other LM-tools and practices, identifies the root causes of wastes to eliminate them, and creates more values.

RFID-Enabled Dynamic Value Stream Mapping (RFID-DVSM)

In today's mass-customization production system, the traditional VSM has many limitations (Abbas et al. 2001). Generally, for enhancing lean practices in such environments; there is a need to develop a real-time computerized VSM instead of snapshot paper-based VSM to address the complexity and dynamical behavior in such production environments. This section briefly presents a framework of computer-based VSM supported with RFID in order to live monitor and control the production processes of entire PSF in term of products value steam.

Through installing RFID and other supportive Auto-ID systems, almost all the manufacturing objects including tools (e.g. cutting tools), movable and stationary assets (e.g. machines, conveyors), spaces and locations, human resources (e.g. operators—if possible), materials, etc., are attached with a RFID-tag to become intelligent/smart objects and become easy to be monitored and tracked. Thus, different types of information such as WIPs arrival/departure time, processing starts/ends time, containers' location/capacity, setup time, supermarket status, equipment/tools status, critical production parameters at workstation like temperature, etc., can be cost-effectively captured and mapped to the DVSM modules for real-time decision making and further analysis concerning continuous improvements. For example, the processing starts/ends time is recorded on machine's and product's tag to be used either for optimizing the WIP lead time or for machine utilization estimation, and maintenance issues which support total productive maintenance (TPM) as one of lean pillars. Generally, through these tags, each object status is tracked or monitored to be included in lean sustainability process.

DVSM has a central database which pools real-time information from all virtual VSMs in term of value stream; here a virtual VSM is a hypothetical computer-based material flow map which is needed to produce a custom product through sequence of operations. In Fig. 1, as the operations are producing and the time progresses, DVSM includes labors and supervisors in lean practices through the momentarily interaction with the real material flow, equipment usage, machine status, WIP level and location, etc., to achieve an effective real-time synchronized production activities with minimum wastes. Furthermore, the pooled real-time data are mapped to the suitable DVSM built-in control modules to generate the right decision at the right time. The steps 1–18 in Fig. 1 describe the sequence of activities and how the logistics and production operators (LO & PO) interact through monitors with real-time operations progress. The work logic of DVSM is summarized in the following steps: (1) Automatically, map the corresponding operations and material flow information to the database of virtual VSM of each custom product. (2) Automatically, generate the custom product actual VSM. (3) Simultaneously, monitor multiple product VSMs at supervisor and labors monitors to track the production progress of each product. (4) Explore the real production time, waiting time, WIP level at each store point, transportation time and routes, and other production constrains. (5) Display the related delays, defect quantity, machines and equipment utilization, setup time, etc., on the VSM timeline. (6) Pool and list all individual VSMs' information under its corresponding database in the DVSM (like machine's processing starts/ends time, labor locations, etc.). Here, DVSM has a central database of production information. (7) Recall the required information from the central database to the built-in control algorithms or control rules and the if-analysis functions. (8) Generate new work instructions, decisions, notifications, and warnings. (9) Display the generated work instructions, decisions, notifications, and warnings to be executed by the right labor at the right workplace.

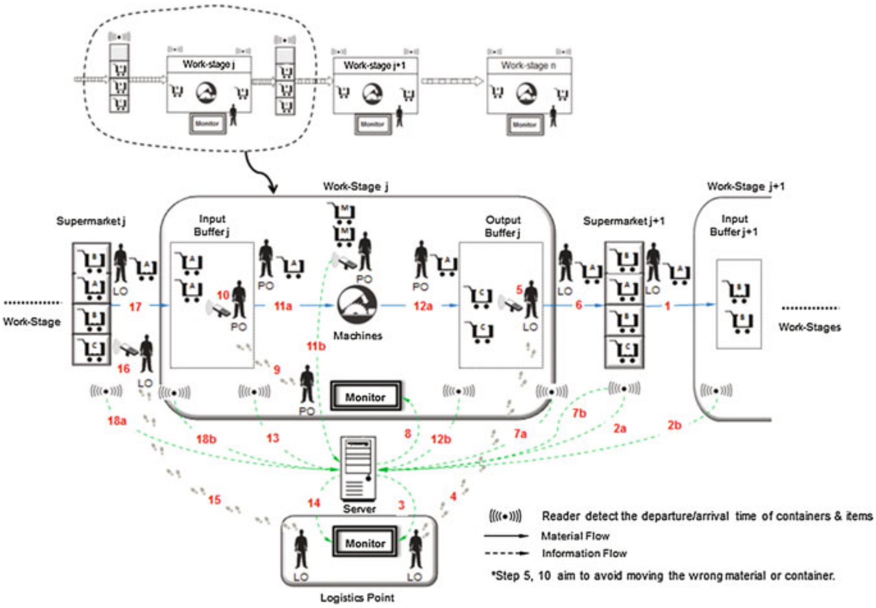

Fig. 1 DVSM enabled real-time operations and material flow control based on pull system

Through DVSM and based on LM concepts, several real-time modules and if-analysis and predictability functions can be constructed to execute powerful tasks to reach higher leanness score. For example, real-time WIP-tracking module is used to identify any type of waste (e.g. Overproduction, defects, inventories, etc.) and track manufacturing lead time components (e.g. processing time, moving time, transporting time, queuing time, etc.) of each product to specify and localize the wastes in term of time along the value stream. Other modules are developed like real-time Kanban control module, real-time LM tools sustainability module (e.g. 5S, Poka-yoke, line balancing, etc.), real-time production performance monitoring module, real-time manufacturing cost tracking module to displays a real-time product cost-development in term of the value stream, and measures the monetary impacts of implementing LM improvements in order to bridge the gap between the operational and financial views in one pool thereby demonstrate and approve these improvements with higher degrees of confidence. This paper discusses the RT-DPG module which is considered as supportive module for real-time Kanban control module.

DVSM-Enabled Dynamic Dispatching Priority Generator

In this section, a built in DVSM real-time dispatching priority generator (RT-DPG) module framework is developed. It is expected to significantly reduce the total waiting time and contribute to eliminate the non-value added activities through increasing the flexibility of material flow along the value stream and improving the accuracy of tasks synchronization during resources interaction-based real-time status of PSF to meet the load-leveling schedule at pacemaker workstation.

In reality, no specific traditional dispatching rule works well all the time (Hopp and Spearman 2008). In this paper, we proposed a new method to set priorities for waiting WIPs according to their current status. This method is called "dispatching priority values" method to prioritizes products processing sequence at the next workstation according to the live working conditions and its valued, for example between "1" as lowest priority until "5" as the highest priority value. To generate the optimal dispatching priority values through this module; several real-time operational (e.g. labor, machines, equipment, material, etc.) and customer constrains are considered which play an important role in determining the most suitable and optimal dispatching rule/value to meet load-leveling schedule.

To do so, the *real-time complex event processing (RT-CEP)* method with "pseudo-event" is used to construct the real-time control rules. In this context, a primitive event is an action occurrence at the specific time point (T_{xi}) and the location ($L_{xi,yi}$) which causes a state change, while complex events are patterns of primitive events and happen over a period of time (Wang et al. 2009). In DVSM function modules, we use this method to aggregate the correlated primitive events in order to generate the most suitable decisions.

DVSM Real-Time Dispatching Priority Generator Based on RFID-Complex Event Processing

The RT-DPG module in DVSM as shown in Fig. 2 includes three main functions: First: CHECK in *real-time production condition function (RT-PCF)*: which frequently checks the actual PSF's operational information in DVSM and their corresponding managerial information in ERP software. The operational information is in the form of primitive events which mainly contain (object ID, location, Timestamp) (Wang et al. 2009).

In other words, ERP is tied and interacts with reality on PSF through DVSM. We classify the data into ERP-managerial data and DVSM-operational data. For instance, the ERP-managerial data contains bill of materials (BOM) of each custom product, standard production operations time along the value stream and assets related information, orders due date/penalty value/customer importance, existence of hot jobs or special custom product, and the availability of subassemblies/components and materials in warehouse. The DVSM-operational data contains actual production operations time (start/end) and actual status of each WIP and resource along the value stream like availability of machines/equipments/quantities of WIP in supermarkets to start operation. As mentioned earlier, each event is a minor change in the status of PSF in term of time and location. This step is considered as real-time scanning and updating of the PSF condition.

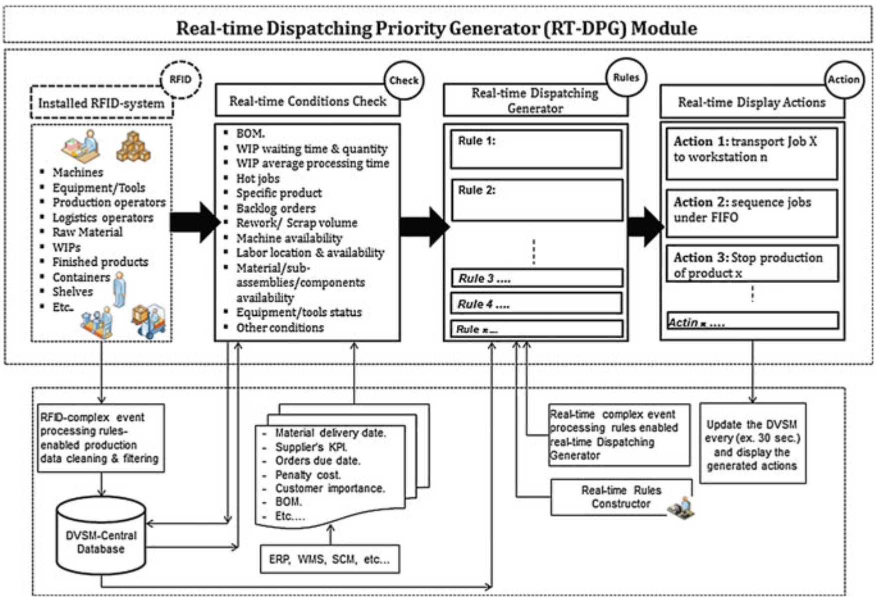

Fig. 2 The working logic of real-time dispatching priority module in DVSM

R1- Rule condition key: Hot Job

1- **[Check]** WIP types P_i & quantity QP_i,waiting time of each P_i, due date of each P_i, penalty cost of each P_i backlog-order at supermarket S_i
2- **[Check]** Availability of machine M_i
3- **[Check]** Availability of LO & PO at M_i
4- **[Check]** Availability of required material at M_i

IF hot jobs are waiting in S_i, **AND,IF** machine M_i is available after time t, **AND,IF** PO & material-if any-at M_i is available; **THEN** Set the highest priority value to hot job HJ_i with the highest penalty cost

Display <"*dispatch* HJ_i *from* S_i *-to-*M_i"> to LO as next task at S_i
ELSE terminate the R1 **AND** set FIFO-rule

Fig. 3 Hot job dispatching rule in RT-DGF

Second: RULES in *real-time dispatching generator function (RT-DGF)*: This contains several control rules aiming to aggregate the correlated primitive events. The satisfied RT-DGF's rule activates several IF-checks with RT-CEP constructors in order to diagnose the exact condition. Finally, according to the identified condition the priority rule/value will be generated.

Third: ACTION in *real-time display and execute function (RT-DEF)*: the output from step two is displayed at relevant labors' monitors such as work-instructions, notification or warnings, etc., in order to be executed immediately or after a certain time.

For simplicity, Fig. 3 presents a control rule to prioritize a hot job with earliest due date or highest penalty cost or highest customer importance to be dispatched from an upstream supermarket to a downstream workstation.

In order to prioritize a hot job with the highest priority value, this example shows that specific information in the ERP is live checked and compared with the actual condition at the supermarket as the target location. In reality, if there is one hot job in supermarket; this rule will be activated in order to assign the highest priority value to this product. But if there are more than one hot job; some criteria like earliest due date, high penalty cost, and customer importance are compared in simple way or through specific algorithms to generate the highest priority product. For comprehensive intelligent PSF control system; complex control rule should be constructed which includes the status of the upstream and the downstream workstations, where the impact of changing the dispatching priorities at one location is considered on the entire value stream performance to avoid any discrepancies. Finally, we have to notice, that the more the tracked objects included and checked in this module the more the precise priority decision will be made.

Conclusion and Future Work

This paper discusses the possibility of expanding the utilization of RFID system beyond tracking to include intelligent production operations, and material flow control in context of LM to face the dynamic behavior of the production systems. DVSM is developed to overcome the limitations of VSM and to keep pace with today's production needs and aspects, and focuses on the value stream aspects to fill the serious gap between the material flow and the information flow in shop-floor. DVSM is used mainly to sustain LM practices in PSF through several real-time operations control modules and if-analysis, and predictability functions to live monitor and control the dynamic behaviors in PSF and sustain LM practice to achieve its aims. It works also as IT-operational platform which ties ERP and the LM on PSF to reach a competitive advantage. In this work, a real-time module called real-time dispatching priority generator is presented to automatically prioritize the material sequence between the workstations based on actual PSF conditions using real-time if-analysis and real-time complex processing concepts. Through this work, several benefits can be gained towered smart LM summarized first in improving the overall value stream visibility on PSF which increases the predictability to eliminate the non-value added activities as well as avoiding serious discrepancies in executing production plans and schedules in advance. As future work, a simulation model should be built to demonstrate the effectiveness of this module which leads to a better performance against the classical scheduling rules.

References

Abbas Z, Khaswala N, Irani S (2001) Value network mapping (VNM): visualization and analysis of multiple flows in value stream maps. Paper presented at the lean management solutions conference, St Louis, MO

Attaran M (2007) RFID: an enabler of supply chain operations. Supply Chain Manage Int J 12 (4):249–257

Baudin M, Rao A (2005) RFID applications in manufacturing. MMTI, Palo Alto, USA, pp 1–12

Blanchard D (2009) The five stages of RFID. Ind Week, 258(1):50–53. Retrieved March 2010, from ABI/INFORM global

Bohnen F, Buhl M, Deuse J (2013) Systematic procedure for leveling of low volume and high mix production. CIRP J Manufact Sci Technol 6(1):53–58

Brintrup A, Ranasinghe D, McFarlane D (2010) RFID opportunity analysis for leaner manufacturing. Int J Prod Res 48(9):2745–2764

Chen X, Xie ZX, Zheng L (2009) RFID-based manufacturing execution system for intelligent operations. In: 16th international conference on industrial engineering and engineering management. IE&EM'09, pp 843–847

Chongwatpol J, Sharda R (2012) Achieving lean objectives through RFID: a simulation based assessment. Decis Sci 44(2):239–266

Ehie I, Madsen M (2005) Identifying critical issues in enterprise resource planning (ERP) implementation. Comput Ind 56(6):545–557

Günther O, Kletti W, Uwe K (2008) RFID in manufacturing. Springer, Berlin

Hopp W, Spearman M (2008) Factory physics: foundations of manufacturing management, 3rd edn. McGraw-Hill/Irwin, New York

Hozak K, Collier DA (2008) RFID as an enabler of improved manufacturing performance. Decis Sci 39(4):859–881

Huang GQ et al (2009) Agent-based workflow management for RFID-enabled real-time reconfigurable manufacturing. Springer, London, pp 341–364 Collaborative design and planning for digital manufacturing

Jiang P, Fu Y, Zheng M (2010) Tracking and visualizing RFID-driven material flows for multistage machining processes. In: International conference on manufacturing automation (ICMA), pp 186–190

Kuen-Min C, Joseph C, Ronald AC (2012) Real time facility performance monitoring system using RFID technology. Assembly Autom 32(2):185–196

Mike R, Shook J (2003) Learning to see: value-stream mapping to create value and eliminate muda: version 1.3. Lean Enterprise Institute

Mueller S, Tinnefeld C (2008) Using RFID to improve supply chain management. New age marketing: emerging realities, pp 397–409

Pavnaskar S, Gershenson J, Jambekar A (2003) Classification scheme for lean manufacturing tools. Int J Prod Res 41(13):3075–3090

Ruhanen A et al (2008) Sensor-enabled RFID tag handbook BRIDGE-project, http://www.bridge-project.eu/data/File/BRIDGE_WP01_RFID_tag_handbook.pdf

Sabbaghi A, Vaidyanathan G (2008) Effectiveness and efficiency of RFID technology in supply chain management: strategic values and challenges. J Theor Appl Electron Commer Res 3 (2):71–81

Shi Y, Pan Y, Lang W (2009) The RFID applications logistics and supply chain management. Res J Appl Sci 4(1):57–61

Velaga P (2012) Production scheduling for job shops. Optisol, http://www.optisol.biz/job_shop_scheduling.html

Visich JK, Powers JT, Roethlein CJ (2009) Empirical applications of RFID in the manufacturing environment. Int J Radio Freq Identif Technol Appl 2(3):115–132

Wang F, Liu S, Liu P (2009) Complex RFID event processing. VLDB J Int J Very Large Data Bases 18(4):913–931

Zhekun L, Gadh R, Prabhu BS (2004) Applications of RFID technology and smart parts in manufacturing. In: ASME-design engineering technical conferences and computers and information in engineering conference

Zhong RY et al (2012) Mining SOTs and dispatching rules from RFID-enabled real-time shopfloor production data. J Intell Manufact, Springer

Zhong RY et al (2013) RFID-enabled real-time manufacturing execution system for mass-customization production. Robot Comput Integr Manufact 29(2):283–292

Applying Product-Integrated RFID Transponders for Tracking Vehicles Across the Automotive Life Cycle

Florian Peppel, Martin Müller, Miguel Silveira, Lars Thoroe, Malte Schmidt and Michael Schenk

Abstract Radio frequency identification (RFID) is a well-established approach for tracking and tracing vehicles. So far, researchers and practitioners have focused on track and trace solutions, which apply RFID transponders that are temporarily attached to vehicles. In this paper, we investigate the potential of integrating transponders into vehicles as actual part of the product. Our research indicates that permanent product integration is feasible from the technical point of view and may support a large variety of track and trace scenarios, e.g., vehicle production and logistics as well as customer applications such as toll collections and parking lot solutions.

Keywords RFID · Automotive · Vehicle · Track and trace

F. Peppel (✉) · M. Silveira · L. Thoroe · M. Schmidt
AutoID Center, Volkswagen Aktiengesellschaft, Wolfsburg, Germany
e-mail: florian.peppel@volkswagen.de; florian.peppel@st.ovgu.de

M. Silveira
e-mail: miguel.silveira@volkswagen.de

L. Thoroe
e-mail: lars.thoroe@volkswagen.de

M. Schmidt
e-mail: malte.schmidt@volkswagen.de

M. Müller
IT-Inhouse Logistics, Volkswagen Aktiengesellschaft, Wolfsburg, Germany
e-mail: martin.mueller8@volkswagen.de

F. Peppel · M. Schenk
Chair of Logistics Systems, Institute of Logistics and Material Handling Systems, University of Magdeburg, Magdeburg, Germany
e-mail: michael.schenk@ovgu.de

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Introduction

In the last couple of years, the automotive industry and associated business sectors came up with various radio frequency identification (RFID) applications that support the tracking and tracing of vehicles. This particularly refers to the implementation of passive ultra high frequency (UHF) technology (860–960 MHz). Vehicle manufacturers, for instance, implement such passive RFID solutions to support internal production and logistics (ISIS 2011; Sinha 2008). Distributors and dealers use RFID to support yard management and shipping processes (Gillert and Hansen 2007; Ruthenbeck et al. 2010). Recently, there are strong indications that UHF technology will be used to operate commodity applications such as toll collection (Kamarulazizi and Ismail 2010; Laghari et al. 2012; Maldonado 2012; Persad et al. 2007; Thober 2012) and payment procedures for parking decks (Pala and Inanc 2009; RFID im Blick 2007). We therefore suggest that passive RFID application is a well-established approach for tracking and tracing vehicles and is likely to get even more attention in the near future. However, our research indicates that so far the implemented RFID solutions only have a limited scope. Current RFID solutions either focus on production and logistics at the vehicle manufacturer or they are setup to support specific downstream track and trace applications. Accordingly, RFID transponders that are used for internal production and logistics at the vehicle manufacturer are removed once the vehicle leaves this specific field of operation. Downstream applications therefore require attaching another RFID transponder. Such discontinuous RFID application negatively affects process and cost efficiency. Considering the fact that the previously mentioned RFID solutions are based on UHF technology and support similar process scenarios, we assume that a product-integrated RFID transponder which is applied to vehicles in an early manufacturing step may support internal production and logistics processes at the vehicle manufacturer as well as downstream logistics and follow-up commodity applications. As such, we are convinced that permanent, vehicle-integrated RFID transponders will generate benefits for the entire automotive value chain.

In this paper, we propose a product-integrated RFID transponder for tracking and tracing vehicles. Our research is based on project activities conducted by the AutoID Center (RFID laboratory) at Volkswagen AG. The AutoID Center implements a living laboratory approach (Bendavid and Bourgault 2010), collaborating with various universities and research centers to develop an RFID approach, which enables the tracking and tracing of prototype vehicles and assembled prototype parts within the vehicle development process (VDA 2012). These project activities are also referred to as the “Gläserner Prototyp” (Autogramm 2013; Kovac 2013). The AutoID Center also participates in multiple RFID projects that target vehicle tracking in series production and logistics; therefore, we are confident that the proposed solution is likely to cover a large variety of RFID applications within the automotive industry and associated business sectors.

The rest of this paper is organized as follows: In section "Positioning of the Vehicle-Integrated RFID Transponder" we identify a favorable position for a product-integrated vehicle transponder to support common RFID applications along the automotive value chain. In section "Testing the Performance of the Vehicle Transponder" we conduct extensive performance tests. In section "Summary and Future Research" we summarize our main findings.

Positioning of the Vehicle-Integrated RFID Transponder

The objective of our research is to integrate an RFID transponder into vehicles. The positioning of the RFID transponder shall meet the following requirements:

- R1: The RFID transponder is to be located at a very common position that can be used for a large number of different vehicle types to account for a high degree of standardization.
- R2: The RFID transponder must be applied to the vehicle during an early production step in order to support as many track and trace use cases as possible and increase cost-effectiveness along the automotive supply chain.
- R3: The RFID transponder shall not be visible, as this might interfere with product design issues and respective customer expectations.
- R4: The RFID transponder shall be applied to the actual body of the vehicle. Components and parts of the vehicle are not suitable for permanent vehicle identification as they may be removed or exchanged.
- R5: The positioning of the transponder must account for reliable reading to support all kinds of Track and Trace scenarios along the automotive value chain.

Contemporary solutions for Tracking and Tracing vehicles imply RFID transponders that are attached to the windshield (Brandwein et al. 2012; Halfar 2010; ISIS 2011; Kamarulazizi and Ismail 2010; Laghari et al. 2012; Maldonado 2012; Pala and Inanc 2009; Persad et al. 2007; Thober 2012), to the side windows (Halfar 2010; ISIS 2011), or to the license plate (Brandwein et al. 2012; Laghari et al. 2012). At the Volkswagen Group there are multiple RFID projects for tracking and tracing vehicles (Schmidt 2013). The RFID transponders are applied to the windshield, to the side window, or to the front bumper of the vehicle. SEAT S.A., for instance, follows VDA (German Association of the Automotive Industry) recommendation 5520 (VDA 2008) and applies the transponder to the side window to track vehicles at its plant in Martorell, Spain. Audi AG uses RFID transponders that are attached to the interior of the front bumper (not visible) to track and trace vehicles at its plant in Györ, Hungary. Figures 1 and 2 shows the transponder positions in these applications:

The proposed solutions enable the Tracking and Tracing of vehicles in their specific application scenarios. However, they do not meet all technical requirements that were put forward (R1–R5): Placing the transponder on parts such as the bumper or the license plate means that after the part is exchanged, the vehicle can no longer

Fig. 1 Example: Seat S.A.

Fig. 2 Example: Audi AG

be identified. Placing the transponder at the windshield or to the side window also violates optical requirements, as the transponder is clearly visible. For internal tracking purposes, this optical requirement might be negligible. However, it is a crucial requirement when transferring the vehicle to customers.

As none of the currently used positions meets all of the postulated requirements (R1–R5), we looked for possibilities to integrate the transponder into the actual vehicle body. One possible position for this is the Vehicle Identification Number (VIN) plate behind the windshield. The position of the VIN plate implies that the RFID transponder may be attached to the vehicle in an earlier production step. The VIN plate is firmly attached to the car body and is not removed when exchanging any vehicle components. Furthermore, this position is applicable for all vehicle types that are produced at Volkswagen Group. As the VIN plate is a legal requirement in many countries, we suggest that it is applicable for most car manufacturers and vehicle types, thus provides for a high degree of standardization. Additionally, integrating the transponder into the VIN plate ensures that the transponder is not visible. Figure 3 shows an example of a prototype car with a transponder that is applied to the car body underneath the windshield.

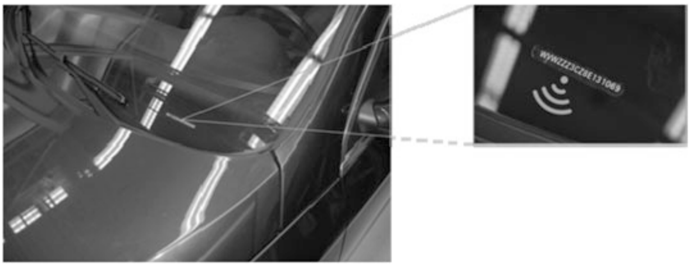

Fig. 3 RFID transponder integrated into the VIN plate *behind* the windshield

This position meets most of the postulated requirements (R1–R4). In the following section, we will test whether it also meets the required reading performance (R5).

Testing the Performance of the Vehicle Transponder

The performance tests were done according to the principles of the Association of German Engineers (VDI) and involved static and dynamic procedures (VDI 2008). The static tests were conducted at the RFID laboratory of Volkswagen AG, i.e., in a controlled environment. Different reading distances and antenna positions were analyzed to test the reading performance of the integrated vehicle transponder. For each of the antenna positions, we varied the antenna height, the antenna inclination, and the Effective radiated power (ERP). The used antenna has circular polarization with a gain of 11 decibel isotropic circular (dBic). The used transponder is an ISO/IEC 18,000-63 (EPC Class 1 Gen 2) compliant passive UHF on-metal tag. In the experiments, we read the Unique Item Identifier (UII) which uses 128 of the 256 available bits. That is, the required bit length to cover the encoded VIN, as described in VDA 5520 (VDA 2008). Figures 4 and 5 illustrate the basic test setup.

In our experiments, the antenna position is defined by polar coordinates varying between −90° and 90° (left and right side of the vehicle). Table 1 shows the test parameters that we applied.

Combining these parameter settings results in the total number of 390 conducted test cycles. For each parameter set, we measured the maximum reading distance and analyzed the impact of the parameters on reading performance. The reading distance between 1 and 5 m was measured in 0.1-m intervals.

In order to understand the impact of the ERP, we analyzed the average improvement in the reading distance when increasing the ERP from 30 decibel (dB) to 33 dB. We compared the two different power settings by applying different antenna configurations (position, angle, and height). The average reading distance

Fig. 4 Top view

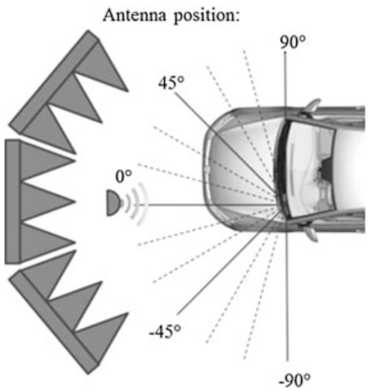

Fig. 5 Front view

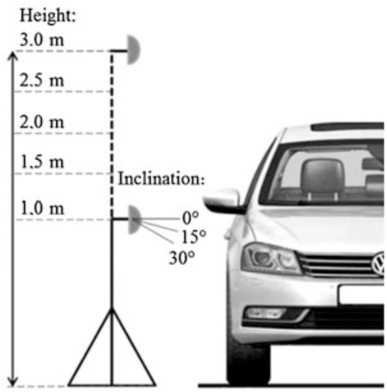

Table 1 Applied test parameters

Antenna position	Antenna height (m)	Antenna inclination	ERP (dB)
−90° to 90° (15° increment)	1.0, 1.0, 1.5, 2.0, 2.5, 3.0	0°, 15°, 30°	30, 33

Table 2 Average reading distances for different antenna positions

Antenna position (angle)	−90°	−75°	−60°	−45°	−30°	−15°	0°	15°	30°	45°	60°	75°	90°
Average reading distance (m)	**2.25**	**2.19**	**1.74**	0.62	0.86	0.69	0.41	0	0.32	0.64	**1.75**	**2.19**	**2.31**

increased from 2.36 to 2.94 m, i.e., by 25 %, when increasing ERP from 30 to 33 dB. Table 2 shows the achieved average reading distances, considering all possible parameter settings including antenna height, antenna inclination, and ERP. The highest reading distances were achieved when reading from the sides of the vehicle, but it was also possible to read from other antenna positions.

Subsequently, we separately analyzed the impact of antenna heights and inclination angles on the reading distance, by considering all the configuration parameters including antenna position and different ERP settings. The highest reading distance was achieved with an antenna height of 2.5 m and an inclination of 15°. Table 3 shows the reading performance for different antenna heights and inclinations.

Figure 6 visualizes the achieved reading distances for the different antenna positions, antenna heights, and inclinations (15°, 30°) with an ERP setting of 33 dB.

As shown, the reading performance highly depends on the position, height, and inclination angle of the antenna. We observed high reading performance when capturing the vehicle from the side. Reading from the front showed to be more difficult due to the fact that the front hood creates undesired shielding effects and reflections, thus negatively influences reading performance.

Table 3 Reading performance for different antenna heights and inclinations

Inclination	Height				
	1 m	1.5 m	2 m	2.5 m	3 m
0°	2.45 m	2.75 m	3.05 m	3.05 m	1.43 m
15°	2.30 m	2.70 m	3.08 m	3.20 m	3.00 m
30°	1.35 m	2.35 m	2.95 m	3.08 m	3.08 m

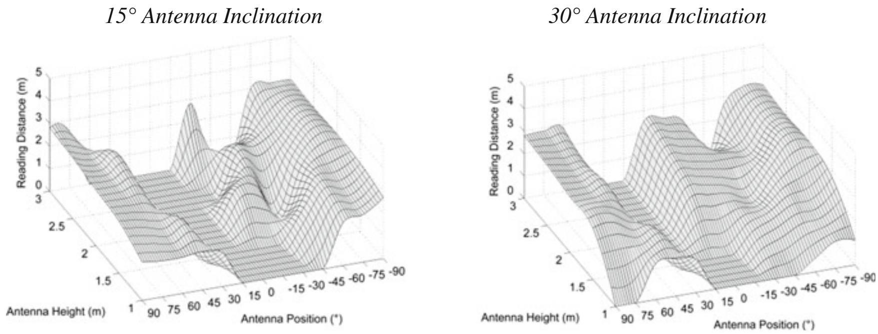

Fig. 6 Reading performance applying antenna inclination of 15° and 30°

Table 4 Summarized results from the dynamic tests

Speed (km/h)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Average	12.7	5.1	5.7	4.5	2.0	1.9	1.4	1.5	1	1	1	1	1	1	1
Standard deviation	1.3	0.7	1.3	1.3	0.0	0.3	0.5	0.7	0	0	0	0	0	0	0
Maximum	15	6	8	6	2	2	2	3	1	1	1	1	1	1	1
Minimum	11	4	3	3	2	1	1	1	1	1	1	1	1	1	1

Subsequently, we applied our laboratory findings and conducted dynamic tests at a speed track to investigate road capability. Based on the results of the static tests, we chose the following setup for the dynamic tests: The antenna was setup on the left side of the vehicle at a height of 2.5 m and an inclination of 15°. The ERP was set to 33 dB. The test track provides for limited control only, therefore the distance between the RFID transponder in the moving vehicle and the RFID antenna varied between 2 and 2.5 m. The tests were done at different speeds, varying between 10 and 150 km/h with 10 km/h intervals. Each test run was repeated 10 times for statistical reasons. Overall, we conducted 150 dynamic test cycles. Table 4 presents the results for each tested speed interval.

Based on these data, we propose an exponential regression model for calculating the number of expected reads, where x is the speed of the vehicle:

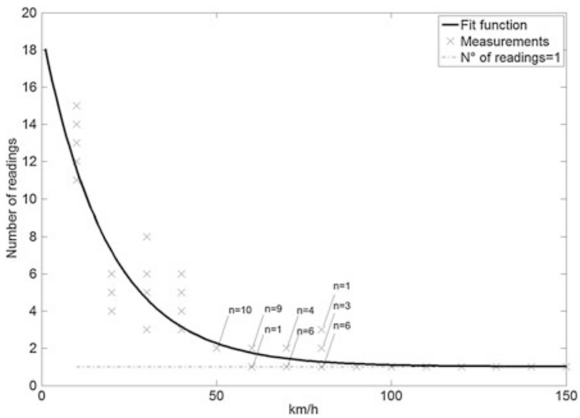

Fig. 7 Fit function and test results of the dynamic tests

$$N(x) = 7.765 * e^{-\frac{x-15.74}{18.76}} + 1.024 \quad (1)$$

Figure 7 shows the plotted graph for this function and our actual reading results.

As shown in Fig. 7 we were able to capture the vehicle transponder at least once ($N(x) = 1$). However, reading the vehicle just once may question the reliability of capturing the vehicle under real-life circumstances. We may have to deal with environmental conditions that prevent the RFID transponder from being read (e.g., shielding effects and reflections). Therefore, we suggest raising the confidence level to an average of $N(x) > 1$. As such, we are confident that the integrated RFID transponders may be read at speeds up to approximately 80 km/h, which is likely to meet the requirements of most RFID applications. High-speed applications may require a different reader configuration than the one that was applied in our test scenario. Our reader configuration focuses on capturing vehicles at speeds which are likely to occur in common track and trace scenarios (0–50 km/h) and leads to reading cycles of approximately 50 ms. This limits the potential of successful reads at higher speeds, as the vehicle may be out of range after the very first successful read cycle has been completed. The impact of the reader configuration is shown in Table 5, which indicates the theoretical number of completed reading cycles. This includes different speed intervals, the distance between the RFID antenna and the vehicle transponder, and the amount of time the vehicle is within reading range.

Table 5 Calculated reading cycles for different speed intervals

Km/h	10	20	30	40	50	60	70	80	90
Reading cycles (N°)	16.62	8.31	5.54	4.15	3.32	2.77	2.37	2.08	**1.85**
Km/h	100	110	120	130	140	150	160	170	180
Reading cycles (N°)	1.66	1.51	1.38	1.28	1.19	1.11	1.04	**0.98**	0.92

The results indicate that up to 80 km/h, there is a very high chance of completing two reading cycles, which significantly raises the chance of capturing the vehicle more than once. Up to 160 km/h we observe a theoretical chance of completing two reading cycles. However, in real life, the vehicle does not necessarily access the range of the RFID antennas exactly when the first read cycle starts. Therefore, completing two read cycles may not be possible. Hence, in case of high-speed scenarios, we suggest adjusting the configuration of the reader and increase the cycle time in order to achieve reasonable confidence levels and ensure reliability.

In summary, the results from our static tests indicate that an integrated vehicle transponder at the proposed position provides adequate reading performance. The dynamic tests confirm these results and show that the position meets the technical requirements of many RFID applications.

Summary and Future Research

In this paper, we analyzed the potential of integrating RFID transponders into vehicles to support the tracking and tracing within production and logistics processes along the automotive supply chain as well as follow-up customer applications such as toll collection and parking lot solutions. We argue that RFID transponders, which are applied to the VIN plate of vehicles, are likely to meet most of the technical requirements that apply within automotive track and trace scenarios. Our test results show that the proposed RFID solution is feasible from the technical point of view. In fact, our positive test results motivated Volkswagen AG to initiate a long-term study and equip more than 1000 test vehicles with integrated RFID transponders in order to confirm technical reliability under real-life conditions. The test results are likely to close remaining research gaps. However, at this point of time our research implies several limitations.

First, real-life RFID scenarios may come with diverse technical requirements. This refers to both environmental factors and applicable hardware and software settings that were not covered in our test scenarios. Therefore, we recommend that additional measures shall be taken before putting the proposed solution into practice. Second, the proposed transponder position is only feasible for vehicle types with nonmetallized windshields. We also ran the same set of tests with a metallized windshield and observed severe shielding effects. Metallized windshields prevent the vehicle from being captured, which may force car manufacturers to demetallize the windshield within areas that cover the integrated RFID transponder. Similar solutions have been implemented in the case of Global Positioning Systems; therefore, we do not expect any severe implementation hurdles. Third, a vehicle-integrated RFID transponder that is applied by car manufacturers in an early phase of the vehicle production process does not necessarily guarantee that the transponder is accessible to downstream stakeholders within the automotive value chain. Car manufacturers and associated business sectors will need to agree on technical standards such as data structures that are written to the product-integrated

RFID transponder and support unique and secure vehicle identification along the entire automotive value chain—this includes production and logistics at the car manufacturer as well as downstream logistic procedures and follow-up commodity applications. Fourth, the conducted dynamic tests show adequate reading performance up to a speed of 80 km/h, reading the UII of 128 bits. Other applications may require reading more data; thus, further testing may be necessary. Finally, apart from the mentioned technical issues, integrated vehicle transponders may raise social concerns such as privacy and security issues, i.e.; customers might not want to buy RFID-enabled vehicles. Although the RFID transponders can be deactivated on demand, foreseeable public discourse is likely to raise the customer's awareness and might even affect the image of car manufacturers.

The limitations of our research indicate that additional measures need to be taken before putting product-integrated RFID transponders into practice. However, there are clear indications that integrated vehicle transponders are likely to positively affect the cost-effectiveness of RFID-enabled track and trace solutions along the automotive value chain. We therefore suggest that researchers and practitioners shall pick up the notion of vehicle-integrated RFID transponders. This refers to technical aspects such as improving and testing our approach as well as research on alternative transponder positions. It also implies research on customer's demand and potential concerns. After all, vehicle-integrated RFID transponders will only be put into practice as long as the proposed solutions comply with both technical and customer's requirements.

References

Autogramm (2013) Vom Lebenslauf der Teile—Projekt Gläserner Prototyp/RFID-Transponder schaffen Transparenz. In: Volkswagen Autogramm, vol 4, p 7

Bendavid Y, Bourgault M (2010) A living laboratory for managing the front-end phase of innovation adoption: the case of RFID implementation. Int J Proj Organ Manage 2(1):84–108

Brandwein D, Uckelmann D, Beenken B (2012) Using RFID in license plates and vignettes for electronic vehicle identification—structured testing of passive UHF systems for vehicle identification. In: Proceedings of the 1st international conference on ImViReLL, Bremen, Germany. doi:10.1007/978-3-642-28816-6_1

Gillert F, Hansen W-R (2007) Lokalisierung von PKWs bei Dat Autohus. In: RFID für die Optimierung von Geschäftsprozessen, pp 191–194

Halfar H (2010) Intelligente Automobillogistik—RFID verdrängt Barcode in der Fahrzeugdistribution. In: RFID im Blick, Special Issue "RFID in Bremen", pp 50–51

ISIS (2011) RFID in der Logistik—Potenziale ausschöpfen in der Supply Chain. In: Ein Praxisbericht der Ford-Werke Köln. ISIS AutoID/RFID Special 1/2011, Munich, Germany

Kamarulazizi K, Ismail W (2010) Electronic toll collection systems using passive RFID technology. J Theor Appl Inf Technol 22:70–76

Kovac F (2013) Untersuchung der Auswirkungen einer RFID-gestützten Bauzustandsdokumentation auf die Dokumentationsqualität in der Erprobungsphase. Dissertation, Karlsruher Institut für Technologie (KIT), KIT Scientific Publishing, Karlsruhe, Germany

Laghari A, Memon N, Pathan A (2012) RFID based toll deduction system. Int J Inf Technol Comput Sci 4:40–46, Hong Kong

Maldonado L (2012) Mexico's national automatic vehicle identification system. In: Proceedings of the all-electronic toll collection conference, Atlanta, USA

Pala Z, Inanc N (2007) Smart parking applications using RFID technology, IEEE, RFID Eurasia, 1st Annual, 5–6 September 2007

Pala Z, Inanc N (2009) Utilizing RFID for smart parking applications. Mech Eng 7(1):101–118

Persad K, Walton M, Wang Z, Hussain S, Robertson C (2007) Electronic vehicle identification: applications and implementation considerations. Technical Report, pp 1–144

Ruthenbeck C, Lappe D, Lampe W (2010) Information management in automotive logistics. Ind Manage 26:9–13

Schmidt M (2013) Migration from barcode to passive UHF-technology in automotive logistics. Dissertation, University of Göttingen, Germany, ISBN 978-3-95404-441-2

Sinha R (2008) RFID enabled vehicle tracking Ford Motor Company. Retrieved from http://www.epcconnection.com/pdfs_np_MANU_Oct15_300_Sinha.ppt.pdf

Thober D (2012) Electronic vehicle registration in Sao Paulo, Brazil. In: Proceedings of the all electronic toll collection conference, Atlanta, USA

VDA (2008) VDA 5520—RFID in the vehicle distribution processes. German Association of the Automotive Industry (VDA), Berlin, Germany, pp 1–33

VDA (2012) VDA 5509—AutoID/RFID-application and data transfer for tracking parts and components in the vehicle development process. German Association of the Automotive Industry (VDA), Berlin, Germany, pp 1–47

VDI (2008) VDI/AIM 4472—Requirements to be met by transponder systems for use in the supply chain: test methods to check the performance of transponder systems (RFID), Part 10. Association of German Engineers (VDI), Düsseldorf, Germany, pp 1–22

Airflow Simulation Inside Reefer Containers

Safir Issa and Walter Lang

Abstract Transporting of sensitive commodities in strict ambient conditions becomes necessity not only to fulfill regulations but also to maintain their quality and to reduce the rate of losses. Temperature, which mainly affects the transported produce, is controlled by airflow pattern in reefer containers. Consequently, obtaining airflow pattern enables predicting hot spots and then taking the necessary actions to minimize their effects. We present, in this paper, a *k*-*ε* simulation model to evaluate airflow pattern in reefer container loaded with bananas. Simulation results predict the place of the hot spots. Moreover, we found that the cooling distribution is improved by modification of the scheme for placing pallets in the container, the so-called chimney layout.

Keywords Characterization · Airflow · *k*-*ε* simulation · Banana transport · Reefer container

Introduction

Nowadays, the "fresh" agriculture products are available in markets almost all over the year due to the huge progress in logistic transport. Nevertheless, the intercontinental transport of sensitive products, such as banana, still has serious challenges to maintain the quality of these products. Banana, as an example, is a sensitive

S. Issa (✉) · W. Lang
Institute for Microsensors, Actuators and Systems (IMSAS), Microsystems Center Bremen (MCB), University of Bremen, Otto-Hahn-Allee, Bld. NW1, 28359 Bremen, Germany
e-mail: safir.issa@uni-bremen.de

W. Lang
e-mail: wlang@imsas.uni-bremen.de

S. Issa · W. Lang
International Graduate School for Dynamics in Logistics (IGS), University of Bremen, c/o BIBA Hochschulring 20, 28359 Bremen, Germany

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product that is highly affected by surrounding environments. Its optimum temperature for transport and storage is 13–14 °C (Paull 1999). Higher temperatures may speed up the ripening process or cause the senescence, whereas lower temperatures may cause freezing or chilling injury. Therefore, it is essential to have uniform temperatures throughout the system to maintain commodities quality and shelf life during transportation processes. Obtaining homogeneous air distribution is extremely complex due to operational factors such as loading practices and product properties (Smale et al. 2006). In reefer containers, convection is the dominant mode of heat transfer; therefore, the temperature and its distribution are governed by airflow pattern (Moureh et al. 2009). Distributed airflow is responsible of removing generated heat not only from container's walls and doors caused by external heat sources, but also the heat generated by the commodities themselves. Fruits keep producing heat and moisture after harvesting. In some regions of the transport container, where ventilation is poor, hot spots start to be created. As a consequence, commodities in these stagnant zones are object to different deteriorations that degrade their quality. Hot spots can emerge in different areas of the container. The difficulties to predict their location and development (Jedermann et al. 2013) cause a major problem for the supervision of banana transports. In order to understand flow behavior in such enclosed areas, researchers have been developing airflow models in the last four decades. With the new powerful computers, computational fluid dynamics (CFD) became their preferred choice. Such numerical models, regarding their advantages of fast time and low cost, offer a powerful tool to understand fluid flow and heat transfer in the intended enclosed environments.

Zou et al. (2005) developed a CFD modeling system of the airflow patterns and heat transfer inside ventilated apple package through forced air cooling. The model was validated by temperature measurements of products, but this model is concerned by food packages and not the whole container. Moureh et al. (2009) presented a numerical approach and experimental characterization of airflow within a semitrailer enclosure loaded with pallets in a refrigerated vehicle with and without air ducts. Measurements of air velocities were carried out by a laser Doppler velocimeter in clear regions (above the pallets) and thermal sphere-shaped probes located inside the pallets. The velocimeter is placed outside the vehicle and the measurement is done through a glass window. Results showed the importance of narrow spaces around pallets to reduce temperature variability in the truck, in addition to the fact that using air ducts improves the ventilation homogeneity. Xie et al. (2006) presented a CFD model, which studies the effect of design parameters on flow and temperature field of a cold store. Many other CFD studies were reported.

In section "Simulation Model", we present CFD simulations of air flow pattern inside a container loaded with pallets. The simulations were done using the k-ε model of the COMSOL Multiphysics software. Locations with low airflow, which are prone to develop hotspots, are identified by the simulations. Because the size of banana pallets does not fit the container dimensions, part of the pallets have to be rotated to 90°. The effect of a new scheme for loading the pallets to the container to the equability of the airflow was verified by the simulation. In section "Evaluation and Conclusions", we validate the simulation results by comparison with the result of the experimental test. Finally, we summarize the founded results by the achieved work.

Simulation Model

The CFD is used to determine airflow distributions by solving a set of equations describing the fluid motion and energy conservation. The CFD predicts turbulent flows through three basic approaches: direct numerical Simulation (DNS), Larg–Eddy Simulation (LES), and Reynolds-Averaged Navier–Stokes (RANS) equations. First, DNS solves Navier–Stokes equations without approximation for the whole range of spatial and temporal scales of the turbulence. Consequentially, DNS requires a very fine grid resolution and very small time steps which lead to an extremely long simulation (Nieuwstadt et al. 1994). Second, LES corresponds to the three-dimensional, time-dependent equations with the approximation of eliminating the very fine spatial grid and small time step. This consideration comes from the fact that macroscopic structure is characteristic for turbulent flow. Moreover, the large scales of motion are responsible for all transport processes. The LES still needs a considerable computing time but in the other side gives detailed information on airflow turbulence (Zhai et al. 2007). Third, RANS equations with turbulence models deal with the mean of the air parameters, which is more useful than the instantaneous value of the turbulent flow parameters. As a consequence, airflow distributions can be quickly predicted. The RANS approach evaluate Reynolds-averaged variables for both steady state and dynamic flows. The k-ε model is one of the most common turbulence models belonging to this approach. It is a two-equation model, i.e., it includes two extra transport equations to represent the turbulent properties of the flow. Due to its smaller requirements of computer resources, RANS approach has become very popular in modeling airflow in enclosed environments (Zhai et al. 2007).The Reynolds-averaged Navier–Stokes equations are given as:

$$\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\frac{(\mu + \mu_t)}{\rho}\frac{\partial U_i}{\partial x_j}\right] \tag{1}$$

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{2}$$

where U_i is the mean velocity of the ith component of fluid velocity (u) at the point of space (x) and at the time (t); P is the mean static pressure; ρ is the mean fluid density; μ is the dynamic viscosity; and μ_t is the turbulent eddy viscosity defined by Boussinesq relationship:

$$-\overline{u_i' u_j'} = 2\frac{\mu_t}{\rho} S_{ij} \tag{3}$$

where $\overline{u_i' u_j'}$ is the Reynolds stress and S_{ij} is the mean strain rate given as:

$$S_{ij} = \frac{1}{2}\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) \tag{4}$$

The two equations for k-ε model are the kinetic turbulent energy (k) equation and the turbulent dissipation rate (ε) equation. They are given as:

$$\frac{\partial k}{\partial t} + U_j \frac{\partial k}{\partial x_j} = \frac{\mu_t}{\rho} S^2 - \varepsilon + \frac{\partial}{\partial x_j}\left[\frac{1}{\rho}\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] \tag{5}$$

$$\frac{\partial \varepsilon}{\partial t} + U_j \frac{\partial \varepsilon}{\partial x_j} = \frac{\varepsilon}{k}\left(C_{1\varepsilon}\frac{\mu_t}{\rho} S^2 - C_{2\varepsilon}\varepsilon\right) + \frac{\partial}{\partial x_j}\left[\frac{1}{\rho}\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] \tag{6}$$

where S is the strain rate magnitude. In these equations, there are five free model constants and their standard values are as follows: $C_{1\varepsilon} = 1.44$; $C_{2\varepsilon} = 1.92$; $C_\mu = 0.09$; $\sigma_k = 1$; and $\sigma_\varepsilon = 1.3$.

In our simulation, we used COMSOL MULTIPHYSICS program to evaluate airflow distribution in predesigned container. Boundary conditions are as follows: inlet velocity is 8 m/s which is equivalent to the cooling unit capacity of 5480 m^3/h at 50 Hz power supply. Turbulence intensity (I) is set to 3 %. This value is estimated from the experimental airflow measurements mentioned earlier. The turbulence length scale (l) is estimated to be 0.004 m which represents 5 % of the channel height of the inlet.

The inner dimensions of the cargo hold of a standard 40 ft reefer container are as follows: 11.590 m for length; 2.294 m for width; and 2.557 m for height. This container is equipped with a Thermoking Magnum Plus cooling unit. Inlet and outlet are at the bottom and top of the reefer side, respectively, as shown in Fig. 1. Airflow pattern were extracted for loaded container with banana pallets. One pallet consists of 48 banana boxes, distributed into 8 layers (tiers) 6 boxes in each. Dimensions of one box are 0.5 × 0.4 × 0.25 m^3. The standard scheme (L1) of pallets layout inside the container is shown in Fig. 2 (left). A new layout, called also chimney layout (L2), is tested in our simulations and measurements. In this new layout, a considerable gap is created between each four pallets as in Fig. 2 (right).

In order to be in accordance with the experimental setup, simulations were done for a reduced number of pallets in the container, 11 for L1 and 12 for L2 (see Fig. 2). This difference in pallet number is to obtain approximately aligned ending of the two rows in both layouts. In order to separate the pallets from the unused space in the container, a mobile wall was installed behind the last row of pallets and air sealed using foam and duct tape.

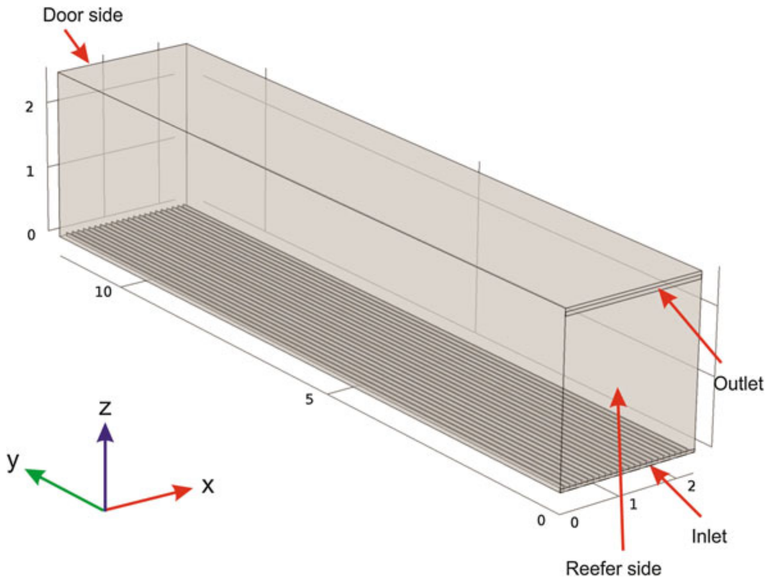

Fig. 1 Empty container

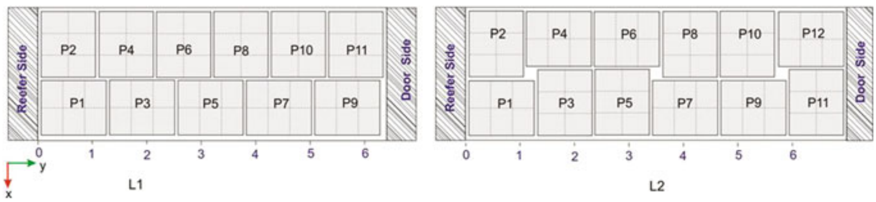

Fig. 2 Top view of the container for both layouts L1 (*left*) and L2 (*right*)

Simulations for the two layouts were achieved. We assumed that free convection is negligible, since the maximum recorded temperature difference is about 2 °C. To show these results in a comparative way, we consider some particular planes in the container. First, in the XY plane, three basic cases are essential to be discussed, under the pallets, in the pallets level, and above the pallets. In the inlet level, i.e., under the pallets, as shown in Fig. 3, we notice high velocities in the front of container which decrease gradually with the y coordinate. Velocity values are about 8 m/s at the inlet level, 4 m/s in the middle, and 2 m/s at the end of the simulated part. All cases show approximately similar results. However, for higher levels, i.e., in pallets level ($z = 0.2$–2.2 m), contradictory results were found. In the front part of the container, very low air velocities less than 0.2 m/s at reefer side and then they increase gradually to be about 1 m/s at the middle of the container, and about 3 m/s at the end of the container (see Fig. 4). Chimneys don't have identical impact on airflow distribution. Chimney near reefer side has lower velocity values than the

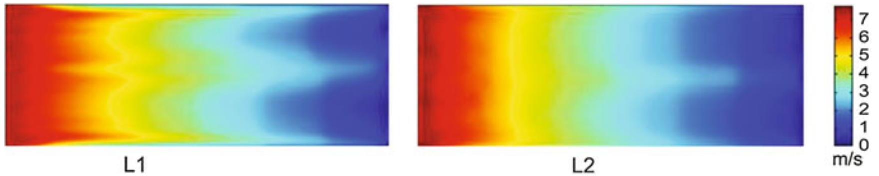

Fig. 3 Airflow pattern in the inlet level for both layouts: L1 and L2

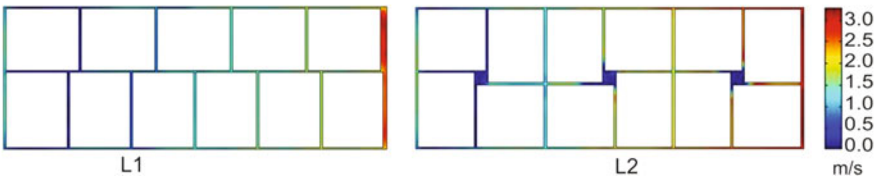

Fig. 4 Airflow pattern in pallets level for both layouts: L1 and L2

one in the middle, which in turn has less value than the one near the door. In the L2 case, where the top of the chimney is closed, we notice how airflow is forced to flow in the gaps surrounding the chimneys (Fig. 4 L2). This causes a more uniform distribution of air velocity in L2 layout comparatively with L1 layout.

Third level is the outlet level, i.e., above the pallets. There, we have similar airflow distribution to the one at the inlet level with the difference in velocity values and homogeneity (see Fig. 5). In Fig. 5, we notice that the returning airflow starts with low velocities of about 0.5 m/s and increases gradually to about 3 m/s at the outlet level in reefer side. It is distinguishing that there are two separated clouds of velocity above the two rows of pallets in L1 case. However, for the L2 case, we notice a uniform velocity distribution above the first half of the container, where the two clouds are merged together for this region and start to separate in the second half. The previous Figs. 3, 4 and 5 show that the expected hot spots can be created in the first part of the container. Because the cooling air is supplied from the floor side, the best cooling is achieved in the lowest tier 1. The highest tier 8 is additionally cooled over its top side from the return air flow. The highest temperatures were found in tiers 5–7 according to our temperature measurements (Jedermann et al. 2013). Therefore, the boxes in these tiers of the first two pallets are the most likely to produce hot spots. L2 produces, comparatively, the best homogeny airflow distribution.

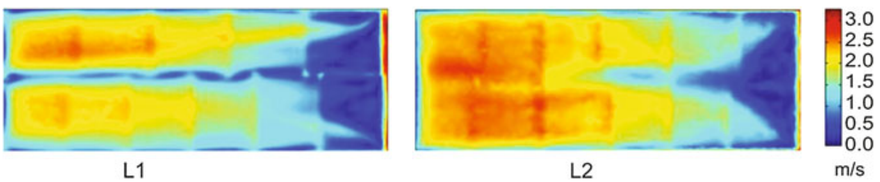

Fig. 5 Airflow pattern above the pallets level for both layouts: L1 and L2

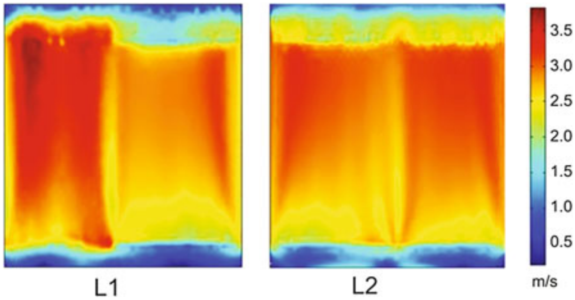

Fig. 6 Comparison between airflow distribution in the XZ plane at the end of the container in the gap between the end pallets and the door

In the XZ plane, airflow velocity distribution is highly influenced by the y coordinate of this plane. We notice that velocity, in the pallets level, increases with the y coordinate. Highest values are at the end of the container, especially in the gap between the door and the last row of pallets. By comparing the velocity distribution at that gap, we find different behavior between L1 and L2 as shown in Fig. 6. In this case, there is nonsymmetric distribution. This difference is not only because of the different layout but also because of the lager gap on the left side. The two rows of L1 layout do not end at the same coordinate, and the maximum difference is about 4 cm.

The hot spot detected by temperature measurements and proved by the simulation can be explained by the existence of a big eddy in the region near the cooling unit. Figure 7 shows airflow simulation in the YZ-plane in the gap between the two rows of pallets in the standard scheme L1. This also explains the highest temperature values in this region. Changing the layout to the chimney scheme participates in limiting this phenomena and increases the velocity in this region as shown in Fig. 8.

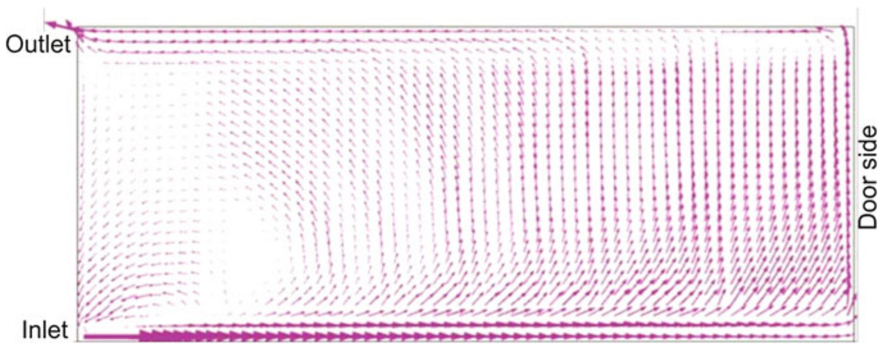

Fig. 7 Airflow pattern in the YZ-plane in gap between the two rows of pallets of L1

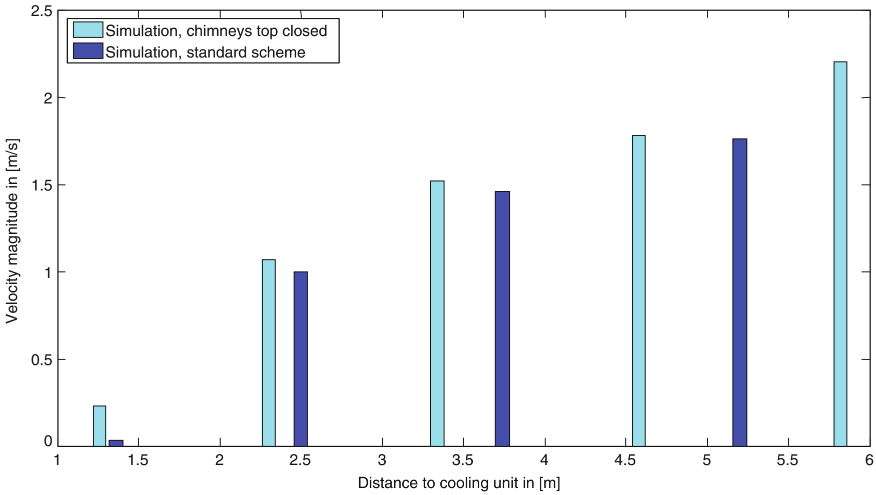

Fig. 8 Average velocity in gaps by simulations

It is evident from Fig. 8 that the chimney layout improves the airflow distribution inside the container than the standard scheme layout. However, for both layouts, the velocity values in the first part of the container are still small between the pallets. An idea to increase the velocity in this area is by constructing tube intakes at the bottom of the first chimney, in such a way that we force airflow to go in the vertical direction. In this way, we can decrease the entrainment effect which causes the big eddy near the cooling unit. This idea needs to be validated by both simulation and measurement.

Evaluation and Conclusions

In order to evaluate simulation results, we made some experimental measurements within the Intelligent Container Project. We used flow sensors based on the thermal principles in these measurements. These sensors include hot wire anemometers in addition to the IMSAS airflow sensors (Lloyd et al. 2013). In this context, we cite one example of the experimental results just to compare it with the simulation results. Figure 9 shows a comparison between the simulation model and experimental results. It is in the floor level of the container under the pallets (inlet plane). In this level, there are no obstacles in front of the flow. Both results show a good agreement. Maximum error is about 0.5 m/s which is considered quite good, taking into consideration the high turbulence flow inside the container.

As conclusions, simulation of airflow in a logistic container is achieved by this work. Simulation results enable understanding airflow distribution which allows predicting the most likely positions of hot spots in the container and consequently,

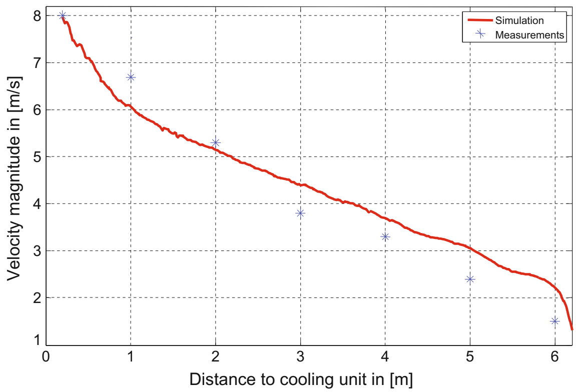

Fig. 9 Comparison between simulation and measurement for velocity magnitudes in the inlet level

taking corrective and preventive actions to maintain the quality of produce and reduce loss rate. Simulations were done by a *k*-ε turbulent flow model based on COMSOL simulation program. Results explain some phenomena such as the existence of hot spots near the cooling unit. It proved that the recently introduced scheme of pallets, the "chimney layout," improves cooling inside the container and gives better airflow distribution.

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References

Jedermann R, Geyer M, Praeger U, Lang W (2013) Sea transport of bananas in containers—parameter identification for a temperature model. J Food Eng 115(3):330–338

Lloyd C, Issa S, Lang W, Jedermann R (2013) Empirical airflow pattern determination of refrigerated banana containers using thermal flow sensors. The intelligent container, cool-chain-management. 5th international workshop, University of Bonn

Moureh J, Tapsoba S, Derens E, Flick D (2009) Air velocity characteristics within vented pallets loaded in a refrigerated vehicle with and without air ducts. Int J Refrig 32:220–234

Nieuwstadt FTM, Eggels JGM, Janssen RJA, Pourquié MBJM (1994) Direct and Large–Eddy simulations of turbulence in fluids. Future Gener Comput Syst 10(2–3):189–205

Paull R (1999) Effect of temperature and relative humidity on fresh commodity quality. Postharvest Biol Technol 15(3):263–277

Smale NJ, Moureh J, Cortella G (2006) A review of numerical models of airflow in refrigerated food applications. Int J Refrig 29(6):911–930

Xie J, Qu XH, Shi JY, Sun DW (2006) Effects of design parameters on flow and temperature fields of a cold store by CFD simulation. J Food Eng 77(2):355–363

Zhai ZJ, Zhang Z, Zhang W, Chen QY (2007) Evaluation of various turbulence models in predicting airflow and turbulence in enclosed environments by CFD: part 1—summary of prevalent turbulence models. HVAC&R Res 13(6):853–870

Zou Q, Opara LU, McKibbin R (2005) A CFD modeling system for airflow and heat transfer in ventilated packaging for fresh foods. J Food Eng 77:1048–1058

Cloud-Based Platform for Collaborative Design of Decentralized Controlled Material Flow Systems in Facility Logistics

Orthodoxos Kipouridis, Moritz Roidl, Willibald A. Günthner and Michael Ten Hompel

Abstract In order to cope with the increasing need for flexibility, today's material flow systems move toward decentralized and modular approaches. However, operation and control of the majority of such systems are based on manufacturer-specific standards, thus resulting in the loss of their reusability and making the task of integrating two or more such systems a rather complex one. In this paper, we present a software platform for supporting collaboration between partners at designing and testing of heterogeneous decentralized controlled systems, prior to deployment. As a use case scenario, we demonstrate a virtual merge of two remote logistics labs, namely, an electric overhead monorail system pilot plant at institute fml of the Technical University of Munich and a conveyor system at institute FLW of the Technical University of Dortmund.

Keywords Collaboration · Cloud computing · Distributed material flow control · Internet of things · Data sharing

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O. Kipouridis (✉) · W.A. Günthner
Lehrstuhl für Fördertechnik Materialfluss Logistik (fml), Technische Universität München, Bolzmannstr. 15, 85748 Garching b. München, Germany
e-mail: kipouridis@fml.mw.tum.de

W.A. Günthner
e-mail: guenthner@fml.mw.tum.de

M. Roidl · M. Ten Hompel
Lehrstuhl für Förder- und Lagerwesen (FLW), Technische Universität Dortmund, Jospeh-von-Fraunhofer-Str. 2-4, 44221 Dortmund, Germany
e-mail: moritz.roidl@flw.mb.tu-dortmund.de

M. Ten Hompel
e-mail: michael.tenHompel@flw.mb.tu-dortmund.de

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Introduction

In the past decade, applied research in the field of automated material flow systems has introduced decentralized control approaches (Windt and Hülsmann 2007; Mayer 2009) with numerous commercial applications already making their way into market. Main reason for this development is the demand for flexible, reusable systems that can adapt to the evolving requirements of today's rapidly changing facility logistics area. Such a decentralized control paradigm is referred to as "Internet of Things" (IoT) in the facility logistics (Günthner and Hompel 2010), and it describes a decentralized approach to in-house material flow. The IoT enables the separation of the operational and machine control enabling the manufacturing of highly modular systems (Fig. 1). Nowadays, technological advances such as service-oriented software architectures and data distribution offer new possibilities for system manufacturers, system integrators, and researchers to collaborate on common projects by taking advantage of the benefits that decentralization offers, when merging their systems in larger application domains (Libert 2011).

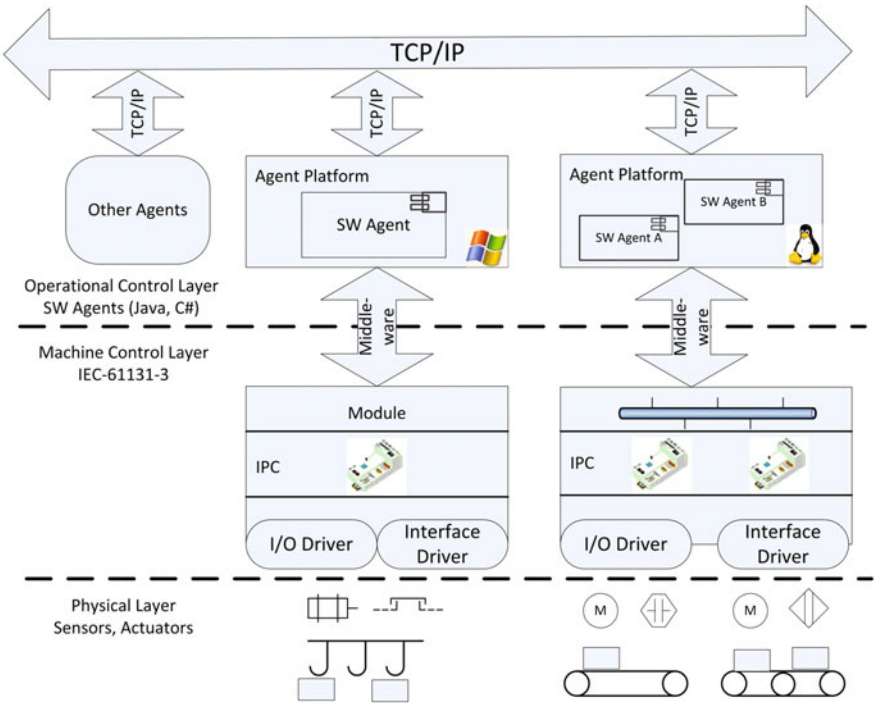

Fig. 1 Example of an internet of things modular control architecture (Kuzmany 2010). In the top layer, software agents are assigned to each module (crane and conveyor system) and communicate with each other to take routing decisions. In the machine control layer, each module is controlled through an IEC-61131-3 program that is executed on industrial PCs (*IPC*). The mediating middleware can be instantiated at each software agent and is responsible for transferring information between the two layers (operational and machine control)

Our contribution focuses on presenting a software platform for supporting collaboration between partners at projects in which the integration of various subsystems of decentralized controlled plants comes into play. The platform is being developed in the context of the "KoDeMat—Collaborative design of Decentralized material flow systems" research project. The KoDeMat platform supports the efficient planning of multiple plant subsystems located at remote logistics labs.

This paper is structured as follows. In the next part, the challenges with regard to designing decentralized control of material flow systems as well as the tasks by collaborative planning of such systems are presented. In the third part, we describe the software platform, its architecture, core elements, and functions. In the following part, we demonstrate a sample use case scenario of a virtual merge of two remote test plants located in the participating institutes, and finally a summary and an outlook to future work is presented.

Designing Heterogeneous Decentralized Controlled Systems

In this section, the main concepts of decentralization according to the "IoT" paradigm are introduced, and the challenges that arise for integrating multiple decentralized controlled systems are highlighted.

Configuring Material Flow Systems in Joint Projects

The control concept of IoT has an impact to the development process of handling systems (Chisu 2010). The modular structure of the mechanical parts and control logic allows for a high degree of reusability that consequently leads to a reduction in design, implementation, and testing costs in comparison to conventional systems (Kuzmany 2010; Fig. 2). A large part of this cost reduction is also owed to the one-time design costs due to project-independent development of software and hardware parts.

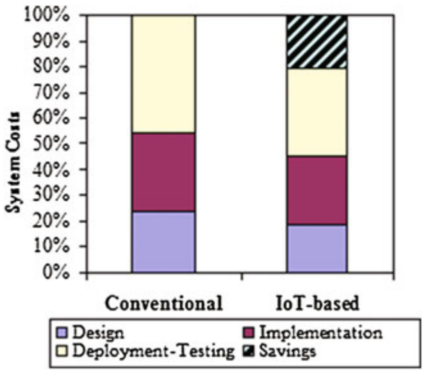

Fig. 2 Cost savings at IoT projects (quantitative), according to (Kuzmany 2010)

During the design and realization phase of a complex decentralized material flow system, there are a large number of activities and tasks involved that have diverse requirements on personnel and engineering mechanics. More specifically, the entire system must be configured in various levels (Günthner and Hompel 2010):

- System Topology: Specification of the topological information by determining the neighboring relationships between the modules while taking into account spatial restrictions.
- Workflow definition: Although control of the system including the respective handling strategies will be decentralized deployed, the global system functions should be collaboratively determined and agreed upon
- Configuration of individual Modules: In order for software agents to communicate with the underlying machine layer, the intermediate middleware layer should be properly configured.
- Distribution of the Control Software: The developed software has to be distributed to the mechatronic modules.

To support the execution of the above-mentioned tasks, manufactures, planners, and system integrators can employ a large number of software tools (Fig. 3). However, these tools are task specific offering individual solutions, and therefore, they are not optimal for the use case of designing automation systems in the logistics area. Based on the current practice regarding the joint development of large in-house material handling projects, collaboration takes place in a multitude of media and is characterized with a large number of e-mails that are exchanged between the project partners. Meanwhile, source code files, documentation, and test information reside in various formats such as text, application data, and simulation project files.

The absence of transparency regarding collaboration between partners can only be counteracted with a high organizational cost taken up from all participating sides and which consequently leads to a rise in the project's development costs (Morinaga et. al. 2006). The aforementioned expenses rise, respectively, with a larger number of collaborating parties, greater distance between the sites, and time zone differences. In order to fully exploit the potential of decentralization in the control schemes of material flow systems, and taking into account the lack of standardization in this

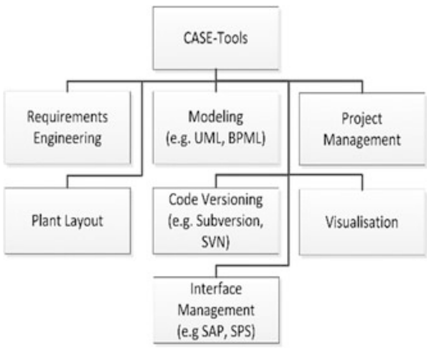

Fig. 3 Software tools used in material handling systems development process

area, there is a need of collaborative engineering concepts, which will allow system manufactures to effectively work together on project-specific activities. Moreover, to take advantage of the full potential of IoT-based systems, configuration and testing can be performed early and in-house from the manufacturers rather than late and at the customer's facility.

Cloud-Based Collaboration Platform

In this section, we introduce the KoDeMat collaboration platform, and we describe its architecture and main components.

Domain Description—Requirements—System Functions

As described in the previously, owing to an absence of standardization and to the heterogeneity of application domains, the interoperability between different agent-based controlled systems is not guaranteed. In joint projects, several manufacturers are called to integrate their products as subsystems in a larger "overall" system, which will furthermore have to be integrated with a client existing facility. Based on the current industry practices, the design and integration processes are carried out at client premises, without making full use of the advantages of decentralization, namely, the flexibility and reusability.

To address the challenges that arise, there is the need for Internet-enabled ICT Software tools for providing collaboration services that support the processes of design, implementation, and deployment of heterogeneous in-house logistics systems. The proposed solution in this work is KoDeMat, a platform that aims to be used during the system design phase, when the various subsystems must be configured to be compatible with each other, and later until the run-up phase, where it can be used to test and visualize the operation of the resulted system. However, it is not meant as a replacement for the respective subsystem simulation software. The software targets developers, planners, and system integrators. Prerequisites include that the involved project partners are interconnected via a virtual private network (Fig. 4) and that every partner has access to agent-based simulation software of his respective logistics system so that a virtual merge of the subsystems into a joint system is possible before deploying the system. The resulting material flow system will be totally independent of the collaboration platform and should be functional even without the existence of it. With a view of establishing a common understanding, between diverse groups of partners, the platform should fulfill the following functional requirements:

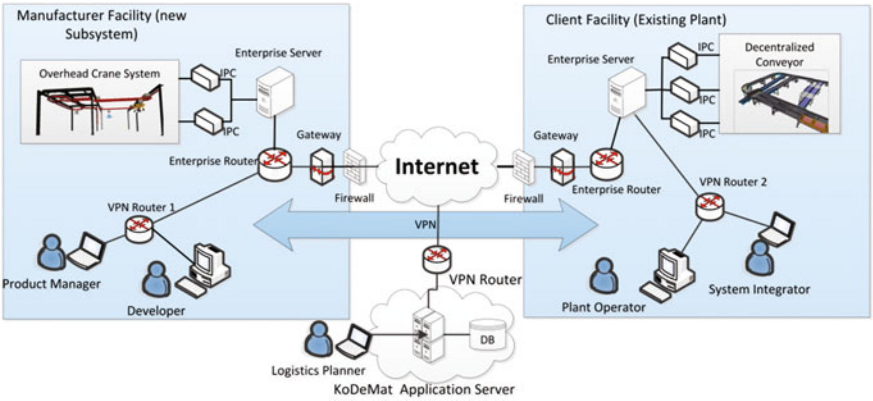

Fig. 4 The deployment diagram of a sample scenario for the KoDeMat platform

- Need for data sharing: The relevant data such as system topology, telegram specifications, module details, and so on should be shared among the involved partners and exported/imported through service interfaces.
- Synchronous and Asynchronous Collaboration: Users should be able to connect to the platform and join an active session at any time. Moreover, changes will be performed concurrently on the same data; therefore, data integrity should be preserved.
- Every synchronized object is required to keep a history of the changes that were performed on it. Based on this status history, a reverse of the changes can be invoked from each user.
- Authentication and Authorization: For each individual user and party, there should be given the possibility to allow specific permissions and access to specific features (e.g., update/commit).

In a multi-user collaboration scenario, every single user should be provided with the freedom to perform changes and also target that the editing group reaches an agreement (Kamrani and Nasr 2008). These are two conflicting goals when one or more users work at the same time and on the same objects. To provide a useful collaboration environment, a very strict reliability and a deterministic behavior of the system had to be ensured. It is clear that all undo actions by different users should result in a deterministic behavior of the global system, and no user can destroy the changes of other users or alter the history of changes to an object.

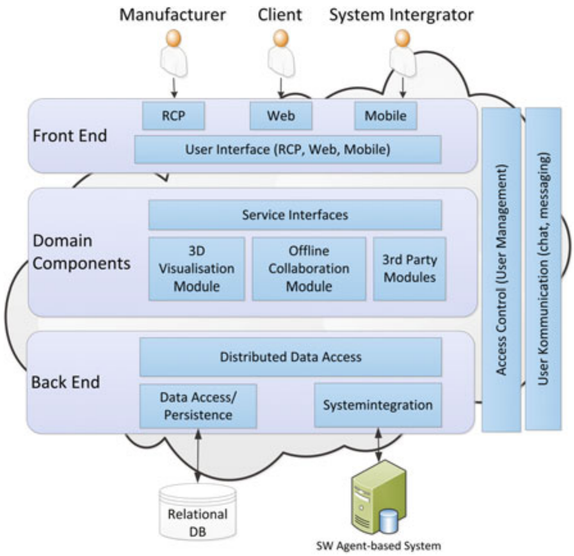

Fig. 5 High-level architecture of the KoDeMat platform

High-Level Software Architecture

The KoDeMat platform is modular and based on a service-oriented architecture. It consists of the following main elements (Fig. 5):

- A frontend that provides a single point of access with and customization facilities for individual users, including integrated and easy-to-use facilities for real-time communication and information exchange between business partners.
- A cloud-based layer and technical architecture, wherein domain-specific capabilities, named "Modules" for better supporting the visualizing and configuring of logistics system design processes.
- A back-end layer, which is a distributed cluster that is responsible for synchronizing data between clients and supports the integration of external business systems (e.g., agent-based controlled material flow systems, standard business software) as well as importing and exporting data into and from the platform.

Designing a Plant Layout with the 3D Visualization Module

The module layer builds on top of the platform's back end and offers a set of customizable services that allows definition of domain-specific data for specific use case scenarios. In this context, the visualization module is provided as an example of such a service. With a view of enhancing the collaboration experience, the visualization module uses visual metaphors that aim to promote a common understanding between the users, by allowing the simultaneous interaction of users

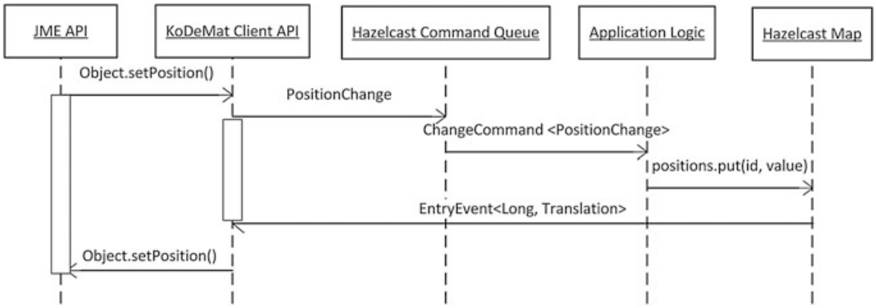

Fig. 6 Sequence diagram of the message flow by repositioning of 3D model objects

and object models in the 3D virtual environment. To accomplish this, a 3D graphics engine based on java, namely, the JMonkeyEngine (JME, Kusterer 2013) is employed. The users are expected to import 3D models of their respective subsystems that are subsequently synchronized in the platform. Figure 6 shows the messages that are exchanged between the platform entities in order to communicate the change in a 3D object's position. Each change request is added to a command queue that keeps a track of the action and time that was submitted, while the application logic handles all requests in a guaranteed fashion. IMap data structures as described in Hazelcast (2013) are used for storing the object state and attributes so that the new clients who join a session can retrieve it.

The 3D-visualization module supports the following user interactions:

- Import and edit of system 3D models and images (for instance, system CAD models and facility ground view data). The changes performed by one user are immediately communicated to all users. The history of changes at any object is also stored on a per-object basis.
- API, which enables the connection to external systems and third-party services, such as visualization agents of decentralized controlled plants.
- Support of a logistics layout editor: Operations such as moving, rotating, and deleting can be performed on the 3D objects. Users can furthermore define interfaces among the subsystems (e.g., interconnection points) and assign logistics functions such as transport, switching, or merging. The module also offers the possibility of exporting (importing) the resulting topology in a standardized XML graph format, namely, the open GEXF format (Gephi 2013).

Use Case Scenario: Connecting Two Remote Test Pilot Plants

To demonstrate the platform's functionality, we present a scenario where two agent-based controlled material handling pilot plants located in the test facilities of the participating institutes were merged in a virtual joint system. Specifically, at the

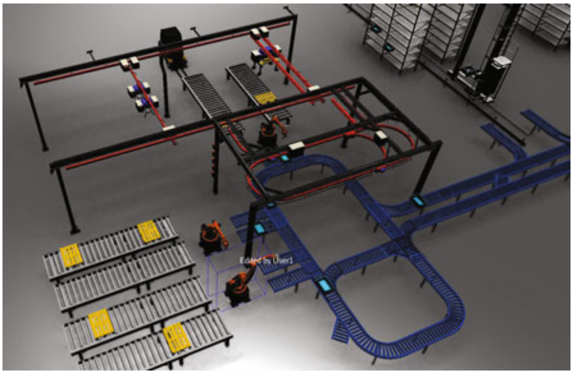

Fig. 7 Screenshot of the implemented software platform visualization module. In this, a material flow system is shown, visualizing the virtual joint operation of two subsystems (overhead monorail system and conveyor pilot plant) that are remotely located on the two participating research institutes

institute FLW in Dortmund operates a conveyor system that is composed of several components such as branching points, rotary tables, and conveyor roller belt, each of which is individually controlled by an industrial PC, the test facility of the Institute for Materials Handling, Material Flow. Logistics (fml) in Munich is equipped with an electric overhead system pilot plant. This plant consists of a circular path with three switch points, a single-carrier crane, and two single-carrier trolleys (Günthner and Tenerowicz-Wirth 2012). Both plants are based on an agent-oriented approach for the distributed control of the material flow.

In this scenario, the visualization agents of the two pilot plants are connected through an API interface to a KoDeMat client. The coordinates of each transport module's position are normalized and sent to a Hazelcast client member (Hazelcast 2013), which forwards the message to the graphics engine. This is done for each connected system, allowing users to simultaneously visualize the state of every connected system in a 3D virtual environment. Additionally, using the platform's back end, the users can interact with each other as well with the models. Example of such interaction is highlighting a position on a handling system to indicate a possible deadlock or adding a visual marking on a specific position of the 3D model to draw attention of other users for a potential operational problem. In Fig. 7, such a behavior is demonstrated in the screenshot of the perspective of a user connected to the platform.

Summary and Ongoing Work

In this article, we presented a cloud-based software platform that enables an efficient collaboration between partners working in joint projects of integrating heterogeneous decentralized material flow systems. Through the introduction of decentralized systems that support development of large systems, the design and testing can be performed remotely as a form of "in-house" testing, thus leading to time and cost savings. In the future, with Internet technologies presenting increased possibilities in terms of speed, reliability, and business penetration, it is expected that collaborative engineering concepts will be gaining in importance and enable small- and medium-sized companies to increase their competiveness in the global market.

The case of off-line collaboration, i.e., versioning of object states was not addressed in this work. There is currently ongoing work on this topic with a goal of integrating open-source frameworks for allowing users to commit, update, and merge their models and data (layout and interface specifications). Support for conflict detection and resolution in a fashion similar to popular code versioning products is also under development.

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References

Chisu R (2010) Kommunikations- und Steuerungsstrategien für das Internet der Dinge. Dissertation, Technische Universtität München, Institute fml, Garching

Gephi (2013) The open graph visualization platform. https://gephi.org/. Accessed 10 Oct 2013

Günthner WA, Hompel MT (2010) Internet der Dinge in der Intralogistik. VDI-Buch. Springer, Berlin

Günthner WA, Tenerowicz-Wirth P (2012) Agent-based emulation of an electric overhead monorail system pilot plant. Impact Virtual, Remote, Real Logistics Labs, Commun Comput Inf Sci 282:90–101

Hazelcast (2013) An open source clustering data distribution platform for Java. http://www.hazelcast.com. Accessed 10 Oct 2013

Kamrani AK, Nasr EA (2008) Collaborative engineering. Theory and practice. Springer, New York

Kusterer R (2013) jMonkeyEngine 3.0 beginner's guide. Develop professional 3D games for desktop, web, and mobile, all in the familiar Java programming language. Packt Publ, Birmingham

Kuzmany FA (2010) Konzeption und Entwicklung von Modulen für das Internet der Dinge. Dissertation, Technische Universität München, Institute fml, Garching

Libert S (2011) Beitrag zur agentenbasierten Gestaltung von Materialflusssteuerungen. Logistik für die Praxis. Verl. Praxiswissen, Dortmund

Mayer SH (2009) Development of a completely decentralized control system for modular continuous conveyor systems. Dissertation, University-Verl. Karlsruhe, Karlsruhe

Morinaga H, Kakinuma H, Ito T, Higashiki T (2006) Development of a platform for collaborative engineering data flow between design and manufacturing

Windt K, Hülsmann M (2007) Understanding autonomous cooperation and control in logistics. The impact of autonomy on management, information, communication and material flow. Springer, Berlin

Preactive Maintenance—A Modernized Approach for Efficient Operation of Offshore Wind Turbines

Stephan Oelker, Marco Lewandowski, Abderrahim Ait Alla and Klaus-Dieter Thoben

Abstract Operation and maintenance of offshore wind turbines (OWTs) play an important role to guaranty and improve the reliability, availability, and sustainability during the life time of an OWT. Common maintenance approaches from reactive to preventive maintenance show difficulties in being applied throughout offshore wind park operations. In the field of preventive maintenance, the condition-based maintenance shows a significant upturn. This paper gives a valuable insight into a modernized approach to "preactive" measures in different dimensions. To this end, existing approaches for condition-based maintenance are pointed out. Based on this knowledge, a new approach, using existing information and knowledge to encounter relevant events, is introduced. A maintenance strategy by context enables a dynamical adjustment of maintenance time slots based on different information, like, for example, weather, the general condition of a wind turbine, and availability of staff. Finally, the concept will be illustrated with an example.

Keywords Maintenance concepts · Offshore wind park · Preactive maintenance · Data and information management

S. Oelker (✉) · A. Ait Alla · K.-D. Thoben
BIBA—Bremer Institut für Produktion und Logistik GmbH, Bremen, Germany
e-mail: oel@biba.uni-bremen.de

A. Ait Alla
e-mail: ait@biba.uni-bremen.de

K.-D. Thoben
e-mail: tho@biba.uni-bremen.de

M. Lewandowski
Universität Bremen, LogDynamics, Bremen, Germany
e-mail: lew@biba.uni-bremen.de

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Introduction and Problem Description

Common maintenance approaches from corrective to preventive maintenance still show difficulties in being applied throughout offshore wind park operations. The operational reality implies that different maintenance concepts are combined at the same time in order to deal with uncertainty, e.g., in unexpected faults, access conditions, and availability of resources. Due to diverse components with specific technical or compliance requirements, the single consistent application of modern maintenance approaches like, e.g., condition-based maintenance based on sensor data remains unrealistic. This paper gives a valuable insight into a modernized approach to “preactive” measures in different dimensions, investigated in a case of a German wind turbine manufacturer.

The operation and maintenance (O&M) of an offshore wind turbine (OWT) plays an import role to guarantee and improve the reliability, availability, and a sustainable energy resource during the lifetime of an OWT. The contribution cost of O&M is expected to be between 15 and 30 % of the cost of energy generated by offshore wind farms (Besnard et al. 2013; Godwin et al. 2013). Furthermore, the O&M of offshore wind has to deal with different challenges such as high installation costs, resource availability, and a harsh maritime environment. Consequently, there is an intensive interest for developing appropriate maintenance strategies and investigating various maintenance optimizations to cope with these challenges in the context of offshore wind energy. In principle, maintenance activities can be subject to two major maintenance activities: corrective maintenance and preventive maintenance (Fig. 1).

In the case of the corrective maintenance (known as **failure-based maintenance**), the maintenance activities are performed after the occurrence of the actual failure or disturbance. Regarding the preventive maintenance strategy, the maintenance activities are carried out in preventive ways in order to avoid any possible failures. In addition, the **preventive maintenance** can be subdivided into two categories: (1) **time-based maintenance**, which means that the maintenance and inspection of wind turbines are carried out, e.g., at an interval of a predefined

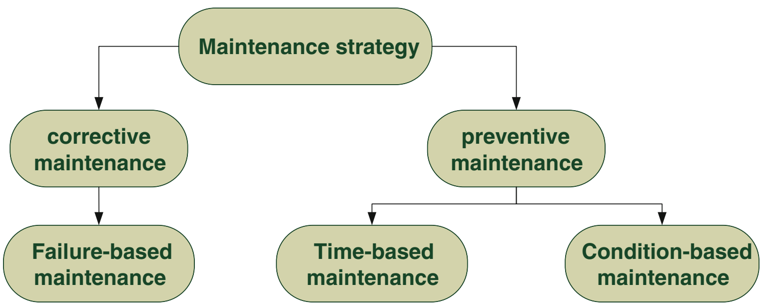

Fig. 1 Systematics of maintenance strategies (*source* SSI-EN 13306 2001)

number of operating hours or after a particular time horizon and (2) **condition-based maintenance** (**CBM**), which leverages a condition monitoring system, to observe different indicators, that can describe the health condition of the OWT. Hence, the maintenance program can be planned whenever one or more indicators show that the OWT is going to fail.

Due to the rapid development of modern technology and information technology, the CBM is showing a significant upturn. Indeed, CBM is considered as the most cost–beneficial strategy leveraging the continuous monitoring of wind turbine performance to determine the best time for a specific maintenance activity (Hameed et al. 2010). However, the CBM optimization has to cope with the big challenge of limited knowledge concerning failure modes and their relationship with observed data. Furthermore, due to the harsh environmental conditions at sea, it is difficult to guarantee a reliable sensor data of all wind turbine components and easily access the OWT for maintenance (Ding and Tian 2013). Therefore, maintenance practices show that the time-based and failure-based maintenance strategies are still the popular maintenance strategies adopted widely by the offshore wind industry (Andrawus et al. 2007). The O&M in offshore wind industry can leverage from the long technology experience in the field of the onshore wind industry. However, the O&M in onshore wind industry show a significant difference to the offshore wind industry. This means that shifting the experience must take various factors into consideration, such as the wind turbine size, maritime environment, and high accessibility, which distinguish both wind areas. In general, the maintenance strategy includes two main steps. First, the health condition of the wind turbine should be accurately determined and predicted. Second, based on the state prediction, the maintenance plan can be generated in order to guarantee availability of a sustainable system and reduce maintenance costs.

There are trends to exploit the data supplied by SCADA systems by means of artificial intelligence approaches so as to develop different methods that can be used to assess the state of wind turbines. Hameed et al. (2009) reviewed different techniques, methodologies, and algorithms developed to monitor the performance of main components of a wind turbine. In another paper, Hameed et al. (2010) investigated the viability and the implementation of a condition monitoring system for a wind turbine. Godwin et al. (2013) presented a robust and accurate expert system for the classification and detection of wind turbine pitch faults through SCADA data analysis. Schlechtingen and Santos (2011) developed various normal behavior models in order to monitor different signals. Through direct comparison of the model's output and the real measured signal, the estimation error can give an indication of signal behavior changes and thus possible faults can be derived. Kusiak and Verma (2012) proposed a methodology that explores fault data provided by the SCADA system and offers fault prediction at three levels: (1) fault and no-fault prediction, (2) fault category, and (3) the specific fault prediction. In this context, different data-mining algorithms have been applied to develop models predicting possible faults. Miguelanez and Lane (2010) surveyed current techniques of fault detection and diagnosis with specific focus on an offshore scenario. The authors classified these techniques into two main categories: model-free methods and model-based methods.

Regarding the maintenance planning strategies, there are numerous authors who have investigated the benefits of corrective, preventive, and CBM in wind industry in their literature. Ding (2010) investigated the benefits of the application of each maintenance strategy considering the case of multiple-turbine wind farms. To this end, they developed an optimization model in order to optimize the average maintenance cost for each strategy. Besnard et al. (2009) presented an opportunistic maintenance optimization model for offshore wind power systems. The proposed model consists of a mathematical integer optimization model, which takes wind forecast and corrective maintenance activities in order to perform optimal planning of corrective and preventive time-based maintenance activities with the objective of minimizing maintenance costs. Wojciechowski (2010) investigated the opportunistic maintenance problem by means of a stochastic programming approach, which takes the problem of uncertainties such as weather forecasts and lifetime of components into consideration. The objective of the stochastic optimization is the minimization of maintenance costs for the corrective and preventive maintenance activities. Besnard and Bertling (2010) presented an approach to optimize CBM strategies for components whose degradation can be classified regarding the severity of the damage. The proposed optimization model was tested for wind turbine blades. The maintenance of the components is based on visual inspection, inspection with condition monitoring, or online condition monitoring systems. Furthermore, the authors used the Monte Carlo simulation to estimate the maintenance costs. A simulation method was proposed to evaluate expected life cycle maintenance costs for inspection based on maintenance strategies as well as maintenance based on online condition monitoring. In further work, Besnard et al. (2013) presented a model for optimizing the maintenance support organization of an offshore wind farm. The model considers decisions regarding the location of the maintenance accommodation, the number of technicians, the choice of vessels, and the use of helicopters. Bian et al. (2012) proposed a method to optimize the offshore wind farm maintenance strategies by network planning. The objective is to minimize the total cost, by taking different factors, such as weather, boat availability, and the location of the wind farm into account. Sorensen (2009) described a risk-based life cycle approach for optimal planning of O&M of OWTs which is based on the preposterior Bayesian decision theory. There is significant uncertainty in the inspection and monitoring of deterioration mechanisms such as fatigue, corrosion, wear, and erosion before failure of the component occurs. The described approach requires a damage model subjected to uncertainty, a decision rule used to choose the maintenance actions based on information from inspection, stochastic models for the uncertain parameters, and cost models for the costs along the life cycle.

Most of the literature existing nowadays and cited earlier deals either with the development of suitable health conditions for **individual** components of wind turbines or the optimization of maintenance activities in which the maintenance strategy should have been adopted already. However a few papers have drawn attention to integrative challenges by combining the health condition assessment for OWT with **multiple** components as well as the optimization of maintenance activities in offshore wind scenarios. This has already been done in the context of onshore industry but is still in development for offshore industry (Garcia et al. 2006). Indeed, Garcia et al. (2006) developed a maintenance framework for onshore wind energy which is able to optimize and dynamically adapt a maintenance calendar for a monitored wind turbine according to the real needs and operating life. Furthermore, their proposed software application takes the information coming in real time from condition monitoring systems and other information sources into account, in order to detect possible anomalies in the normal behavior of the industrial components.

The purpose of this paper is to fill this gap in an offshore wind scenario and presents a new preactive maintenance framework addressed to process different information provided from different sources in real time. These sources include CMS, maintenance archives, weather forecast, and resource availability, in order to optimize the planning of corrective maintenance, CBM as well as time-based maintenance activities in a mixed but practically used strategy.

Approach of Preactive Maintenance

As mentioned earlier, nowadays, wind park operators collect a large amount of data from different sources. From the maintenance point of view, the data will in general be used to determine the condition of a wind turbine. An easy way to do this is to define limits and match them with the data stream. Consequently, a corrective maintenance strategy has to be applied. The main difficulty with this strategy is that the planning of the maintenance measure starts with the detection of the failure, which means that in general it is already too late.

In conclusion, the data must be transferred into information first and then has to be linked to different information sources in order to gain knowledge at an early stage. For example, the historical data and the weather conditions together might be used to define the risk of a future failure of the wind turbine. Taken together with a current investigation of the sensor data streams, this risk figure gets more concrete, which means less uncertain. Failures must be detected as soon as possible, and the resources, needed for the maintenance measure, must be planned and controlled automatically by anticipating the scope of the measure. To this end, troubleshooting has to be considered in the overall context (that means the whole wind park or even several wind parks) and prioritized under multicriteria aspects.

Beside this, the preactive maintenance concept includes the continuation of preventive interval-based inspection and maintenance. Preactive in this sense, however, means that the scope of the inspection or maintenance should be adjusted according to the particular context. One hypothesis of predictive maintenance is that through the availability of information about the system and the behavior of its components, the scope of an interval-based maintenance can be dynamically adjusted to the particular needs under cost/risk considerations. Of course, the data of the preventive maintenance operation will also be used for optimization of the sociotechnical systems by planning and controlling resources such as technicians, tools, logistics, and so on. Another point is that the period for preventive maintenance measures nowadays is defined by the respective manufacturer of the component. By gaining experience and knowledge following this approach, longer intervals could be arranged in accordance with the particular needs.

Figure 2 illustrates the general components of the preactive approach. As described earlier, the fundamental basis is the mining of task-relevant information from data that are related to maintenance. A concrete software-based architecture would support this challenge with a collection of methodologies and techniques for processing the data to information.

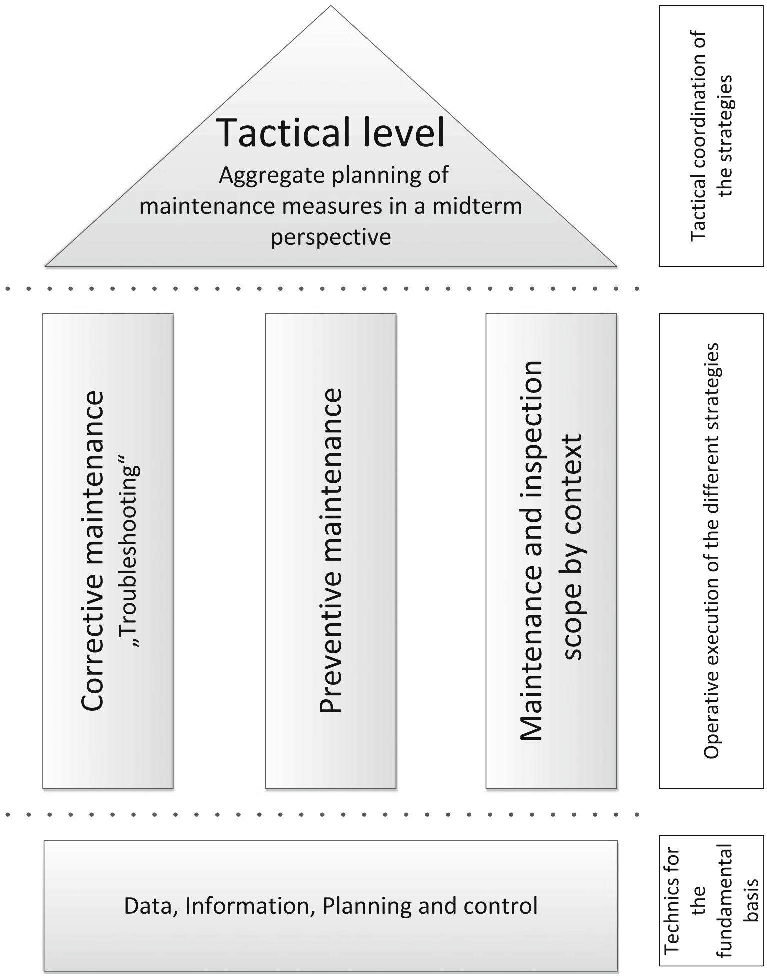

Fig. 2 General concept of the preactive maintenance approach

On top of that, the output of the basic level should support the three objectives explained earlier. First, corrective maintenance tasks (so-called troubleshooting) are supported by recognition of failures at an early stage in order to enable planning and controlling as well as the scheduling of tasks and the allocation of resources. Second, preventive maintenance as known from the literature is in particular included for some components, essentially with a linear wear-out curve. Tasks derived from these components should be evaluated according to cost/risk criteria and scheduled for instance together with other tasks. Third, the maintenance and inspection based on fixed intervals will be continued in contrast to many other condition-based approaches. Nevertheless, the data and information enable the "preactive" adoption of dynamic maintenance and inspection scopes according to the particular condition of an OWT. In the concrete preactive maintenance systems, the output of this level is the operative executions of the tasks based on an optimized order under the criteria described earlier.

The top of the concept consists of the roof that enables the change in parameters of disposition and scheduling of task and allocation of resources. The concrete architecture should address experts who coordinate the three strategies within the enterprise by giving them information and knowledge bases from the previous levels. The scope is on a tactical, mid-term level enabling a continuous improvement in the system.

First Example for Preactive Maintenance

Due to the aggregated information of the general condition of a wind turbine, it is possible to deduce a maintenance priority automatically. Preventive maintenance concepts for an offshore wind park usually prescribe that once a year, each wind turbine should be maintained. Because the weather conditions at sea are better in the summer months, the time slot for the annual maintenance is very short. Furthermore, other circumstances such as nature conservation lead to more limitations. Because of that, the operative process has to be very efficient and disturbances such as sudden failures must be avoided.

In this context, one of the main questions is which is the most suitable sequence for maintaining the wind turbines? Aggregated information and ratings are needed in order to schedule on the basis of the particular context or condition. An indicator for scheduling, e.g., is the knowledge about the condition of each wind turbine (Fig. 3). Potential damage or breakdowns could be avoided through early maintenance activities.

Another point regards the annual maintenance scope. Today, the time slots between maintenance measures for each component are defined by the manufacturer of the component on the basis of statistical data. Due to the availability of information about the behavior of the wind turbine and the components, the times lots, and scopes could be dynamically adjusted. On the one hand, inefficient measures could be avoided and on the other hand the obtained data could be used

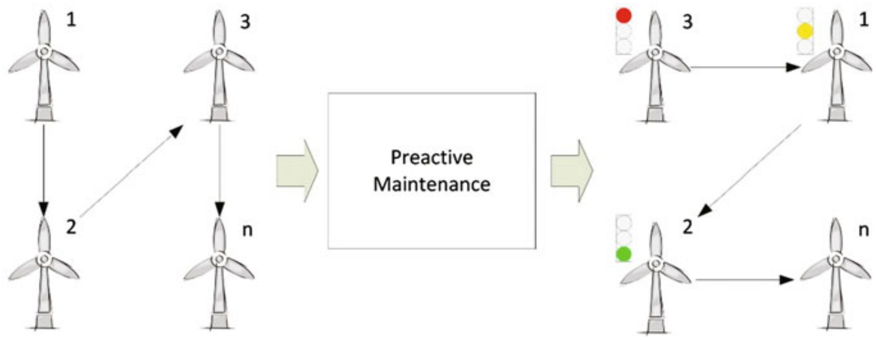

Fig. 3 Example of the preactive maintenance approach for an annual maintenance in wind parks

for improving the wind turbine. It naturally isn't possible to ignore the manufacturer's instructions, but on a mid-term perspective and maybe with the support of the manufacturer, maintenance based on the context and condition is more efficient than the classical concepts.

Besides, there are further examples of how the general approach could optimize the O&M system, e.g., by arranging inspection and general maintenance together with troubleshooting of mistakes that have occurred.

Conclusion

In conclusion, the general conditions offshore have to be considered within the planning of maintenance measures. Due to this, the successful maintenance concepts for the landside cannot be copied one by one. Instead of that, the O&M have to learn how to handle the circumstances offshore and find new ways for efficient maintenance processes. The introduced concept of preactive maintenance is an approach that uses existing information and knowledge to encounter the particular best-fitting maintenance strategy. Outputs are relevant operational events. Next tasks will include the development and implementation of techniques for the fundamental processing basis. The case of wind park maintenance will be observed in order to cope with other processes and challenges.

References

Andrawus JA, Watson J, Kishk M (2007) Wind turbine maintenance optimisation: principles of quantitative maintenance optimisation. Wind Eng 31(2):101–110

Besnard F, Bertling L (2010) An approach for condition-based maintenance optimization applied to wind turbine blades. IEEE Trans Sustain Energy 1(2): 77–83

Besnard F, Patriksson M, Strömberg A-B, Wojciechowski A, Bertling L (2009) An optimization framework for opportunistic maintenance of offshore wind power system. In: IEEE bucharest power tech conference

Besnard F, Fisher K, Bertling L (2013) A model for the optimization of the maintenance support organization for offshore wind farms. IEEE Trans Sustain Energy 4(2): 443–450

Bian X, Li G, Fu Y (2012) Study on offshore wind farm maintenance strategies optimization. Adv Mater Res 347: 795–799

Ding F (2010) Comparative study of maintenance strategies for wind turbine system. Master thesis, Concordia Institute for Information Systems Engineering, Montreal, Canada

Ding F, Tian Z (2013) Maintenance modeling and optimization for wind turbine systems: a review. 2013 In: International conference on quality, reliability, risk, maintenance, and safety engineering (QR2MSE)

Garcia MC, Sanz-Bobi MA, Del Pico J (2006) SIMAP: intelligent system for predictive maintenance application to the health condition monitoring of a windturbine gearbox. Comput Ind 57:552–568

Godwin JL, Matthews P, Watson C (2013) Classification and detection of electrical control system faults through SCADA data analysis. Chem Eng Trans 33:985–990. doi:10.3303/CET1333165

Hameed Z, Hong YS, Cho YM, Ahn SH, Song CK (2009) Condition monitoring and fault detection of wind turbines and related algorithms: a review. Renew Sustain Energy Rev 13 (2009):1–39

Hameed Z, Ahn SH, Cho YM (2010) Practical aspects of a condition monitoring system for a wind turbine with emphasis on its design, system architecture, testing and installation. Renewable Energy 35:879–894

Kusiak A, Verma A (2012) A data-mining approach to monitoring wind turbines. IEEE Trans Sustain Energy 3(1): 150–157

Miguelanez E, Lane D (2010) Predictive diagnosis for offshore wind turbines using holistic condition monitoring. 978-1-4244-4333-8/10/$25.00 ©2010 IEEE

Schlechtingen M, Santos IF (2011) Comparative analysis of neural network and regression based condition monitoring approaches for wind turbine fault detection. Mech Syst Signal Process 25 (5):1849–1875

Sorensen JD (2009) Framework for risk-based planning of operation and maintenance for offshore wind turbines. Wind Energy 12(5):493–506. doi:10.1002/we.344

Swedish Standards Institute (2001) Maintenance terminology. SS-EN 13306, 2001

Wojciechowski A (2010) On the optimization of opportunistic maintenance activities. Thesis for the Degree of Licentiate of Engineering, Göteborg, Sweden

Eco- and Cost-Efficient Personal E-mobility in Europe—An Innovative Concept for the Informational Synchronization Between E-vehicle users and the Smart Grid of the Future Using NFC Technology

Antonio Lotito, Jan Heitkötter, Moritz Quandt, Thies Beinke, Michele Pastorelli and Maurizio Fantino

Abstract Due to the European-wide target to reduce greenhouse gas emissions from the transport sector, electric mobility (EM) is considered by many countries to have a high potential to contribute to this reduction. The challenges connected to the extensive introduction of EM are the battery capacity of the vehicles, high procurements costs, and the access to charging infrastructure. Innovative user services associated with EM can contribute to establish this new technology. Therefore, this paper provides a scientific approach to use mobile devices, like e.g., smart phones or tablets, of electric vehicle users as personal energy assistants (PEAs). This PEA supports the charging process for electric vehicles (EV) associated with a specific user. The service contains user-generated loading profiles, the definition of thresholds for electricity rates by the user, battery-protecting charging management, energy-efficient navigation as well as routing assistance to specific charging stations. The communication between mobile device of the vehicle user, electric vehicle, and smart charging infrastructure is

A. Lotito (✉) · M. Fantino
Istituto Superiore Mario Boella (ISMB), Via Pier Carlo Boggio 61, 10138 Turin, Italy
e-mail: lotito@ismb.it

J. Heitkötter · M. Quandt · T. Beinke
Bremer Institut für Produktion und Logistik (BIBA), Hochschulring 20, 28359 Bremen, Germany
e-mail: hej@biba.uni-bremen.de

M. Quandt
e-mail: qua@biba.uni-bremen.de

T. Beinke
e-mail: ben@biba.uni-bremen.de

M. Pastorelli
Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Turin, Italy
e-mail: michele.pastorelli@polito.it

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enabled by near field communication (NFC). This communication standard ensures an immediate and safe communication that enables services such as mobile payment and a user-specific configuration of the charging infrastructure by a simple gesture. In conclusion and outlook, additional future services will be described that refer, e.g., to a battery health monitoring, a drive style monitoring, and driving style-related rental rates for EV.

Keywords Smart grid · NFC · Electric vehicle/mobility · Mobile devices · Wireless

Introduction

While the CO_2 emissions from other sectors are generally decreasing, the transport sector is showing a contrasting development (EIA 2013). The emissions from transport increased by 26 % from 1990 to 2008 (EC 2012), while passenger vehicles and vans accounted for more than 50 % of these greenhouse gas emissions (Hill et al. 2013). Therefore, the large-scale deployment of electric mobility (EM) can contribute to a reduced dependency on fossil fuels and the impact on the world's climate. The European Commission aspires to establish Europe-wide standards for communication and recharging infrastructure, funding for the research and development of electric vehicles (EV) and infrastructure as well as investigating the effects of EM on the electricity grid (EC 2010). Along with the efforts in the field of EM, the electricity grid of the future, referred to as "smart grid" (SG), is in the focus of industry and research. The SG will allow pervasive control and monitoring of the electricity grid, by applying advanced information and communication technology. This enables all involved players to find new ways of interacting and transact innovative businesses across the SG (Farhangi 2010). On the one hand, these developments offer the possibilities to tackle challenges connected with the operation and management of future electricity systems, following from the integration of a large fleet of EVs in the electricity grid (Pecas Lopes et al. 2011), like, e.g., impacts on electricity grid stability caused by many EVs charged simultaneously in a specific area or forecast uncertainties caused in connection with spatially distributed charging infrastructure and mobility patterns of the EVs (Galus et al. 2010).

Besides the technical solutions to integrate EVs into an SG, the introduction of an SG also offers opportunities to create innovative services that combine the advantages or neutralize disadvantages connected with these new technologies. The regular charging cycles of EVs requires public charging infrastructure in addition to the common approach to charge EVs overnight at home (Kaebisch et al. 2010). Therefore, this paper introduces an approach that offers innovative services simplifying and personalizing the charging process at public charging spots by applying near-field communication (NFC) in mobile devices. In the following, this service will be named personal energy assistant (PEA).

Requirements Analysis

As the connection of the EVs and their charging infrastructure to the SG of the future tangents a wide interest group, there are also different requirements on an intelligent service to simplify and personalize the charging process at public charging infrastructure. Within this chapter, the main stakeholders of such a system will be described as well as their challenges within the dynamic environment of EM (see Table 1). Finally, the meaning of these challenges will be analyzed with respect to the requirements of the PEA.

As described in the introduction section, the main objectives of the development of the PEA will be the promotion of EM in general and the coordination of energy offers and demands. Therefore, there are four main stakeholder groups for such a system: EV users, charging spot operators, electricity suppliers, and distribution system operators.

In order to make EM more successful in the future, an approach is needed which contributes to the solution of as much challenges as possible. Therefore, the approach to be developed has to simplify the payment process at public charging infrastructure to raise the general attractiveness of such charging spots. Furthermore, the concept should provide standardized real-time data exchange between SG and EVs. This will give the possibility for balancing energy produced and consumed even on short notice. From an economic point of view, the grid balancing can be supported by applying flexible electricity rates at charging stations. The following sections of the paper will describe possible technical solutions for the implementation of such an approach as well as services considered crucial to enable a PEA.

Table 1 Challenges of EM for the stakeholder groups

Stakeholder groups	Individual challenges
EV user	1. Unsatisfying economy and range of EVs compared to vehicles with combustion engine 2. Additional costs for sustainable mobility 3. Insufficient spatial distribution of charging infrastructure
Charging spot operators (CSO)	4. High invest to build up the infrastructure 5. Operating charging spots economically 6. No generally accepted norms and standards for the energetic and informational exchange
Electricity supplier (ES)	7. Have to face a highly competitive and dynamic market 8. Efficient marketing of the energy mix
Distribution system operators (DSO)	9. Avoidance of over- and underloads in the electricity grid caused by a rising share of fluctuating renewable energies 10. Integration of a growing number of EVs into the grid

State of the Art

Currently, mobile devices allow their users to access remote services on the move and have already highlighted the new role of mobile personal assistance in different fields from medical (where people can monitor their own physical condition whenever they want and wherever they are, in order to accelerate the promotion of preventive healthcare models; Aridarma et al. 2011) to home automation (where users can manipulate appliances anytime, anywhere, letting houses become more and more automated and intelligent; Annan et al. 2012). Different research activities are also exploring the capabilities of mobile devices in automotive fields, where the mobile devices are, e.g., used to offer value-added services to driver and passengers (Campolo et al. 2012; Araújo et al. 2012).

In these new roles of personal assistants, the mobile data exchange technologies are commonly used to enable communication between mobile devices and infrastructures, sensors, actuators, appliances, and also vehicles. In this case, the wide range of communication technologies is limited considering only the subset of communication capabilities offered by mobile devices. With this restriction, the subset is mainly limited to Bluetooth, Wi-Fi, and NFC in addition to cellular GPRS and UMTS technologies. Bluetooth and Wi-Fi are already perceived as important parts of any smart energy solution, as they make deployment of smart meters and their extension into a Home Automation Network much easier. Such technologies are already used to connect electricity meters to the utility and to appliances around the home, to connect gas and water meters to the gateway as well as to collect, exchange, and check data.

Nevertheless, the aforementioned technologies are thorough as data communication technologies. They are considered not satisfying from security and user experience point of views. These perspectives are mandatory in order to define a complete and user-centric PEA that is also enabling payment via mobile devices. These motivations are the basic reasons why the authors decide to go beyond and deep investigate NFC technology. The NFC is a short-range radio technology that is mainly used for mobile payment and ticketing. The number of use cases applying NFC technology is continuously growing and includes, e.g., advertisement, home automation, education, and touristic scenarios. This growth is mainly reasoned by the ease of use: Using NFC simplifies the user experience. It is intuitive and easy to understand. There are no menus to deal with to create connections, and it is as simple as picking up an object to look at it.

Concluding, each technology has strengths and weaknesses, but for the purposes of the services related to a PEA, the authors consider the NFC technology the most promising one, useful to cover and satisfy the requirements of a PEA in terms of security, bidirectionality, versatility, reliability, and ease of use. Moreover, the NFC specifications also cover the chance to handover the NFC connection toward a second communication mean (e.g., Bluetooth or Wi-Fi), which is useful when the scenarios require, e.g., high data rate. In this case, again, the ease of use covers an important role because handover and set up of the second communication channel are transparent for the user and enable new complex scenarios.

Table 2 Charging modes for EVs (Bauer et al. 2010)

Type	kVA	Charging time	Charging method
Slow/normal	1–5	6 h	AC: 1 phase, 230 V, 16/32 A
Semi-fast/medium	10–25	1–3 h	AC: 3 phase, 230 V, 32/63 A
Fast	180–400	5–15 min	Undetermined, DC off-board charging

In conjunction with the future scenario of a widespread distribution of EVs, the issue of charging these vehicles cannot be neglected (Schuh et al. 2013). Especially for urban areas and to cover greater distances, a public charging infrastructure is needed (Bessler et al. 2011). A simple and standardized charging process is considered a key enabler to establish EVs on the market. The consideration of usability for the EV users, operability, or billing a communication between EV and electricity grid are essential for a successful introduction of EM (Kaebisch et al. 2010). Currently, there are several standardization activities considering the communication of EVs and SGs that are developed simultaneously by different standardization bodies, e.g., IEC 15118-2 for a standardized V2G communication (Kaebisch et al. 2010; Schuh et al. 2013), SAE J2293 as standard for the power line communication between DC chargers and EVs (Botsford and Szczepanek 2009), and SAE J2836/1 that establishes use cases for the communication between plug-in EVs and the electricity grid (Chatzimisios et al. 2013). Another important research theme is the impact of EVs on the electricity grid regarding different charge modes (see Table 2).

The charge mode to choose for the EV user depends on several factors. The price for the charging process will be directly connected to the charging mode. From the point of view of an electricity supplier, slow charging would be less expensive than fast charging, and energy prices will also fluctuate during the day, especially with a high amount of renewable energies in the grid. Other important factors are the actual utilization of the electricity grid at the time of charging as well as the battery of the EV that determines the charging rate depending on the used battery technology (Botsford and Szczepanek 2009).

As far as the applied or conceptualized services for public charging infrastructure are concerned, the research focuses on payment methods (Schamberger et al. 2013; Qui et al. 2012; Monteiro et al. 2012). Bessler et al. (2011) conceptualized a routing and reservation service for EV users including multimodal transport (public transport, walking distance, etc.) from the charging point to destination.

Scientific Approach

The widespread penetration of mobile devices, such as smartphones and tablets, is creating opportunities for more flexible and adaptive services and applications. At the same time, the SGs, as anticipated in the introduction, could also be able to provide services on demand and to benefit from a programmatic interaction with the users. In this scenario, EVs have a great potential, due to the energy stored in their batteries, to interact with the electricity grid. This chance, in an SG context, could also encourage the development of different technologies and approaches related to interaction with the users' smartphones. These considerations are the premises to the usage of mobile devices as PEA. The interaction between mobile devices and SG can be seen as a path to follow for developing new kind of services and applications. Here, NFC technology represents the ideal bridge technology to share data among users, vehicles, and charging stations and can be an enabler to establish different services useful for the mentioned stakeholder groups. Although all stakeholder groups are addressed, the approach to be developed will mainly focus on the EV users because of their central role in the diffusion process of EM. Nevertheless the approach generates possibilities for the other stakeholder groups to establish innovative business models.

In particular, the NFC technology, through peer-to-peer communication, is a profitable means to enable the bidirectional data exchange. The PEA, using this short-range radio technology, can greatly simplify how users gather data, interact with their environment, and share additional data. When a mobile device touches, or is held near another NFC capable device (i.e., the charging station), the device can exchange information. These data could be a link to download the agreement about the usage of recharging station, the percentage of energy sources used to recharge the batteries, the cost threshold under which the user is interested in recharging the battery, the destination of the users, the receipt of the charging payment: The possibilities are endless and the interaction is established in a very simple way, through a tap gesture.

In this approach, the authors have identified some services considered crucial to enable a PEA that generates possible benefits for the stakeholder groups. These services are as follows:

1. Charging process facilitator:
   The user can choose the specific loading profile (fast vs. normal recharge cycle) directly on his own device, which is also used as navigation unit. The service can analyze both the path to reach the destination, the remaining energy, the positions of recharging areas, and the rates for the energy. After this analysis, the service is able to suggest to the user the best trip/recharging strategy. This enables to exploit both the synergy between the charging areas to offer best rates for the user needs and dynamically changing the energy rates considering the real usage or load.
2. Cost Efficiency Algorithm:
   The PEA will provide users the chance to set some cost thresholds useful to enable an if-then-else decision support recharging tool. For example, users will be able to set a threshold value, under which recharging the vehicle, even if the remaining mileage would be enough to reach the destination and, consequently, the recharging would not be necessary. The algorithm will also be able to accept different cost thresholds for different charging levels: Typically, in fact, users are willing to pay more for recharging the battery when they really need to do it and their predisposition to pay for recharging decreases inversely with the available mileage.

3. Energy efficient navigation and routing assistance:
   Building on the findings of the state of the art, an algorithm will choose the most energy-efficient route toward a specific destination, exploiting both real-time information (i.e., traffic, road type and condition, weather condition, etc.) and vehicle-related information (i.e. number of passengers, cargo weight, etc.) together with position-based data calculated via GPS systems. The algorithm will be able to calculate the driving directions in order to minimize the energy consumption. Moreover, the algorithm will also be able to minimize both travel time to reach a charging point and waiting time, ensuring that charging spots and power are available, without overloading the grid.
4. Mobile payment:
   The payment will be possible with any NFC mobile device and will exploit peer-to-peer mode, using SNEP protocol, to send the driver's identity from the mobile device to the charging terminal and to establish a closed loop payment, loyalty, and coupon redemption (Lotito and Mazzocchi 2013). A peer-to-peer approach is chosen instead of the classic Card Emulation, to avoid the usage of the Secure Element and, consequently, to stay away from agreements with the mobile network operators and mobile device manufacturers, in order to access to the secure element, and to enable a bidirectional "secure as required" challenge response algorithm useful to provide the payment solution.

The table shows which service contributes to the accomplishment of the challenges identified in the Requirements analysis (Table 3).

The four crucial services introduced contribute to meet a wide range of the challenges for the different stakeholders identified in the requirement analysis. As the acceptance of the EV users play a vital role for a successful large-scale diffusion of EM, the challenges of the EV users are particularly considered in the PEA approach. In addition to these crucial services of the PEA that can already have an impact on the successful diffusion of EM, further services can be introduced to enable new business opportunities for the stakeholders of EM. The aforementioned services are useful only with a programmatic data exchange among the actors: users (mobile devices), vehicles (EVs), and the grid (recharging stations). Consequently, once identified the ideal channel useful to exchange data (NFC technology) and the minimal set of services useful to build a PEA, particular attention needs to be focused on data to be exchanged in order to implement the aforementioned services. The information and control signal flows of the aspired PEA solution are illustrated in Fig. 1.

Table 3 Contribution of the services to the accomplishment of the identified challenges

	No. of challenge (see Table 1)									
	EV user			CSO			ES		DSO	
Service	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	x	x	x		x			x	x	x
2.		x					x	x		
3.	x		x	x					x	x
4.		x			x	x		x		

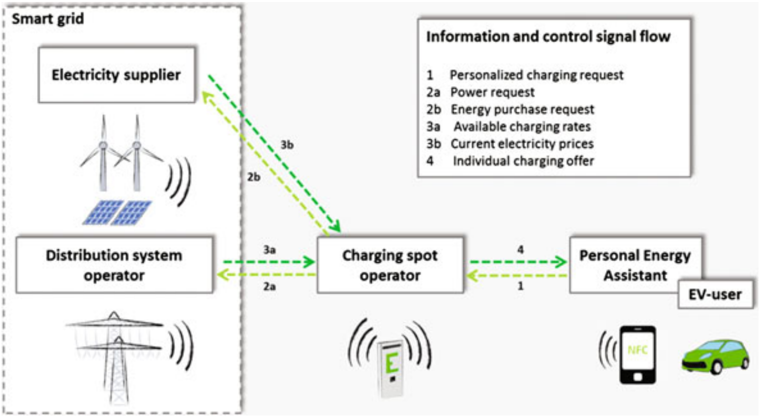

Fig. 1 Information and control signal flows associated with the PEA (following: Bernard 2013)

Other additional information are useful for the charging control, but they are not strictly necessary for the power transfer, for example:

1. Starting and ending time in which the EV is available for power/energy exchange are useful to optimize the transfer and can be encouraged by proper pricing. This means that the energy is available, with a defined maximum power for an assigned time interval and the grid manager can decide if and when to employ it;
2. best values of power/energy regarding battery life;
3. status of the battery, in order to compute the amount of energy that can be stored in the battery itself; and
4. temperature of the battery.

Conclusion and Outlook

In this paper, the authors presented an innovative EV user-centered approach to foster the diffusion of EM in Europe. This service uses mobile devices of EV users to initiate communication between users, charging infrastructure, and the SG of the future via NFC technology. The aim of the fundamental concept is to promote sustainable EM in Europe. To reach this overarching goal, the service will simplify the payment at public charging spots using NFC peer-to-peer mode. This allows the users to process the payment with a simple gesture. Furthermore, the concept allows the user to predefine individual loading profiles, which contain, e.g., the desired share of renewable energy, the acceptance of fast loading, and threshold for the price the user is willing to pay. These profiles are the basis for the implementation of flexible electricity rates, which are an extremely important instrument in order to use EVs as flexible and dynamic energy storage in a smart electricity grid. In addition, the profiles allow an increased utilization of the slow charging mode, which will lead to a higher lifetime of battery systems used in EVs.

The aforementioned services, as anticipated, represent the initial subset of services useful to achieve a PEA. The authors are already thinking about additional services useful to enhance this assistant, considering other aspects related to:

- Battery management and battery health:
  In order to maximize the battery lifetime, it is important to monitor the battery status during the use of the battery itself. Normally, the current from a battery pack is generally monitored for safety and electric drive control sensors. The measurement of the voltage across every single element of the battery can be performed to carry out a complete monitoring and control of the battery.
- Driving style monitoring:
  Analyzing the energy consumption of a trip together with data related to energy, positions, and speeds accelerations, it is possible to understand the driving style of the users: prudent, fearless, green, and so on, and once recognized a driver profile it is possible, for example in a car rental scenario, to suggest appropriate rental rates: enabling, for example sport, normal, and city center rates.

References

Annan Z, Peijie L, Shuying Ch (2012) Design and realization of home appliances control system based on the android smartphone. In: Proceeding of 2012 international conference on control engineering and communication technology

Araújo R, Igreja A, de Castro R, Araujo RE (2012) Driving coach: a smartphone application to evaluate driving efficient patterns. In: Proceedings of 2012 intelligent vehicles symposium Alcalá de Henares, Spain

Aridarma A, Mengko TL, Soegijoko S (2011) Personal medical assistant: future exploration. In: Proceeding of 2011 international conference on electrical engineering and informatics, Bandung, Indonesia, 17–19 July 2011

Bauer P, Yi Z, Doppler J, Stembridge A (2010) Charging of electric vehicles and impact on the grid. In: Mechatronika, 13th International Symposium http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5521157. Accessed 30 Oct 2013

Bernard G (2013) Slow or fast charging: how to choose? In: CHAdeMO European annual conference http://www.chademo.com/wp/wp-content/uploads/2013/02/3.Presentation_ERDF.pdf

Bessler S, Groenbaek J, Herry M, Schuster A, Tomschy R (2011) Supporting e-mobility users and utilities towards an optimized charging service. European electric vehicle congress EEVC. http://userver.ftw.at/~bessler/papers/eevc-bessler.pdf

Botsford C, Szczepanek A (2009) Fast charging versus slow charging: pros and cons for the new age of electric vehicles. In: EVS24 international battery, hybrid and fuel cell electric vehicle symposium http://www.cars21.com/assets/link/EVS-24-3960315%2520Botsford.pdf

Campolo C, Iera A, Molinaro A, Paratore SY, Ruggeri G (2012) SMaRTCaR: an integrated smartphone-based platform to support traffic management applications. In: Proceedings of first international workshop on vehicular traffic management for smart cities (VTM)

Chatzimisios P et al (2013) A survey on smart grid communications: from an architecture overview to standardization activities. Elsevier, Amsterdam

European Commission (EC) (2010) A European strategy on clean and energy efficient vehicles. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0186:FIN:EN:PDF. Accessed 17 Oct 2013

European Commission (EC) (2012) Proposal for regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0393:FIN:en:PDF. Accessed 24 Oct 2013

Farhangi H (2010) The path of the smart grid. IEEE Power Energy Mag 8(1):18–28

Galus M, Zima M, Andersson G (2010) On integration of plug-in hybrid electric vehicles into existing power system structures. Energy Policy 38(11):6736–6745

Hill N, Newman D, Kirche F (2013) Low emission car measures under the EU's CO2 regulations for passenger cars. Ricardo-AEA/R/ED58633/Issue No. 4. http://www.greenpeace.org/eu-unit/Global/eu-unit/reports-briefings/2013/Ricardo-AEA_Low-Emission-Car-Measures_final.pdf. Accessed 24 October 2013

Kaebisch S, Schmitt A, Winter M, Heuer J (2010) Interconnections and communications of electric vehicles and smart grids. In: First IEEE international conference on smart grid communications. doi:10.1109/SMARTGRID.2010.5622035

Lotito A, Mazzocchi D (2013) OPEN-SNEP project: enabling P2P over NFC using NPP and SNEP. In: Proceedings of 5th international workshop on near field communication (NFC), Zurich, Switzerland. doi:10.1109/NFC.2013.6482447

Monteiro DM, Rodrigues JJPC, Lloret J (2012) A secure NFC application for credit transfer among mobile phones. In: International conference on computer, information and telecommunication systems (CITS), pp 1–5. doi:10.1109/CITS.2012.6220369

Pecas Lopes J, Soares F, Rocha Almeida P (2011) Integration of electric vehicles in the electric power system—a conceptual framework for integrating electric vehicles into electric power systems is given; impacts and benefits arising from their use are discussed. In: Proceedings of the IEEE, vol 99, no 1, Jan 2011. doi:10.1109/JPROC.2010.2066250

Qiu Z, Luo L, Luo J (2012) A cross-platform mobile payment solution based on web technology. Spring congress on engineering and technology (S-CET), pp 1–4. doi:10.1109/SCET.2012.6341937

Schamberger R, Madlmayr G, Grechenig T (2013) Components for an interoperable NFC mobile payment ecosystem. In: 5th international workshop on near field communication (NFC), pp 1–5. doi:10.1109/NFC.2013.6482440

Schuh G, Fluhr J, Birkmeier M, Sund M (2013) Information system architecture for the interaction of electric vehicles with the power grid. In: 10th IEEE international conference on networking, sensing and control (ICNSC) 2013. doi:10.1109/ICNSC.2013.6548844

US Energy Information Administration (EIA) (2013) International energy outlook 2013. http://www.eia.gov/forecasts/ieo/pdf/0484%282013%29.pdf. Accessed 17 Oct 2013

Food Traceability Chain Supported by the Ebbits IoT Middleware

Karol Furdik, Ferry Pramudianto, Matts Ahlsén, Peter Rosengren, Peeter Kool, Song Zhenyu, Paolo Brizzi, Marek Paralic and Alexander Schneider

Abstract The paper presents the food traceability prototype, which was implemented as a pilot application of the FP7 EU project ebbits. The platform architecture, built upon the principles of the Internet of Things (IoT), People, and Services, is described in aspects of the supported interoperability and semantic orchestration of services involved in the food production chain. The platform represents physical objects as digital objects that go through different phases in the production chain. The information produced in each phase is stored by involved

F. Pramudianto (✉) · A. Schneider
Fraunhofer Institute for Applied Information Technology, Sankt Augustin, Germany
e-mail: ferry.pramudianto@fit.fraunhofer.de

A. Schneider
e-mail: alexander.schneider@fit.fraunhofer.de

M. Ahlsén · P. Rosengren · P. Kool
CNet Svenska AB, Danderyd, Sweden
e-mail: matts.ahlsen@cnet.se

P. Rosengren
e-mail: peter.rosengren@cnet.se

P. Kool
e-mail: peeter.kool@cnet.se

S. Zhenyu · P. Brizzi
Istituto Superiore Mario Boella, Turin, Italy
e-mail: song@ismb.it

P. Brizzi
e-mail: brizzi@ismb.it

K. Furdik · M. Paralic
InterSoft, a.s., Kosice, Slovakia
e-mail: karol.furdik@intersoft.sk

M. Paralic
Technical University of Košice, Košice, Slovakia
e-mail: marek.paralic@intersoft.sk; marek.paralic@tuke.sk

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actors and could be retrieved back by the consumers through orchestrating services provided by the actors in the production chain. These services are resolved by a product service orchestration, which is supported by a semantic backend.

Keywords Internet of things · Food traceability · Service orchestration

Introduction

Food traceability is nowadays considered as essential and an indispensable feature for food safety and protection of consumers (Welt and Blanchfield 2012). It typically involves the monitoring and recording of the origin and various relevant characteristics of products, while the goal is to ensure the quality of food during all the production chain, in a "from farm to fork" sequence of providers, suppliers, and consumers. Obviously, the food production and delivery process is rather complex, namely, in terms of number, geographical distribution, and heterogeneous information resources of involved actors.

To overcome some of these difficulties, the Internet of Things (IoT) and related technologies of future Internet have been identified as a suitable approach for food traceability solutions, which are, from end customers' perspective, also referenced as food awareness applications (Reiche et al. 2012). The IoT benefits of IP-based communication and data transfer, RFID and EPC standards, wireless embedded technologies as well as advanced features such as context awareness, service, and data integration enable to construct enterprise systems supporting the food traceability (Zhao et al. 2012) as well as many other application areas (Camarinha-Matos et al. 2013).

Research related to the IoT domain is extensive, and in European context, there are activities and projects under the European Research Cluster on the IoT (IERC, http://www.internet-of-things-research.eu) Specifically, the involved FP7 project SmartAgriFood addresses the innovative IoT solutions for farming, agriculture logistics, and food awareness (Brewster et al. 2012). Investigations on a unified IoT research strategy in Europe, definition of a common vision and community-building activities, are in focus of the IoT-I and IoT-A projects. Namely, IoT-A provides a general reference architecture model for the interoperability of IoT systems (Magerkurth et al. 2012), which is generic and reusable for concrete IoT application cases.

The FP7 project ebbits, which is also included in the IERC cluster, focuses its research on the architecture, technologies, and processes, which allow businesses to semantically integrate IoT into mainstream enterprise systems and support interoperable end-to-end business applications. It extends the concept of IoT on people and services by providing mechanisms for sensor-generated data fusion and its integration with the information obtained from involved actors, semantically supported context awareness and service interoperability. This approach is demonstrated on two pilot applications in domains of automotive industry and food production (Brizzi et al. 2013).

The technical solution of ebbits is based on the achievements of FP6 project Hydra (Eisenhauer et al. 2010), namely, on the semantic IoT middleware later called LinkSmart, which is available as an open source project at http://sourceforge.net/projects/linksmart/. Functionality enrichments on device networking, architecture, eventing, and so on, which resulted in a release of the currently available LinkSmart ver. 2.0, have been accomplished within the ebbits project. In the next sections of this paper, we present an adaptation of the LinkSmart middleware as an IoT enabler for the food traceability scenario, which has been accomplished within the pilot application of ebbits.

Food Traceability Scenario

The food traceability application in ebbits is particularly focused on seamless and interoperable information exchange between all the actors involved in the food production chain, which is achieved by a semantic orchestration of data generation services provided by sensors, devices, and information resources connected in a peer-to-peer (P2P) network of LinkSmart nodes.

The application scenario, schematically depicted in Fig. 1, was prepared in a cooperation with TNM A/S Denmark, http://www.tnmgruppen.dk, user partner in ebbits and the main facilitator of contacts to the respective process actors. The scenario covers the whole life cycle of product—beef meet, starting with the feeding farm through slaughtering, transport, up to the delivery to supermarkets, and to end consumers. In Fig. 1, gray ovals represent the data contained within the ebbits system as concepts in the underlying semantic model. The middle hexagons

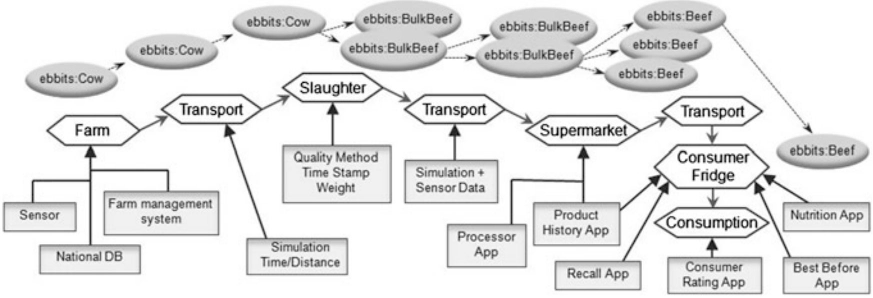

Fig. 1 Data flow and steps of the food traceability chain

represent the various states during the lifetime of the meat. The rectangular boxes represent data inputs and related application services for each state.

Data resources for the scenario in its prototype implementation have been collected for each process state. For example, the farm data came from a local farm management system and installed sensors (e.g., parameters of milking, movement of animals, etc.) as well as from The National Cattle Database in Denmark that provides information on each individual animal such as date of birth, parents ID, medical treatment, and production efficiency. Other process states are supported in a similar way—respective data resources and related data providing services are taken from dedicated sensors, specialized applications, or even simulations.

Technology and Solution

The food traceability prototype implements a decentralized architecture of LinkSmart (Kostelnik et al. 2011), where a number of ebbits applications are involved in the meat production chain. The deployment view of the prototype architecture consists of a number of geographically distributed LinkSmart server machines, which are used to execute the different applications and ebbits components of the scenario. In contrast to the food traceability solutions employing a centralized data store (Zhao et al. 2012), the distributed IoT architecture of ebbits allows autonomous data storage and information processing facilities for each of the connected data resources or applications.

The ebbits solution integrates the connected devices and information resources into a P2P network structure of nodes (or, optionally, deployed in a Cloud environment), where the communication and data transfer between the nodes are based on a loosely coupled event processing model (Furdik and Lukac 2012). Each of the connected devices is wrapped with a Web service extension, which enables to transform heterogeneous APIs of devices into uniform LinkSmart interfaces. This proxy mechanism is described in detail in the next section.

Sensors and Physical World Adaptation

In order to provide a common framework to support interactions between different "physical world" devices (e.g., a set of heterogeneous devices, actuators and subsystems) and the LinkSmart-based platform in ebbits (next referred as "ebbits platform"), a Physical World Adaption Layer (PWAL) is developed as a glue layer between them. The PWAL is composed by a set of PWAL Drivers, each one in charge of communication with a different physical device family and containing all the technology-specific logic needed to manipulate those adapted physical devices. Also, an administrative mechanism is implemented to manage different PWAL Drivers at a time, such as loading, unloading, and configuring heterogeneous physical devices. Furthermore, each adapted physical device or subsystem is

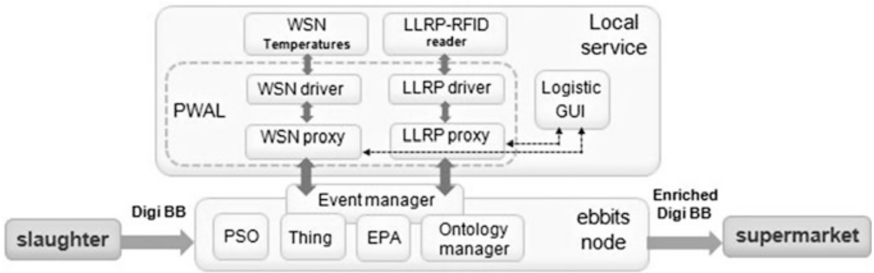

Fig. 2 PWAL components used in the food traceability scenario

represented as a virtual device in PWAL to facilitate the data fusion and transformation of the raw information obtained by the local services.

Figure 2 illustrates how PWAL works in the transport state in the food traceability scenario. In order to provide a better control of shipment, a Wireless Sensor Network (WSN)-based temperature monitoring system is mounted to the truck to record the temperature variations in the beef. Meanwhile, the Low Level Reader Protocol (LLRP) RFID readers are attached to the beef to record the identification and relevant contextual information.

The two PWAL drivers (i.e., WSN driver and LLRP driver) are managed by their software proxies, which interact with the ebbits platform through the event manager to expose the control management services for the RFID Reader and the WSN. More specifically, the event manager interacts with the event processing agent (EPA), which in turn first reads and processes the Digi-BB events generated at the slaughter state, to write the associated farming and slaughtering information into RFID tags at the beginning of the transportation. During the transportation, the temperature information collected by the WSN can be stored into an on-board PC or a temperature logger. When the temperature monitoring system on the truck is equipped with a GPRS or Wi-Fi network interface, the beef temperature variation can be stored centrally and displayed on a dedicated supervision system in real time. Otherwise, the temperature records can be manually or automatically retrieved at the end of the transportation. Finally, the transportation-related information (e.g., truck ID, transport route, and beef temperature logs) combined with the information recorded in RFID are added to the Digi-BB events, namely, Enriched Digi-BB, in Fig. 2, when the transportation completed event is detected by the event manager and is processed by the EPA. After this processing, the Enriched Digi-BB events containing the enriched traceability information (including the farming, slaughtering, and transporting information) are forwarded to the subsequent state (called supermarket in Fig. 1) in the food traceability scenario.

Semantic Model for Orchestrating the Food Traceability Services

Ebbits uses a dedicated semantic model to support the service orchestration. It is required to describe meta-information of services offered by actors involved in the food production chain, which can be retrieved by the orchestration engine. The semantic model, which combines the traceability domain model and the model of services, is derived from the IoT meta-model proposed by the IoT-A (Magerkurth et al. 2012).

As depicted in Fig. 3, the semantic model introduces a representation of various physical objects by a conceptual digital object. The digital object is abstracted by *ebbits:DigitalThing* concept, which can be inherited into more specific classes such as *ebbits:DigitalAnimal*, *ebbits:DigitalFood* and so on.

Additionally, ebbits provides an identity management that creates a unique ID for these objects and manages the references to/from related entities—for instance, to link a *Cow* object to the meat products originated from the *Cow* (Brizzi et al. 2013).

The semantic model enables us to link the digital object concepts with services that provide information and perform actions upon the objects. For instance, a digital *Cow* is linked with a service, provided by the farmer, to retrieve information about the feed and breeding record. After the cow is slaughtered, its conceptual representation is additionally linked to the service of the slaughterhouse that could provide information on the meat quality. The semantic model of services follows the OWL-S model (Martin et al. 2004), which describes concepts such as service input, output, precondition, and postcondition. These concepts are required to automate the service invocation by a service orchestration engine.

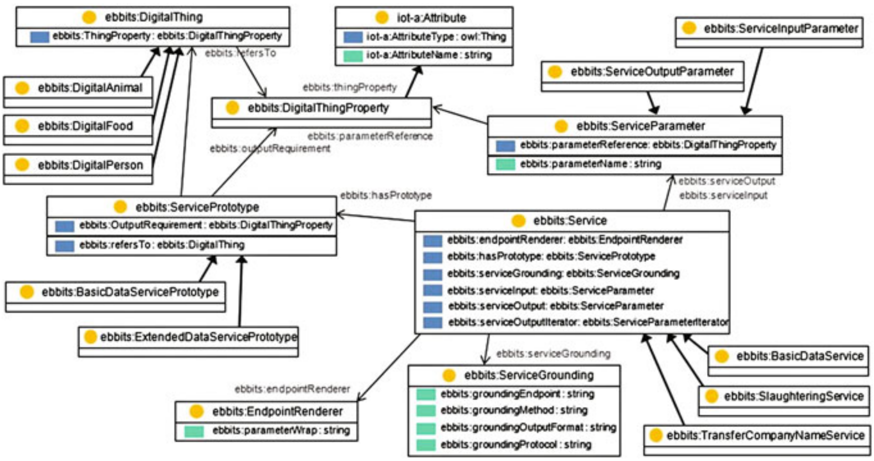

Fig. 3 Ontology schema for the traceability scenario

Thing Management

In order to manage the traceability data for specific products, in ebbits traceability processes, the *ebbits:DigitalThing* concept was transformed into the functional module "Thing" and was introduced into the LinkSmart architecture. In general, a Thing can represent any physical or digital entity. In the food traceability scenario of ebbits, the child concepts of *ebbits:DigitalThing* typically represent animals and meat products. This way, the Thing module acts as a hub for collecting product-relevant events and data and manages the storage of the collected information.

The ebbits traceability prototype is deployed as a number of nodes in a P2P network. These nodes can be considered as being independent of each other except, when a Thing is transferred to or from the node. Figure 4 shows the details of a traceability node with the Thing and the related ebbits components.

The components involved in the traceability node (cf. Fig. 4) are as follows:

- *PSO*: A definition for what needs to be traced at each step for the Things. It contains information of which events are relevant as well which services need to be invoked.
- *Thing*: Refers to an object representing the thing that is the subject of the trace. Each instance that is traced is represented by one Thing object, i.e., there will be multiple Things in most scenarios. The Thing itself contains a number of managers, the most important are *Thing Manager* provides the Thing with general traceability services. *Storage Manager* provides the Thing with storage capabilities, and the *PSO Manager* provides interfaces to local services that need to be invoked as part of the trace.
- *Ontology Manager Service Ontology*: Provides mappings of services defined in the PSO to actual local services.
- *Event Manager*: Provides simple eventing that exposes events from local services as well as from Things.
- *EPA*: Provides the functionality to move Things in between traceability nodes using event and routing rules.

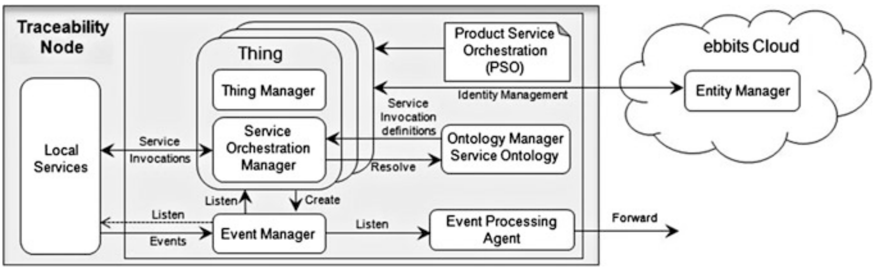

Fig. 4 Architecture of a traceability node

- *Local Services*: The services available at the node that can be invoked for retrieving different kinds of information.
- *Entity Manager*: Provides functionality for creating and maintaining globally unique identifiers and also manage the mapping to local identifiers. Note that this service is a global service and runs in the cloud.

Product Service Orchestration

The Thing component is built on top of the LinkSmart device architecture, which means that its instances contain functionality for discovery, both of individual things and publishing the existence of a thing using UPnP. The most important component related to the Thing is the PSO, which contains XML definitions of what is to be traced at different stages in the product life cycle. The Thing basically evaluates the PSO and performs the actions defined in the PSO.

The PSO describes the product life cycle and the relevant information that needs to be traced for the product. The main concepts in the PSO are as follows:

- *Product*: The overall product with all parts of the product life cycle.
- *Stage*: Represents on stage in the product life cycle. For instance, for beef a stage could be when the cow is living on the farm.
- *ThingProperties*: Contains information of what information/properties should be added to the Thing in a certain stage. Typically refers to services defined in the Service Ontology.
- *Life cycle*: Contains information of what is to be traced for the Thing during the stage. Typically, it can contain events that are to be traced as well as service invocations to be done at a certain interval or when a specific event occurs.

A simple PSO example that demonstrates the service orchestration in the food traceability scenario is presented in Fig. 5. The product life cycle starts when the *cowBorn* event occurs. The Thing will then, using the service ontology, map *basicThingData* to local service calls in order to extract basic properties of the Thing. In this case one could include race, ID, and so on. The *livingInFarm* stage parameters indicate that the *feed* will be most likely traced in future, after the service selection criteria will be specified. Furthermore, the *medication* is traced if the *medicationAdministered* event is raised. Finally, when the thing exits the stage, the *raisingCondition* service will be invoked.

The Thing Manager is the component that interprets the PSO and manages the actual tracing of properties and events for the thing (cf. Fig. 4). It also provides a Web service interface that can be invoked for all Things exposing a common interface toward external parties.

An important part of Thing manager is to maintain the history of the Thing and also to make the history available for outside parties, including end users—consumers buying a beef in supermarkets and exploring the historical data by means of

```
<?xml version="1.0" encoding="utf-8"?>
<product modelRef="EbbitsProductOntology" type="beef">
  <startCondition><event type="cowBorn"></event></startCondition>
  <stage type="livingInFarm">
    <startCondition><event type="cowBorn"></event></startCondition>
    <thingProperties><services><basicThingData/></services></thingProperties>
    <lifeCycle><services>
        <feed modelRef="ServiceOntologyID"><!-- Search criteria for selection service -->
          <frequency type="daysInBetween">1</frequency>
        </feed>
        <medication modelRef="ServiceOntologyID">
          <event type="medicationAdministered"/>
        </medication>
        <raisingCondition modelRef="ServiceOntologyID">
          <event type="onStageExit"/>
        </raisingCondition>
      </services></lifeCycle>
  </stage>
  <stage type="transport">...</stage>
</product>
```

Fig. 5 Sample PSO settings

```
<row>
    <Time>2013-06-16 23:32:15</Time>
    <Value>
      <selectedforslaughter>
        <basicthingdata>
          <cowid>116</cowid>
          <farmid>81417</farmid>
          <birthdate>2011-10-30T22:00:00Z</birthdate>
          <race>LIM</race>
          <category>6</category>
          <ecological>false</ecological>
          <recall></recall>
        </basicthingdata>
      </selectedforslaughter>
    </Value>
    <id>2</id>
  </row>
```

Fig. 6 Product history listing and mock-up of related end-user application

dedicated applications. Figure 6 depicts the mock-up user interface of the Product History application (see also in Fig. 1) presenting the traceable information on beef quality and various related parameters that were collected during the food production and recorded in the history list.

The History service, provided by the Thing manager, can be used to retrieve a complete history of the Thing. The basic format of the history, presented in the left part of Fig. 6, is quite simple, XML based, containing row elements that represent single events in the Thing—i.e., during a product life cycle. The row has a time stamp, and in the *Value* field any additional data can be placed. These additional data are either the event data from the event that triggered the history entry or the result from service invocations.

Other important aspect when dealing with the Things is the service discovery of Things, i.e., the ability to find and interact with known things at a specific place. Since the Thing is based on the LinkSmart *IoTdevice* class, the LinkSmart service discovery mechanism was adapted to the Thing. The service discovery is based on UPnP announcements.

The Thing UPnP announcements follow the UPnP/DNLA standard: Accordingly, announcements are given when a Thing is created, moved, and destroyed at regular intervals for keeping consistency. These announcements are collected by the *ThingBrowser* component of the ebbits platform. The ThingBrowser acts as a Thing catalogue providing services for querying which things are available in the traceability node and also provides the end points to the Things that can be used for calling individual Things. The ThingBrowser is intended to be used by both ebbits components and by external components/applications.

Conclusion

The presented ebbits solution of IoT-enabled meat traceability has been implemented in its prototype version, covering all the steps of the food traceability chain (see Fig. 1). The prototype gathers a real-world data from selected farms in Denmark; however, the phases of transport and selling to end consumers are simulated. Experiments accomplished so far have been focused on the interoperability and orchestration of services extracted from connected sensors, devices, and heterogeneous information resources. Deployment of the solution to a production environment is planned for the next phase of the ebbits project, where the validation of pilot applications will drive the final technical development and testing toward an integrated ebbits platform.

To facilitate an interaction with potential customers, developers, and various parties of interest, a demo of the meat traceability prototype has been assembled and regularly disseminated in fairs (CeBIT, Hannover 2012), EU IoT Week (Helsinki 2012; Vilnius 2013), Hackathon (London 2013), and in the IERC cluster. It is expected that the demonstration efforts will spread the awareness of the IoT-based food traceability solution, as well as of the ebbits platform itself, which will give the project valuable feedback for improvements.

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References

Brewster C, Wolfert S, Sundmaeker H (2012) Identifying the ICT challenges of the agri-food sector to define the architectural requirements for a future internet core platform. In: Proceedings of the eChallenges e-2012 conference, Lisbon, Portugal, 17–19 Oct

Brizzi P, Conzon D, Pramudianto F, Paralic M, Jacobsen M, Pastrone C, Tomasi R, Spirito MA (2013) The ebbits platform: leveraging on the internet of things to support meat traceability. In: Proceedings of the EFITA-WCCA-CIGR conference 'sustainable agriculture through ICT innovation', Torino, Italy, 23–27 June

Camarinha-Matos LM, Goes J, Gomes L, Martins J (2013) Contributing to the internet of things. In: Technological innovation for the internet of things, IFIP AICT Series 394/2013, Springer, Berlin, pp 3–12

Eisenhauer M, Rosengren P, Antolin P (2010) Hydra: a development platform for integrating wireless devices and sensors into ambient intelligence systems. In: The internet of things, Springer, New York, pp 367–373. doi:10.1007/978-1-4419-1674-7_36

Furdik K, Lukac G (2012) Events processing and device interoperability in a smart office IoT application. In: Proceedings of the 23rd central european conference on information and intelligent systems (CECIIS 2012), University of Zagreb, Croatia, pp 387–394

Kostelnik P, Sarnovsky M, Furdik K (2011) The semantic middleware for networked embedded systems applied in the internet of things and services domain. Scalable Comput: Pract Experience. Sci Int J Parallel Distrib Comput 12(3): 307–315

Magerkurth C et al (2012) D1.4 converged architectural reference model for the IoT v2.0. Deliverable of the internet of things architecture (IoT-A) project No. 257521

Martin D et al (2004) OWL-S: semantic markup for web services. W3C member submission, 22 Nov 2004. http://www.w3.org/Submission/OWL-S/. Accessed 22 Oct 2013

Reiche R, Lehmann RJ, Schiefer G (2012) Visions for creating food awareness with future internet technologies. Informations technologie für eine nachhaltige Landbewirtschaftung, Gesellschaft für Informatik, pp 243–246. http://gil-net.de/Publikationen/24_243.pdf. Accessed 22 Oct 2013

Welt B, Blanchfield JR (2012) Food traceability. IUFoST scientific information bulletin (SIB). http://www.iufost.org/iufostftp/IUF.SIB.Food%20Traceability.pdf. Accessed 24 Oct 2013

Zhao J, Wu L, Wang Z, Peng Y, Zhang C (2012) Research on the beef product traceability system based on the internet of things technologies. Adv Eng Forum 6–7:1203–1208. doi:10.4028/www.scientific.net/AEF.6-7.1203

A BCI System Classification Technique Using Median Filtering and Wavelet Transform

Muhammad Zeeshan Baig, Yasir Mehmood and Yasar Ayaz

Abstract The brain–computer interface (BCI) system allows us to convert brain activity into meaningful control signals. This article presents an efficient BCI signal classification technique that uses median filtering and wavelet transform (WT) to improve classification performance and reduce computational complexity. In one preprocessing step, median filtering is carried out in order to attenuate noise, and WT is used to extract features that are classified by support vector machines (SVM). The database we use for this purpose is from BCI competition-II 2003 provided by the "University of Technology, Graz." We show that using these two techniques in series, the classification accuracy can be increased up to 90 %. This method is therefore a very good approach toward designing online BCI and it is not computationally intensive.

Keywords BCI · Median filtering · Wavelet transform · SVM

Introduction

The brain–computer interface (BCI) is a device that allows brain signals to interact with the environment and to communicate with the machine. The two types of BCI are invasive in which the electrodes are mounted into the brain skin to extract signals (require surgery) and noninvasive in which electrodes are mounted on the surface of the scalp to acquire signals (McFarland and Wolpaw 2008). The BCI

M.Z. Baig (✉) · Y. Ayaz
Department of Robotics, SMME, National University of Sciences and Technology (NUST), Islamabad, Pakistan
e-mail: zeeshan@jinnah.edu.pk

Y. Ayaz
e-mail: yasar@smme.nust.edu.pk

Y. Mehmood
Communication Networks (ComNets), University of Bremen, Bremen, Germany
e-mail: ym@comnets.uni-bremen.de

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system is used to help paralysis, quadriplegics, and amyotrophic lateral sclerosis people to drive computers and machines directly by brain signals rather than by physical means, and it is equally useful for nondisabled individuals. With advances in research the BCI system can be applied to the extensive range of areas including robotics, biomedical technologies, and so on (Daly and Wolpaw 2008).

There are many sources of brain measure activities for BCI which include electroencephalogram (EEG), electrocorticography, functional magnetic resonance imaging, and magnetoencephalography (Andersen et al. 2004). The reliable and mostly used source of brain activity is EEG to input a BCI system; BCI is preferred because of the availability of noninvasive EEG electrodes and its high temporal resolution.

Several channel electrodes are available in market that include 14, 64, 128, and so on that can be used for acquirement of EEG signal. But for controlling of motor imagery-related BCI, scientists suggest to use the channels C3, C4, and Cz (Andersen et al. 2004). The main step after signal acquisition is to extract dominant features. The most widely used features are mean, variance, short-time Fourier transforms, standard deviation, recursive energy efficiency, wavelet transform (WT), and Hjorth parameters. Once the features are extracted, the next big hurdle is to classify these features efficiently with maximum accuracy in order to make an online BCI. The features vectors dimension can be reduced by applying principal component analysis or independent component analysis.

The BCI performance is measured by its classification accuracy. In order to make online classification, the classifiers must be quick enough to do real-time classification of the EEG signals. Mostly used classifier are k-nearest neighbor (KNN), support vector machine (SVM), and so on. The main objective of this writing is to show a new technique, i.e., median filtering, before extracting features to remove noise and applying WT to extract features. Both the median filtering and the WTs are very popular in designing a BCI, but there is no literature that found improvement in results after combining the above-mentioned techniques.

Related Work

Median Filtering

The mostly used nonlinear filtering method is median filtering, which efficiently degrades the interference pulse while maintaining the original characteristic of the signals. That is why it is widely used as a preprocessing technique. The length of the filtering window is describe as n where signal length is N. The output of the filter is given by the function:

$$\mathrm{med}(a_i) = \begin{cases} a_{k+1} n = 2k+1(\mathrm{Odd}) \\ \frac{[a_k + a_{k+1}]}{2}\; n = 2k(\mathrm{even}) \end{cases} \tag{1}$$

Here a_k is the k-th maximum observed data and $a_1, a_2, a_3 \ldots a_k$ are the observed data. Consider an example in which data set contains 7 samples, i.e., {2, 3.5, 1, 3, 1.5, 4, 2.5}, then the output of the median filter is 2.5. The signal will remain as it is if the pulse has a length of $k + 1$ or greater, else it will be degraded from the sequence. It is the highlighting characteristic of the median filter that it eliminates the pulse noise, and local details remain intact. After this technique, the resulting signal is then provided to the feature extraction block, where the WT is applied to the signals to extract features.

Wavelet Transform

The inability to tackle nonstationary signals is the main reason not to use the Fourier transform, as they neglect the small changes in high-frequency components (Mu et al. 2009). On the other hand, WT has the capability to distinguish spatial domain features of a signal from temporal features, so the WT way of feature extraction from low-frequency signals is very effective. The EEG signals from two of the three channels that are C3, C4 decomposed through a biorthogonal WT rather than Daubechies WT used in Bhattacharyya et al. (2010) to acquire the frequency bands of the EEG signals. The wavelet function $\psi(t) \epsilon L^2(R)$ has zero mean

$$\int_{-\infty}^{+\infty} \psi(t)\mathrm{d}t = 0$$

The mother wavelet is given by:

$$\psi_{s,u}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right)_{u,s\epsilon R,u > 0},$$

where u is the scattering parameter, s is the scaling parameter, and R defines the wavelet space. In this study, biorthogonal 6.8 (bior 6.8) mother WT is used. Table 1 shows the frequency band extracted after WT.

The wavelet and scaling function of bior 6.8 is shown in Figs.1 and 2.

Support Vector Machines

In supervised learning techniques, SVMs are very popular for classification. The SVM is generalized as linear classifiers, so it can be directly applied to both the

Table 1 Frequency band of EEG signals

Delta	0–4 Hz
Theta	4–8 Hz
Alpha	8–13 Hz
Beta	13–30 Hz

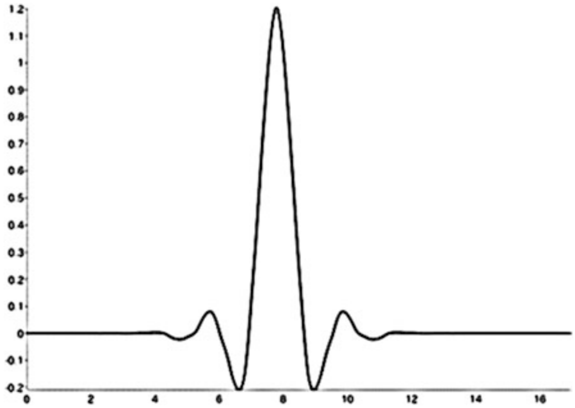

Fig. 1 Decomposition scaling function ϕ

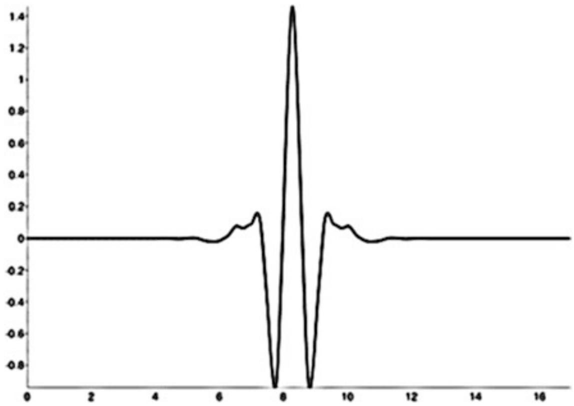

Fig. 2 Decomposition wavelet function ψ

untransformed and the nonlinear transformed feature sets of the original variables (Jakkula 2006). The SVM makes a maximal dividing hyper plane with a maximum threshold among the groups by increasing the dimensionality of feature space as shown in Fig. 3.

Consider a training set X defined as $\{x_i,\ i = 1, 2, \ldots., n\}$ belonging to one of the two ω_1 and ω_2 with corresponding labels $y_i = \pm 1$. The function $\gamma(x) = \omega^T x + \omega_0$ is known to be the discriminant function, where ω is the weight of the coefficient vector and ω_0 defines the threshold. The classifying rule is:

$$\omega^T x + \omega_0 > 0 \Rightarrow x \in \omega_1; \quad y_i = +1$$

$$\omega^T x + \omega_0 < 0 \Rightarrow x \in \omega_2; \quad y_i = -1$$

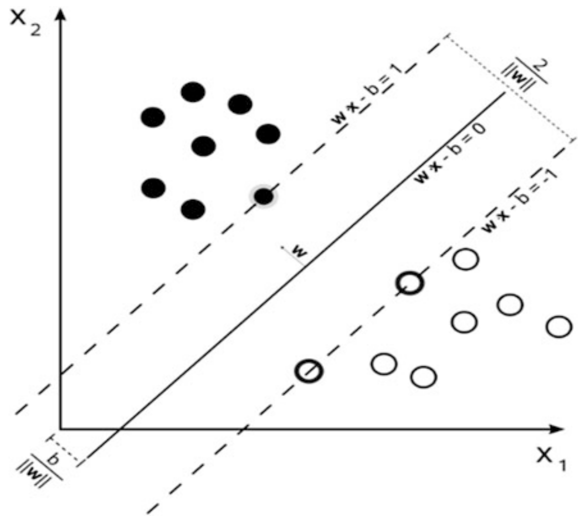

Fig. 3 An example of SVM

A margin b ($b > 0$) is introduced so that the solution becomes:

$$y_i(\omega^T x + \omega_0) \geq b,$$

where the points whose distance is greater than b form the dividing hyper plane. If $b = 1$, the canonical hyper planes ($H1$ and $H2$) are given by:

$$H_1 : \omega^T x + \omega_0 = +1$$
$$H_2 : \omega^T x + \omega_0 = -1$$

Thus we have,

$$\omega^T x + \omega_0 \geq +1; \quad \text{for } y_i = +1$$
$$\omega^T x + \omega_0 \geq -1; \quad \text{for } y_i = -1.$$

Proposed Methodology for Identification

The cycle from input to output is divided into four main groups:

(a) signal acquisition,
(b) preprocessing,
(c) feature Extraction, and
(d) classification.

The detail of each process is as follows:

Signal Acquisition

The data set was gained from BCI Competition 2003 that is named Graz data. The data set was collected from a usual subject during a reaction sitting, where the subject was comforting on a chair with supports to its arms. The goal is to move a block by giving EEG signals to the BCI consisting of left and right movement. The electrodes are placed on the scalp as on the location shown in Fig. 4.

The database contains 280 trails, each 9 s contains data of three electrodes Cz, C4, and C3 in which 140 correspond to training set and 140 correspond to testing signals. The experimental stimulus is shown in Fig. 5 in which a visual clue has been generated for 9 s consisting of a box and the subject having to move the box by generating EEG signals corresponding to left- and right-hand movement. The sampling rate is 128 Hz. The brain signals are of low frequency that is in the range of 0.3–40 Hz. Therefore, 0.5–30 Hz band is extracted through a band-pass filter (Wang and Makeig 2009).

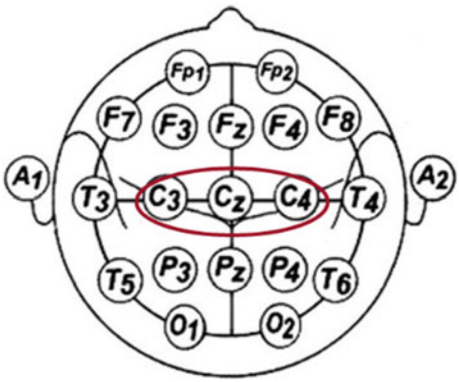

Fig. 4 Electrode placement based on the experiment

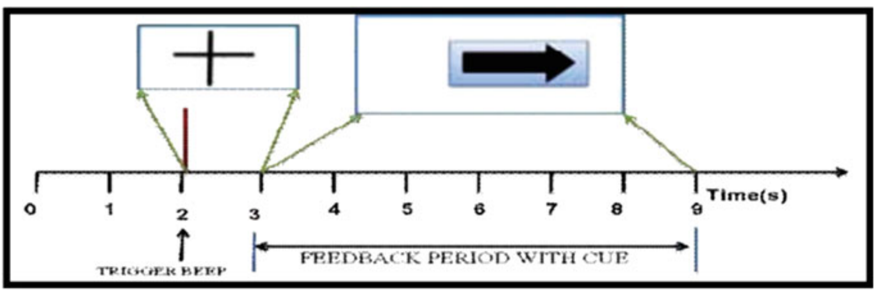

Fig. 5 Visual stimuli along with timing scheme

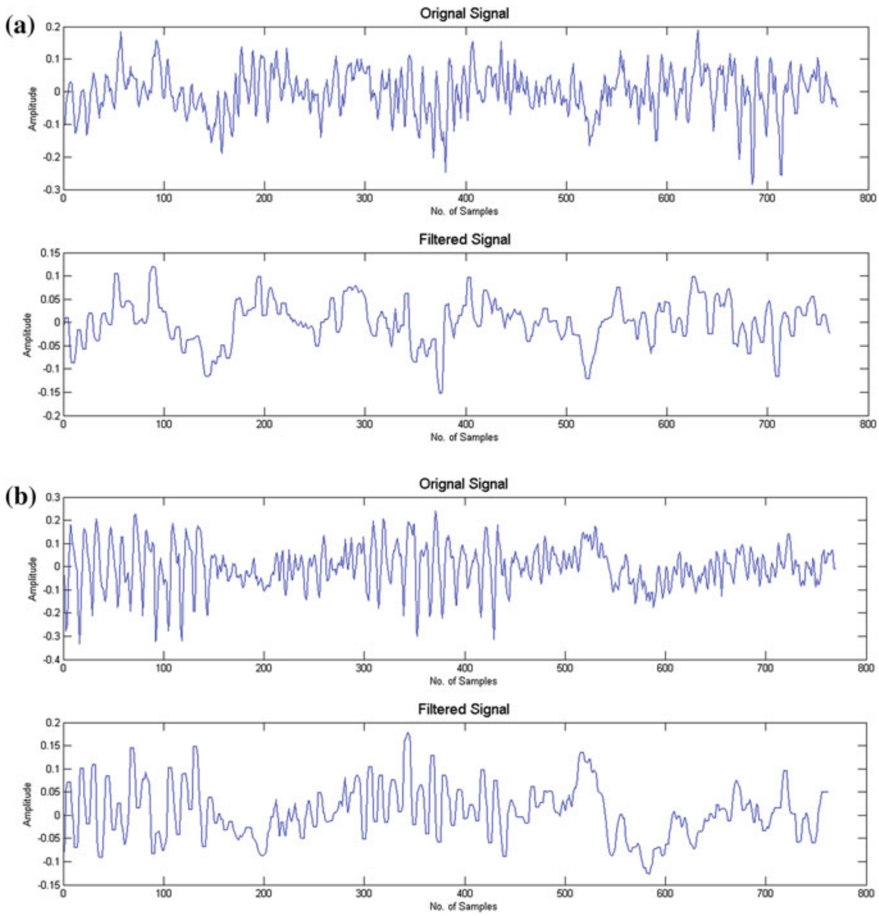

Fig. 6 Noise removal using median filtering. **a** Left-hand movement. **b** Right-hand movement

Preprocessing

In order to remove pulse noise, a median filter is applied with a window size of 50 and length with a single trail of 769. The median filter is regulated with zero mean and unity variance. The results of the median filter are shown in Fig. 6.

Feature Extraction

Feature vectors are extracted from the predefined channels C3 and C4 (Xu et al. 2009). The feature vectors are based on WT of the selected and used EEG channels. Figure 7 shows the WT coefficients that were used as a feature set.

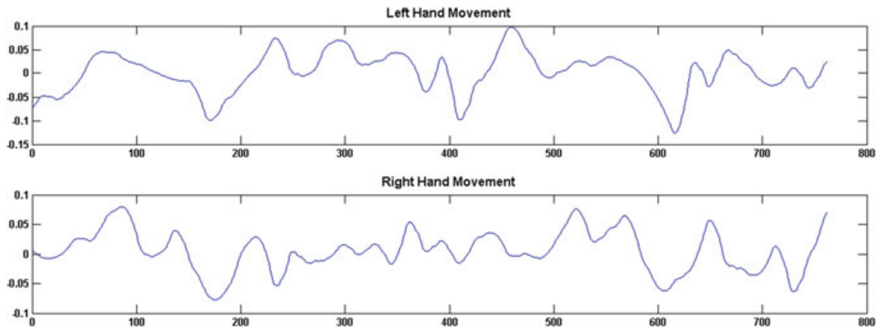

Fig. 7 Feature vector based on WT of the selected EEG channels

Classification

The classifier used for feature classification is SVM-implemented in MATLAB using SVMCLASSIFY. A total of 140 trials are used for training of SVM, and the other 140 are used for the testing of the classification results.

Performance Analysis

The features' vectors were provided to the classification algorithm mention earlier using MATLAB. The classification results presented in Bhattacharyya et al. (2011) are shown in Table 2. The results were compared to old techniques that used the LDA, QDA, kNN, and SVM and WT classifiers to extract the features with the discussed median filter-based technique.

Table 2 shows that SVM does quiet well on the data set, and SVM gives maximum classification results of 88.57 %. The performance accuracy has been increased by simply applying a suitable preprocessing technique, and in the results mentioned earlier, SVM displays a noteworthy rise in the classification results from 81.42 to 88.57 %.

Table 2 Results of classification

No.	Classification algorithms	Accuracy (old techniques) %	Accuracy(presented technique) %
1	LDA	80.30	–
2	QDA	80.50	–
3	KNN	77.50	–
4	SVM (linear)	81.42	88.57

Conclusion

In this article, we have presented an efficient approach to classify motor imagery EEG signals with supervised learning algorithm by applying a suitable preprocessing technique, i.e., median filtering to remove pulse noise and extracting features that found to be the best features for classification. The features are the coefficients of Bior 6.8 WT. A comprehensive analysis has been presented. It can be concluded that the presented technique gave the highest classification efficiency when compared to other algorithms presented in Bhattacharyya et al. (2011) and Khasnobish et al. (2010), which is also authenticated in many writings (Ince et al. 2009). The results show that the classification accuracy has been increased from 80 to 88 %. The combined approach presented here is relatively new, robust, and adaptive when compared to other techniques, so in order to drive EEG-sourced BCI devices (mobile robot), this approach requires less computation and gives maximum efficiency. Our future plan is to design a system that has the ability to classify EEG signals of motor imagery online and is able to control a mobile robot in a real environment.

References

Andersen RA, Musallam S, Pesaran B (2004) Selecting the signals for a brain–machine interface. Curr Opin Neurobiol 14(6):720–726

Bhattacharyya S, Khasnobish A, Konar A, Tibarewala DN, Nagar AK (2011) Performance analysis of left/right hand movement classification from EEG signal by intelligent algorithms. In 2011 IEEE Symposium on Computational Intelligence, Cognitive Algorithms, Mind, and Brain (CCMB). IEEE, pp 1–8

Bhattacharyya S, Khasnobish A, Chatterjee S, Konar A, Tibarewala DN (2010, December). Performance analysis of LDA, QDA and KNN algorithms in left-right limb movement classification from EEG data. In Systems in Medicine and Biology (ICSMB), 2010 International Conference on (pp. 126–131). IEEE

Daly JJ, Wolpaw JR (2008) Brain–computer interfaces in neurological rehabilitation. Lancet Neurol 7(11):1032–1043

Ince NF, Goksu F, Tewfik AH, Arica S (2009) Adapting subject specific motor imagery EEG patterns in space–time–frequency for a brain computer interface. Biomed Signal Process Control 4(3):236–246

Jakkula V (2006) Tutorial on support vector machine (svm). School of EECS, Washington State University

Khasnobish A., Bhattacharyya S., Konar A., Tibarewala, D.N. (2010) K-Nearest neighbor classification of left-right limb movement using EEG data. In International conference on Biomedical Engineering and assistive technologies, NIT Jalandhar

McFarland DJ, Wolpaw JR (2008) Brain-computer interface operation of robotic and prosthetic devices. Computer 41(10):52–56

Mu Z, Xiao D, Hu J (2009) Classification of motor imagery EEG signals based on STFTs. In 2nd international congress on image and signal processing CISP'09, pp 1–4

Wang Y, Makeig S (2009) Predicting intended movement direction using EEG from human posterior parietal cortex. In: Foundations of augmented cognition. Neuroergonomics and operational neuroscience, Springer, pp. 437–446

Xu H, Lou J, Su R, Zhang E (2009) Feature extraction and classification of EEG for imaging left-right hands movement. In: 2nd IEEE international conference on computer science and information technology ICCSIT 2009, pp. 56–59

Interaction Mechanism of Humans in a Cyber-Physical Environment

Marco Franke, Bogdan-Constantin Pirvu, Dennis Lappe, Bala-Constantin Zamfirescu, Marius Veigt, Konstantin Klein, Karl Hribernik, Klaus-Dieter Thoben and Matthias Loskyll

Abstract The research initiative "Industrie 4.0" (I4.0) of the high-tech strategy announced by the German government targets the deployment of a cyber-physical system (CPS) in production and logistics. Such CPS-based environments are characterized by an increasing number of heterogeneous intelligent autonomous and communicating artifacts tightly integrated with humans. Thus, the human's role will become a composite factor ("man-in-the-mesh") for this future CPS environment, playing more than just a simple role inside the control loop. This paper

M. Franke (✉) · D. Lappe · M. Veigt · K. Klein · K. Hribernik · K.-D. Thoben
BIBA—Bremer Institut für Produktion und Logistik, der Universität Bremen, Bremen, Germany
e-mail: fma@biba.uni-bremen.de

D. Lappe
e-mail: lap@biba.uni-bremen.de

M. Veigt
e-mail: vei@biba.uni-bremen.de

K. Klein
e-mail: kle@biba.uni-bremen.de

K. Hribernik
e-mail: hri@biba.uni-bremen.de

K.-D. Thoben
e-mail: tho@biba.uni-bremen.de

B.-C. Pirvu · B.-C. Zamfirescu · M. Loskyll
DFKI—German Research Center for Artificial Intelligence, Innovative Factory Systems, DFKI GmbH, Kaiserslautern, Germany
e-mail: Bogdan-Constantin.Pirvu@dfki.de

M. Loskyll
e-mail: Matthias.Loskyll@dfki.de

B.-C. Zamfirescu
Faculty of Engineering, Department of Computer Science and Automatic Control, ULBS—Lucian Blaga University of Sibiu, Sibiu, Romania
e-mail: Bala-Constantin.Zamfirescu@dfki.de; zbc@acm.org

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investigates the need of a robust communication between CPS and humans, which includes a clear semantic of the exchanged information. For this purpose, a mediation service and corresponding language are presented. Finally, further research activities are presented.

Keywords Interoperability of CPS · Human–machine interaction · Heterogeneous communication standards

Introduction

Current megatrends such as globalization, dynamism of product life cycles, and penetration of new technologies are requiring companies to be more agile and flexible. For example, an automotive manufacturer has to fabricate a wide range of product variants (e.g., mass customization) in a shorter development time, in order to react quickly to the client's or market's demands. To reach this flexibility in production and logistics, modular-designed production systems are required, which should be capable of interacting with similar networked components. The development of such future production systems is supported by the research initiative "Industrie 4.0[1]" (I4.0) within the high-tech strategy of the German government. The goal of this initiative is to develop and implement a *cyber-physical system* (CPS) in production and logistics (Veigt et al. 2013). A structure of a CPS is presented in Broy (2010).

A CPS poses clear-cut characteristics that differentiate it from the more conventional systems (e.g., embedded system), such as (Rajkumar 2007; Lee 2008) integral, sociable, local, irreversible, adaptive, autonomous, and highly automated. Due to the fast-evolving "intelligence" of the automated systems, the standard view of CPSs is to emphasize the integration of physical and computational elements, neglecting the essential human's role (Chituc and Restivo 2009) in solving many of the CPS's undecidable problems (NIST 2013). Therefore, in Zamfirescu et al. (2013), an anthropocentric CPS (ACPS) was defined as a reference model for factory automation that integrates the physical component, the computational/cyber component and the human component to cope with this complexity. The key characteristic of an ACPS reference model is its unified integrality, which cannot be further decomposed into smaller engineering artifacts without losing its functionality.

This paper presents an approach for the communication between the heterogeneous intelligent artifacts and the humans, which together build the most general CPS-based environment. In the next section, the key elements of the anthropocentric cyber-physical reference architecture (ACPA4SF) are summarized. In section "Prevailing Communication Content in Production", the basics for a prevailing communication are

[1]More details: http://www.hightech-strategie.de/de/59.php.

described. Furthermore, in section "Approach", a semantic virtual data integration is presented as an interaction approach between the ACPS types. Finally, the impact of such kind of communication process is given. The proposed semantic data integration approach adapts earlier work in Hribernik et al. (2010).

Anthropocentric Cyber-Physical Reference Architecture

As mentioned previously, the ACPA4SF represents an abstract reference model (i.e., meta-model) of the CPS-based environment (e.g., Smart Factory) for factory automation. The ACPA4SF is defined as a composition of four ACPS types: (1) The ACPS Production System—includes the production resources available in the factory (i.e., machines, transportation, and storage); (2) The ACPS Product Design system—includes all the necessary production knowledge to manufacture a product (i.e., manufacturing operations workflow for a product type); (3) The ACPS Planning and Control system—includes the orders from the customers in terms of product instances; and (4) The ACPS Infrastructure—includes the contextual data and control elements required by the previous ACPS types to operate in a real environment (e.g., buildings, rooms, technological infrastructure).

Among the ACPS types, there is a continuous interactions flow for exchanging the relevant knowledge (Fig. 1). For example, the ACPS Planning and Control system that reflects a product instance (i.e. intelligent product) has to manage its itinerary through the factory by negotiating with other ACPS types to get produced (it embeds instantiations from the other types). Consequently, it needs to know from the ACPS Product Design how to manufacture the product instance ("product manufacturing knowledge"), from the ACPS Production System where and when to

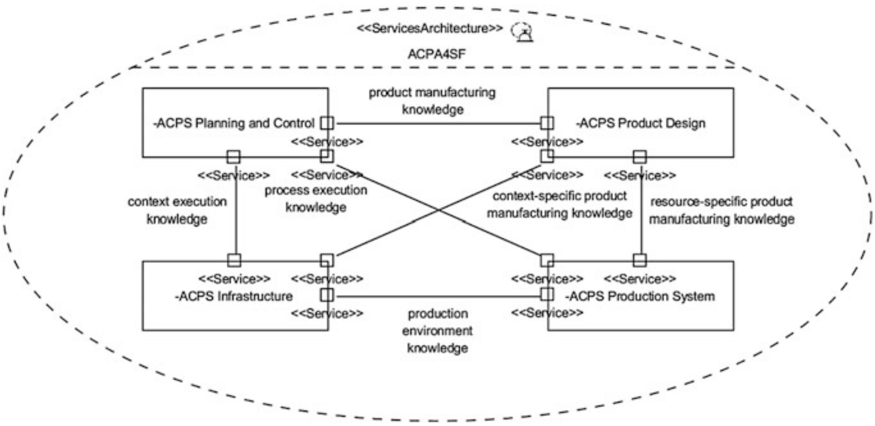

Fig. 1 The interaction among the ACPS types inside ACPA4SF (Zamfirescu et al. 2013)

execute the processing operations ("process execution knowledge"), and from the ACPS Infrastructure if the identified processing resources are reachable at reasonable costs ("context execution knowledge"). Similarly, the ACPS Product Design needs to know, from the ACPS Production System, what are the possible manufacturing operations available in the plant ("resource-specific product manufacturing knowledge") and from the ACPS Infrastructure in what context their availability is valid ("context-specific product manufacturing knowledge"). Note that all these knowledge and negotiation activities are happening in a three-dimensional space (i.e., physical, computational and human). Consequently, they should not be considered as complete automated activities, significant parts being realized via social or physical communication channels. Therefore, the services represented in Fig. 1 are aggregated services that comprise all possible services provided by an ACPS type.

From the engineering stance, the knowledge exchange among the ACPS types require the use of shared ontologies for a coherent interpretation of the messages, either among humans or among systems.

Prevailing Communication Content in Production

There are different types of "embodied" actors in a production, which cover all steps of a production process. All these actors together can be classified into two types, namely, *machines* and *humans*. The category *machine* includes classical producing machines, transport systems, and in future the range from intelligent objects over embedded systems to CPS. On the other side, the category *human* includes employees with different specializations and tasks. A communication operation can occur between all mentioned actors in any sequence. A simplified bidirectional example is given in Fig. 2.

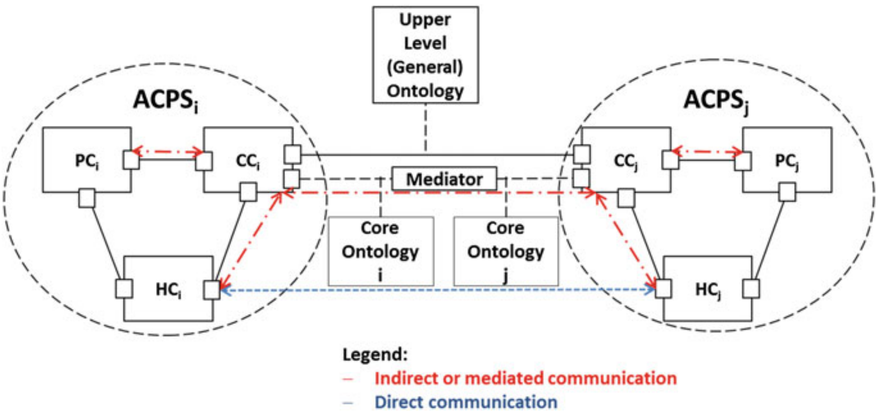

Fig. 2 Example of a communication between ACPS

As illustrated in Fig. 2, a very simplified communication operation may include both types of actors (i.e. machines and humans). The impact of CPS in the communication of future factories is motivated in Franke et al. (2013). The integration of CPS results in a higher amount of systems and in corresponding higher number of communication operations. It will increase not only the communication links between similar components but will also extend it across social, physical, and cyber boundaries. Consequently, an information request will be received by more than one type of actor. This trend will result in the need of an interoperable communication process.

All the possible communication operations from Fig. 2 have the final objective to exchange relevant information from the intentional stance. The main difference between data and information is the fact that "*...data is raw numbers and facts, information is processed data and knowledge is authenticated information ...*" (Vance 1997). Vance mentioned that information is the result of processing data. During the processing, the data will be interpreted. The interpretation process includes, for both machines and humans, the same task. To illustrate the interpretation challenges, an example of a data snippet is given in a specific data format as follows:

UNA:+.?
'UNB+UNOC:3+Senderkennung+Empfaengerkennung+060620:0931+1++1234567'

The snippet represents the sender and the recipient information of an order process. To interpret this snippet, an interpretation process needs, as minimal input, the knowledge that it is represented in the data format EDIFACT.[2] With this knowledge, the data can be transformed into information. A human would represent the same information for a communication operation not in a data format but in his native language, which can be interpreted easily by another human.

Up to now, the number of data formats, natural languages, and dialects is high and results in an interpretation challenge in communication processes.

Apart from the knowledge over the representation form of data, the interpretation of natural language and a data format requires additional information, which contains, e.g., the semantic description. In the natural language, this information is included in a terminology. The following figure demonstrates an example why a terminology is required to enable a unique information transfer between two stakeholders.

Figure 3 shows three semantic regions. Each semantic region could represent, in a real-world example, a terminology or an interpretation method of software. In all regions, the element "brake" is contained. In the upper left and lower left region, this element represents a part of a machine. In the semantic region, which is displayed upper right, the element "brake" represents not a part of a machine but plants near the ground. If a stakeholder (machine or human) uses the semantic of the left semantic region and another stakeholder use the right semantic region, the

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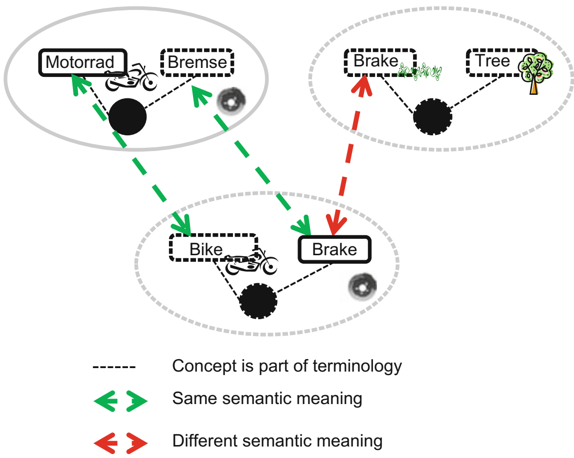
[2]More details: http://www.crossinx.de/docs/crossinx/crossinx_standard_edifact.pdf.

Fig. 3 Example for communication including different semantic



discussion over “Brake” receives a wrong but interesting meaning. Furthermore, a conversation over different concepts of terminologies includes the following restrictions, whereby the set *Concepts* contains elements of type *Concept*, the function *Syntax*(*Concept* c) returns the syntax of the input concept in an abstract form, and the function *Semantic*(*Concept* c) returns the semantic of the input concept in an abstract form.

- $\exists$ (*Concepts* $\{k_1..k_m\} \in$ **Terminology** $T_1) \in$ **Terminology** T_2
- $\exists$ (*Concepts* $\{m_1, m_m\} \in T_2) \notin T_1$
- $\exists((Syntax\ (k_i) = Syntax(m_i)) \Rightarrow \neg\ (Semantic(k_i) = Semantic(m_i)))$
- $\exists((Semantic\ (k_i) = Semantic(m_i)) \Rightarrow \neg\ (Syntax(k_i) = Syntax(m_i)))$

To handle a communication operation between two different types of actors, additional technical background facts are necessary like the chosen transport medium (oral speech, communication protocol, etc.). The amount of information required to establish a communication operation will be referred as context in this paper. In the application field of human to machine, Dey described the context as “…Context is any information that can be used to characterize the situation of an entity” (Dey 2001). An entity is a person, place, or object that is considered relevant to the interaction between the user and the application, including the user and the applications themselves…”. This general definition will be specialized by each application domain. In the application of CPS in production and logistics, the context definition is specialized into four dimensions: (i) economics situation, (ii) geographic position, (iii) administrative scenario, and (iv) culture (Frazzon et al. 2013).

The establishment of a communication process between a set of partners requires that each partner has the context information of the other ones. Furthermore, each partner must have the competency to handle the representation form and the interpretation method, which is called in the context information of each partner.

Consequently, this implies that each additional unknown partner needs to implement all representation forms and interpretation methods to get a complete understanding of the conversation and the communication with the other partners. The mentioned effects cause a high computational and communication effort and decreases the flexibility so much that it is no longer feasible in a dynamical I4.0 environment. Furthermore, a blue-collar worker cannot interpret *n* data representation forms with his skills during his normal work. Apart of the feasibilities of the communication partners, there is an unresolved communication problem in a heterogeneous communication operation. As it was mentioned earlier, the information transfer between terminologies/data formats has some restrictions. To consider these restrictions, a mediation instance is necessary (Fig. 2). The tasks of such an instance would be, e.g., to detect interpretation failures, to resolve the interpretation failures, or to communicate the open issue to the corresponding communication partners. In addition, a mediation service must be considering all common data integration conflicts (Wache 2002; Cheng 1997).

In summary, a communication operation between heterogeneous actors requires the knowledge over the contexts and the feasibility to apply it. In case of a human actor, the interpretation feasibilities are limited. To handle this circumstance, the number of different contexts has to be limited.

Approach

To achieve robust communication a virtual data integration approach is applicable. The main task of a virtual data integration approach is to receive an information request and resolve it against the dissimilar actors.

The actor who requests information is not informed about which actors have the information. This is due to the fact that the requestor gets only the result of his demand from a virtual data integration solution. The benefit of such a kind of approach is that each actor must not be aware of the context of the other ones. An information request and a corresponding result have to be modeled in such a way that the human and the system can interpret it easily. The modeling scope contains the representation form and a query language. The representation form must be satisfying the following requirements for the application in a CPS-based environment:

- Each kind of relevant information of an actor can be modeled.
- Each kind of a dependency between information can be modeled.
- The representation form is common and is applied widely.

Nowadays, relational and object-oriented databases are common data sources in current production and logistic systems. Therefore, the structural information of a database such as hierarchical structures, aggregation, or composition has to be representable in the collaborative used data model. On the other hand, the natural language and terminology require logical operators to model comparative operators such as “equal”, “same,” and its negative forms. The representation of such operators requires at least description logic, which can also represent the structure of a relational and object-oriented database. One well-known and standardized description of logics is done using ontologies. Ontology represents its knowledge in triple. Each triple is similar to a natural language and consists of a *Subject*, *Predicate,* and *Object*. The triple < Clown, hair color, red > defines that the *Subject*: Clown is connected over the *Predicate*: hair color with the *Object*: red. This kind of representation form is interpretable for both humans and systems. The usage of ontology as the common collaborative data model satisfies the three requirements mentioned earlier.

The authors choose to use OWL[3] as a concrete Ontology language. Additionally, we used the standardized RDF/XML[4] to save ontology.

Apart from the representation form, the authors have decided to use a query language for requesting information. As a baseline for this purpose SPARQL[5] was used. SPARQL offers users a query language, which is based on the triple approach mentioned earlier. In SPARQL, a variable is defined, which describes the type of information one wants to request. After that, the variable at each position in a triple can be inserted. The free position choice offers the opportunity to request the *Subject*, *Predicate,* and *Object*. In conclusion, SPARQL offers an easy query language, which can be used to request information from an ontology-based information model of an actor. For this purpose, an actor has to transform not his complete data source but only the requested information into RDF/XML. This transformation approach was applied successfully more than once using the Semantic Mediator (Hribernik et al. 2010). Up to now, the Semantic Mediator can transform information from the following data sources into ontology: *MySQL databases, CSV files, Excel sheets, EDIFACT EANCON*.

Example

The following example shows how information can both be represented and queried.

In Fig. 4, a screen capture of ontology is given. This outtake describes the fact that a *Machine* has parameters for its *name*, *tool*, *starttimestamp,* and an *endtimestamp*. If a user wants to request the selected information (see Fig. 4), he has to generate an SPARQL query. This query consists of two variables, which reflect the two requested information (*tool* and *name*), whereby the syntax of a variable always starts with the character “*?*”. In this example, all requested information take the role of the *Object* in the triple representation. For example, the value of a machine name,

[3]More details: http://www.w3.org/TR/owl-features/.

[4]More details: http://www.w3.org/TR/REC-rdf-syntax/.

[5]More details: http://www.w3.org/TR/rdf-sparql-query/.

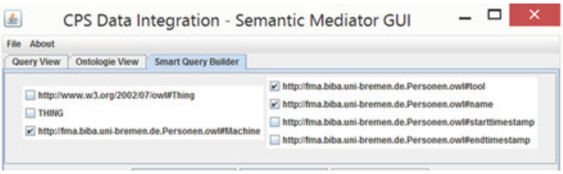


Fig. 4 Example of an ontology

which results in the triple, was requested <*Machine*, *name*, ?*C*> where ?C represents the values of the name. The complete SPARQL query is:

select ?B ?C where {?A a <Machine> . ?A <tool> ?B. ?A <name> ?C.}

As the result, the stakeholder who requested the information gets the result as an ontology or as a table.

In summary, this example shows two proceedings how information can be represented as an ontology and how the information can be requested.

Conclusion

In this paper, we have sketched fundamental concepts constituting the foundation for a robust information exchange between humans and systems, specifically CPS. It reveals the need of human intervention whenever the semantic gap between the core ontologies, used in different CPSs, require mediation for interoperability purpose among machines or blue-collar workers. This foundation motivates the humans' role in future CPS-based environments, which includes the collaborative work of humans and CPS on the same operational level. This is in line with ACPS reference model described in section "Anthropocentric Cyber-Physical Reference Architecture".

For this purpose, the authors proposed a virtual data integration approach as foundation for robust information exchange. This belongs to an ACPS-Infrastructure type in terms of ACPA4SF. The proposed virtual data integration approach uses ontology for data representation and SPARQL as query language to enable a unique information exchange between actors. Using these two methods, the increasing numbers of heterogeneous data formats and natural languages do not pose a problem any longer because each actor maps his data format/mental model into the specific (core) ontology. To shed more light on the significance and usefulness of the approach, further topics must be studied:

1. Case studies, which demonstrate the learnability of the SPARQL query language by humans.
2. Case studies, which identify relevant operating cycles in which a CPS and a human work on the same operational level. For these operating cycles, the relevant information and corresponding information flows have to be identified.

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References

Broy M (2010) Cyber-physical systems: innovation durch softwareintensive eingebettete systeme. Springer, Berlin/Heidelberg

Cheng HG (1997) Representing and Reasoning about Semantic Conflicts in Heterogeneous Information Sources. Phd. MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Chituc CM, Restivo FJ (2009) Challenges and trends in distributed manufacturing systems: are wise engineering systems the ultimate answer? In: Second international symposium on engineering systems, vol 1–15. MIT Press, Cambridge, Massachusetts

Dey A (2001) Understanding and using context. Pers Ubiquit Comput 5(1):4–7

Franke M, Zimmerling R, Hribernik KA, Lappe D, Veigt M, Thoben K-D (2013) Anforderungen an Datenintegrationslösungen in CPS. ProductivITy Management 3/2013 “Standardisierung”: 23–26

Frazzon EM, Hartmann J, Makuschewitz T, Scholz-Reiter B (2013) Towards socio-cyber-physical systems in production networks. In: Procedia CIRP, vol 51–56. Elsevier, Philadelphia, USA

Hribernik K, Kramer C, Hans C, Thoben K-D (2010) A semantic mediator for data integration in autonomous logistics processes. In: Enterprise interoperability IV. Springer, London, pp 157–167

Lee AE (2008) Cyber physical systems: design challenges. In: International symposium object/component/service-oriented real-time distributed computing. Orlando, USA, pp 363–369

NIST (2013) Foundations for innovation in cyber-physical systems. Workshop Report, Available at: http://www.nist.gov/el/upload/CPS-WorkshopReport-1-30-13-Final.pdf. Accessed on 30 Dec 2013

Rajkumar R. (2007) CPS briefing, Carnegie Mellon University

Vance DM (1997) Information, knowledge and wisdom: the epistemic hierarchy and computer-based information system. In: Proceedings of the third Americas conference on information systems. AIS, Pittsburgh, pp 348–350

Veigt M, Lappe D, Hribernik KA, Scholz-Reiter B (2013) Entwicklung eines Cyber-Physischen Logistiksystems. Industrie Management 29(1):15–18

Wache H (2002) Semantische Mediation für heterogene Informationsquellen. PhD thesis, Universität Bremen

Zamfirescu CB, Pirvu BC, Schlick J, Zuehlke D (2013) Preliminary insides for an anthropocentric cyber-physical reference architecture of the smart factory. Stud Inf Control 22(3):269–278

The Influential Factors for Application of the Electric Commercial Vehicle in the Urban Freight Transport

Molin Wang and Klaus-Dieter Thoben

Abstract With deteriorating environment and insufficient energy resource, the electric vehicle has become a solution to reduce the emissions and save the fossil energy. Many automakers begin to develop and research electric vehicles. Most governments support policies to promote the development of electric vehicles. However, the application of the electric vehicle is still in the initial stage (test and demonstration), especially for the electric commercial vehicle (ECV), which carries goods with battery systems. The objective of this paper is to describe an idea, how to apply the ECV in the urban freight transport with analyzing the influential factor.

Keywords Electric commercial vehicle · Urban freight transport · Influential factors

Introduction

With increasing global population, the demand of vehicles will be stronger in the next 50 years (Chan 2003). Fossil fuels as the primary fuel for the traditional transportation market are nonrenewable. They release the greenhouse gas (GHG) such as CO_2 and the other harmful emissions such as the particulate matter 2.5. Based on the statistics, the energy dependency rate of the EU-28 has increased to 52.8 % in 2011 (Euro Union 2013). Moreover, according to the forecasting, the global GHG emissions will increase by 90 % in 2030 without additional policies (Mattila and Antikainen 2011). In order to realize the sustainable transport, increasing environmentally friendly solutions are implemented. Electric vehicles as one of the solution are attracting increasingly global attention. Electricity is becoming the critical propulsion, instead of fuel-driven vehicles. The types of the

M. Wang (✉) · K.-D. Thoben
Bremer Institut für Produktion und Logistik GmbH, University of Bremen, Bremen, Germany
e-mail: wag@biba.uni-bremen.de

K.-D. Thoben
e-mail: tho@biba.uni-bremen.de

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electric vehicle include the Battery Electric Vehicle, the Plug-in Hybrid Electric Vehicle, the Range Extended Electric Vehicle, and the Fuel Cell Vehicle. The first two types are popular in most governments and automobile manufacturers.

The development of the electric vehicles has experienced three stages. From 1834 to the end of the nineteenth century, electric vehicles accounted for more than one-third of the total number of vehicles produced. At the beginning of the 1970s and the last several years, because of the resource shortage and the air pollution, electric power train became a research focus twice (Kley et al. 2011). Based on the German National Platform for Electric Mobility report (2012), there are more than 4500 electric vehicles on the road. However, the application of the electric vehicle is still in the initial stage, especially for the electric commercial vehicle (ECV). There are many logistic companies looking for a cooperation with the automobile manufacturers to provide a platform to apply the ECV in the real life, such as the United Parcel Service (UPS) and DHL Express.

Based on the UPS Corporate Sustainability Report (2012), UPS had 2688 alternative fuel and advanced technology vehicles in 10 countries under actual operating conditions and logged more than 295 million miles since 2000. At the beginning of 2013, UPS announced to deploy 100 fully ECVs and will reduce approximately 126,000 gallons per years (Dickey 2013). In 2011, DHL tested 12 new Renault electric vehicles for combined deliveries in Rhine-Ruhr area (Müschen 2011). In 2013, they deployed 79 electric vehicles in Bonn and surrounding area, and by 2016 the pilot region will demonstrate 141 electric vehicles on the road, then resulting in decreased CO_2 emissions of over 500 tons per year (Müschen 2013).

In spite of this, most logistics companies still apply the conventional vehicle to be the primary transportation because of many factors, such as the costs and the limitation of battery technology. The objective of this paper is to describe an idea, how to apply the ECV in the urban freight transport with analyzing the influence factors.

Motivation

Logistics freight transportation modes include truck, rail, water, air, and pipeline. They serve a distinct share of the freight transportation market. Truck and air modes are typically used for higher value, lower weight, and more time-sensitive freight. According to the statistics, in 2007, trucks moved about 72 % of all freight tonnage and released 20 % of total GHG emission in the United States (Brogan et al. 2013). In Germany, the road freight transport accounted for 66 % of inland freight transport, and the total emissions from the transport sector is the highest one, which accounted for 17 % of the total EU in 2011 (Euro Union 2013). Therefore, applying the ECV is a solution to change the status. Moreover, compared with the passenger cars, the ECV is easier to monitor and manage because of the fixed route, effective GPS, and satellite communication.

Nowadays, long charging times, short driving range, and high initial investments have become the dominant obstacles for the development of the electric vehicle. However, compared with the successful conventional automobile market, the above mentioned factors are not sufficient to explain why it is hard to apply the electric vehicle into the market. Therefore, it is necessary to analyze the successful conventional automobile market and urban freight transport, then find a way to solve the application problem of the electric vehicle.

Research Objective

The objective of my research is to find a set of influential factors, and explainwhy and how the influential factors affect the application of the ECV in the urban freight transport. The objective of this paper is to propose the above idea and describe the motivation, the research problem and the research methodology in detail. The research will develop a simulation model to describe the internal relationship between the ECV and the urban freight transport and simulate with samples to know the interaction of influential factors. The successful conventional automobile market and its requirements are the reference for the model.

Research Problem

There are three modes to classify the vehicles. Firstly, based on the different power train, the type of the automobile is divided into the conventional vehicle powered by engines and the electric vehicle powered by batteries. Secondly, based on the different fuels (gasoline, diesel, electricity, and hydrogen), the vehicles are further classified. Thirdly, according to the EU standard, vehicles are divided into passenger cars (seats $\leq$ 9), light commercial vehicles (weight $\leq$ 3.5 t), and large goods vehicles (3.5 t < weight $\leq$ 12 t, or weight > 12 t). The research tries to understand the complexity of the conventional and electric vehicles and find the influential factors, such as the time horizon, the initial costs, the velocity, and the GHG emissions to be used in the simulation model. Finally, based on the simulation, the factors will be evaluated and a solution will be derived to solve the application problem.

Research Methodology

The research method will include the literature review, survey, and simulation. The first part will focus on collecting and summarizing the influential factors from the previous literatures and then classify them into different domains, such as mechanical, environmental, chemical, and economic. Secondly, the survey will investigate and evaluate the influential factor by a questionnaire; then the research will develop a simulation model and evaluate the interaction of different influential factors. Finally, the research will summarize the best scenario and make some suggestions to the logistics companies.

References

Brogan JJ, Aeppli AE, Beagan DF, Brown A, Fischer MJ, Grenzeback LR, McKenzie E, Vimmerstedt L, Vyas AD, Witzke E (2013) Freight transportation modal shares: scenarios for a low-carbon future. Transportation energy futures series. Prepared by Cambridge Systematics, Inc. (Cambridge, MA), and the National Renewable Energy Laboratory (Golden, CO) for the U.S. Department of Energy, Washington, DC. DOE/GO-102013-3705.80

Chan CC (2003) Advances in electric vehicles. HKIE Trans 10(4):1–13

Daclison-Dickey R. (2013) 100 electric vehicles begin their journey to save 126,000 gallons of fuel per year. http://blog.ups.com/2013/02/08/100-electric-vehicles-begin-their-journey-to-save-126000-gallons-of-fuel-per-year/

Euro Union (2013) Energy, transport and environment indicators. Luxembourg

German National Platform for Electric Mobility (NPE) (2012) Progress Report of the German National Platform for Electric Mobility (Third Report). Berlin

Kley F, Lerch C, Dallinger D (2011) New business models for electric cars—a holistic approach. Energy Policy 39:3392–3403

Mattila T, Antikainen R (2011) Backcasting sustainable freight transport systems for Europe in 2050. Energy Policy 39:1241–1248

Müschen C (2011) Deutsche post road tests 12 new Renault electric vehicles. http://www.dpdhl.com/en/media_relations/press_releases/2011/deutsche_post_road_tests_12_new_renault-electric-vehicles.html

Müschen C (2013) Deutsche post DHL makes Bonn a model city for carbon-free delivery vehicles. http://www.dpdhl.com/en/media_relations/press_releases/2013/carbon-neutral_delivery_bonn.html

UPS Corporate Sustainability Report 2012 (2013). Atlanta

Modeling the Impact of Drivers' Behavior on Energy Efficiency of Medium Duty Electric Vehicles

Tessa T. Taefi

Abstract Freight electric vehicles (EVs) over 3.5 tons are of particular interest to the reduce air pollutants in the urban freight transport sector. However, one main reason why freight transport companies refrain from deploying freight EVs are their higher costs, compared to conventional vehicles. But despite their lower operational costs, the high purchase price of medium duty EVs—which are predominantly used in urban freight transport—renders them uncompetitive, compared to conventional vehicles. One possibility to raise the competitiveness of freight EVs is to increase their range by improving the drivers' behavior. This is an important leverage, since first tests with passenger EVs indicate that the drivers' behavior can influence the vehicles range with up to 30 %. Although sufficient literature about eco-drive strategies for conventional freight vehicles exists, these strategies cannot be directly transferred to freight EVs, due to technological differences, such as recuperation. The research of specific strategies for freight EVs has received little attention so far. Thus the objective of this research proposal is to measure, analyze and model the dependency of medium duty freight EVs energy consumption on the drivers' behavior, by utilizing real world test data.

Keywords Electric vehicles · Urban freight transport · Drivers behavior · Real world · Energy consuption · Eco-driving · Profitability

T.T. Taefi (✉)
Faculty of Engineering and Computer Science, Department of Mechanical Engineering and Production Management, Hamburg University of Applied Sciences, Berliner Tor 5, 20099 Hamburg, Germany
e-mail: research@taefi.de

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Introduction

Electric vehicles (EVs) are of particular interest to reduce air pollutants in the urban freight transport segment. About three-quarters of the freight is transported in the near area below 50 km in Germany (Müller et al. 2006), predominantly with vehicles over 3.5 tons (Wermuth 2012). In urban traffic, these vehicles are the main contributor to nitrogen dioxide and particulate matter (Müller et al. 2006). In contrast, EVs are highly energy efficient in urban traffic and technically suitable for many transport applications (Taefi et al. 2014a). Despite the potential to utilize EVs in urban freight transport applications, EVs accounted for only 0.09 % of the commercial vehicle population in Germany (Kraftfahrt-Bundesamt 2013). One main obstacle to the market ramp-up is the high investment, since profitability is considered the most important factor by the companies (Fraunhofer 2011; Dataforce 2011).

Motivation

To increase the utilization of EVs in urban freight transport, EVs need to become more profitable to companies. One possibility to reduce the total costs of ownership of EVs is to increase the daily kilometrage, since the operational costs of EVs per kilometer are lower and can outweigh the higher purchase price of EVs, compared to vehicles with internal combustion engine. Among the ambient temperature, topography, carried cargo, and electrical consumers, improving the drivers' behavior is a main leverage to increase the range (comp. Fig. 1). Bingham et al. (2012) state in a study on a light electric passenger vehicles, that the gap between good and bad driving styles results in up to 30 % difference in energy consumption and thus range. For heavy electric trucks of 7.5 tons, own interviews revealed that users estimated a similar potential from practical tests. For conventional trucks, literature is available on "eco-driving" strategies. In practical applications, drivers of medium duty electric vehicles are taught general eco-driving strategies, although

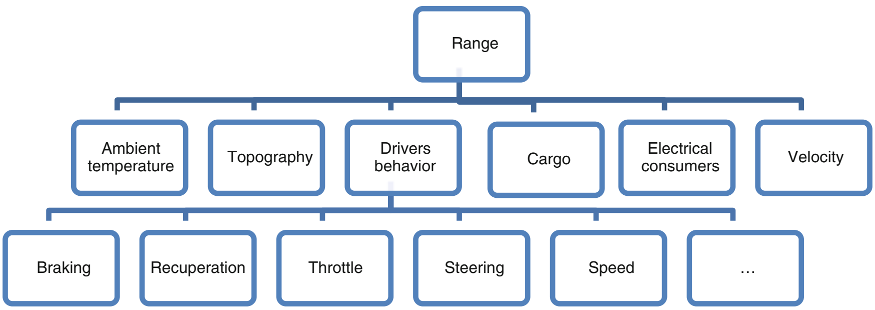

Fig. 1 Factors influencing the range of an electric vehicle

the technology differs (i.e., with regard to recuperation and gear shifting). Thus, there is an uncertainty about the strategies to attain an energy-efficient drive style for medium duty electric trucks, and whether drivers need to follow the same strategies for empty and fully loaded EVs. This makes the drivers behavior an important factor to influence the range. As modern medium duty electric vehicles only have entered the market recently, the influence of drivers' behavior on their range has not been described and analyzed in scientific literature yet.

Research Problem

In the PhD research project, factors that influence the drivers' behavior on medium duty EVs shall be examined. A vehicle of 7.5 tons is chosen for a first evaluation, as it represents a medium dutyl vehicle used often for commercial urban freight transport in Europe today (Taefi et al. 2014b). To eliminate the influence of other factors affecting the range-as described earlier-the data will be recorded with a telemetry system on a predefined real-life test track. The following questions will be answered:

- What difference on the energy consumption can be measured between different drive styles on a 7.5 tons medium duty electric vehicle?
- Which factors of the driving style influence the range to what extent?
- Are the effects the same for an empty and fully loaded vehicle?

Research Objective

The goal of this research is to find out how the driver with his driving style can affect the range of a medium duty electric vehicle and what factor he could be trained on, in order to improve the range. When being able to reach a higher kilometer range, a freight EV could be deployed on more or longer tours on one battery charge. Thus, its profitability would be increased, leading to more commercial EVs in urban freight transport tasks, which would be beneficial under environmental aspects.

Expected Results/Generated Knowledge

Research on electric passenger cars revealed that "the variance of acceleration can provide a performance indicator for 'good driving behavior' in order to maximize energy utilization" (Bingham et al. 2012). It is expected that the tests on empty medium duty EVs will confirm this finding. However, it is also expected that the drivers' behavior on average changes to a more dynamic drive style, once the vehicle is fully loaded and reacts slower to drivers acceleration and deceleration operations. Therefore, the dependency of the drivers' behavior of the carried cargo for medium duty EVs is to be analyzed in this research project.

Results will fill a gap in scientific literature. The influence of drivers' behavior on heavy commercial vehicles with internal combustion engines has been subject to research, as well as first studies on electrical passenger cars exist. To the authors' best knowledge, the influence of the driving style on the energy consumption of medium duty EVs has not been researched so far. This fact will be validated through a systematic literature review at the beginning of the study.

Apart from filling a scientific gap, the research project has significance for logistic companies. The resulting algorithm could be integrated in on-board telemetry systems for analytic prediction of the expected range. Ex-post analyses can reveal training needs of EV drivers. The potential range increase of 30 % could lead to a more profitable deployment of EVs in urban freight transport and thus to more commercial EVs and less emissions.

Research Methodology

In the study, a large amount of quantitative telemetry data from the vehicles will be statistically evaluated. Twenty drivers will drive twice (with cargoload and empty), resulting in 40 sets of data . The sampling frequency of the telemetry system will be one set of parameters per second. In order to detect and explain the impact of different parameters on the energy use of the vehicle, a regression analysis will be performed. The data will be collected cross-sectional on public urban roads and evaluated by a regression analysis. The aim is to design an algorithm to describe the causal relation between the parameters and the energy usage.

In order to eliminate the influence of other factors than the driving style according to Fig. 1, the following factors will be defined as boundaries of the study:

- **Cargo**: The tests are completed with two defined cargo situations, empty and fully loaded.
- **Ambient temperature**: The ambient temperature shall be recorded at the beginning of each round and be as homogenous throughout the test as possible.
- **Topography**: Due to the defined track, the topography will be similar each round.
- **Electric consumers**: Radio, heating, headlights, and ventilation will be defined.
- **Traffic**: To reduce the impact of congestion and other vehicles, the test shall ensure comparable traffic velocity, i.e., through testing in early morning or late evening.
- **Drivers experience**: To reach homogenous results, the experience of drivers with driving electrical trucks should be homogeneous or has to be rated on a scale which needs to be defined.

Links to Other Disciplines

Answering the research question requires the integration of methods and background knowledge of several disciplines.

Advantages and challenges of electric urban freight transport are to be evaluated according to a logistics and traffic planning angle. Profitability and TCO calculations are evaluations of the economic field. The large amount of telemetry data generated will be organized by methods of computer sciences and analyzed with statistical approaches. To understand recuperation the energy flow into and from the battery and its effect on the range, background knowledge of electrical engineering is needed. Understanding drivers' motivation to choose a particular drive style and the suggestion of measures for driver training touches the field of psychology or behavioral studies.

References

Bingham C, Walsh C, Carroll S (2012) Impact of driving characteristics on electric vehicle energy consumption and range. IET Intell Transp Syst 6(1): 29–35. doi: 10.1049/iet-its.2010.0137

Dataforce (2011) Elektrofahrzeuge in deutschen Fuhrparks – Zur künftigen Bedeutung von Elektrofahrzeugen in deutschen Flotten, Dataforce-Studie, Dataforce Verlagsgesellschaft für Business Informationen, Frankfurt a.M

Fraunhofer IAO (2011) Schlussbericht IKONE Teilprojekt wissenschaftliche Begleitforschung, Stuttgart, pp 12–13

Kraftfahrt-Bundesamt (2013) Fahrzeugzulassungen (FZ), Bestand an Kraftfahrzeugen nach Umwelt-Merkmalen 01 Jan 2013, Flensburg

Müller M, Grönert S, Volkamer A (2006) Güterverkehr in der Stadt – ein unterschätztes Problem. Verkehrsclub Deutschland, Berlin

Taefi TT, Kreutzfeldt J, Held T, Konings R, Kotter R, Lilley S, Baster H, Green N, Laugesen MS, Jacobsson S, Borgqvist M, Nyquist C (2014a) Comparative Analysis of European examples of Freight Electric Vehicles Schemes. In: Dynamics in logistics, forth international conference, LDIC 2014. Bremen, Germany (Forthcoming)

Taefi TT, Kreutzfeldt J, Held T (2014b) Strategies to increase the profitability of electric vehicles in urban freight transport. In: E-Mobility in Europe: trends and good practice. Springer, Hamburg (Forthcoming)

Wermuth M (2012) Kraftfahrzeugverkehr in Deutschland 2010 – Schlussbericht, Braunschweig

Part IV
Transport and Green Logistics

Green Bullwhip Effect Cost Simulation in Distribution Networks

Matthias Klumpp, Nihat Engin Toklu, Vassilis Papapanagiotou, Roberto Montemanni and Luca Maria Gambardella

Abstract Sustainability is a modern day requirement toward global supply chains and also in most cases an efficiency challenge for logistic companies. Complementary objectives in decreasing carbon footprint and costs of transports are assumed or claimed, e.g., for an increase in load factors, reduction in transport intervals, and other green transport approaches in scheduling and tour planning. And also conflicting objectives can be identified with a decrease in flexibility due to lower transport intervals and higher load factors, as this research approach shows with a meta-heuristic approach for delivery transports under uncertainty of demand conditions. This uncertainty regarding increasing cost of necessary changes in transport planning due to probabilistic demand changes can be seen as excess flexibility costs. These can lead to increased security stock levels based on bullwhip behavior of logistics deciders, creating an additional green bullwhip effect for supposed sustainable supply chains. Therefore, the overall business and sustainability improvement in measures such as, e.g., reduced delivery intervals are to be evaluated taking this new perspective into account.

Keywords Green bullwhip effect · Uncertainty of demand · Ant colony simulation

M. Klumpp (✉)
Institute for Logistics and Service Management (ild), FOM University of Applied Sciences, Leimkugelstr.6, 45141 Essen, Germany
e-mail: Matthias.Klumpp@fom-ild.de

N.E. Toklu · V. Papapanagiotou · R. Montemanni · L.M. Gambardella
IDSIA, Dalle Molle Institute for Artificial Intelligence, USI-SUPSI, Galleria 2, 6928 Manno, Switzerland
e-mail: engin@idsia.ch

V. Papapanagiotou
e-mail: vassilis@idsia.ch

R. Montemanni
e-mail: roberto@idsia.ch

L.M. Gambardella
e-mail: luca@idsia.ch

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Introduction

Supply chain adverse order and stock-level effects named "Forrester Effect"—respectively "Bullwhip Effect"—have been described since more than 50 years (Forrester 1961; Lee et al. 1997). Since then, transport scheduling and lot sizing in supply chains is an established research and business practice question with different approaches in understanding and mitigating the problem of optimal decisions by logistics managers in different supply chains (Agrawal et al. 2009; Chatfield et al. 2004; Sharma and Lote 2013; Chen et al. 2000; Coppini et al. 2010; Jaksic and Rusjan 2008; Metters 1997; Özelkan and Lim 2008; Paik and Bagchi 2007; Taylor 1999; Wright and Yuan 2008). In a different research segment, concepts and measures regarding sustainability and green supply chain management have been established to comply with the overall demand for sustainable business and transport solutions (Beamon 1999). This is—among other reasons—because the field of logistics has a special "action imperative" by being responsible for about 5.5 % of global climate gas emissions; several efforts regarding technology as well as education and training have been directed toward that challenge (Aronsson et al. 2008; Murphy and Poist 2000; Polonski 2001; Sundarakani et al. 2010).

At the *intersection* of these two research streams, it can be asked what impact sustainable solutions will have on transport scheduling and shipment size decisions taken within supply chains. The *research hypothesis* regarding this field has been outlined already in 2011 with the supposition of a "green bullwhip effect" due to decreased flexibility in green transport concepts; therefore, it is assumed that logistics operatives will tend to decide for *increased safety stock levels* in order to mitigate anticipated flexibility cost increases in case of demand uncertainty (Klumpp 2011). To apply a simulation and optimization approach to this research field of a possible Green Bullwhip Effect for further insight, this research paper uses a theoretical modeling approach for this problem, defining real demands as uncertain, represented by random variables, inspired by previous studies in transportation, with the consideration of uncertainty (e.g., Campbell et al. 2011; Bertsimas 1992). Solutions to the problem are found by applying a meta-heuristic approach based on an ant colony algorithm.

Problem Description and Optimization Approach

Formal Description of the Problem

The Vehicle Routing Problem with Stochastic Demands (VRPSD) has been researched before in a number of papers but with different assumptions to this variant. Whenever not mentioned subsequently, it is assumed that the VRPSD solved is the classical one. The difference in assumptions is that the vehicle returns periodically to the depot to empty its current load (Bertsimas 1992). Uncertainty is handled by building an a priori sequence among all customers of minimal expected length. Also, simple heuristics are proposed and theoretical investigations are performed: In some cases, simulated annealing is used to solve VRPSD (e.g. Teodorovic and Pavkovic 1992). Also, an exact algorithm for the VRPSD is proposed by formulating it as a two-stage problem and solving the second stochastic integer program using an integer L-shaped method (Gendreau et al. 1995). Bianchi et al. (2006) analyzed different hybrid meta-heuristics in terms of performance comparable to state-of-the-art algorithms. Specifically, an Ant Colony Optimization (ACO) is proposed called "neighborhood-search embedded Adaptive Ant Algorithm" in order to solve VRPSD (Tripathi and Kuriger 2009). Tan et al. (2007) use a multiobjective version of VRPSD by means of evolutionary methods. The algorithm finds trade-off solutions of complete routing schedules with minimum travel distance, driver remuneration, and number of vehicles, with constraints such as time windows and vehicle capacity. Further research imposed duration constraints on the expected delivery costs, and this affects the structure of the set of a priori tours (Erera et al. 2010). The problem studied in this paper can be expressed as a 2-stage Vehicle Routing Problem with probabilistic demand increases. In this problem, we consider the case of a company that needs to serve multiple customers with demands and has to decide on the routes and number of vehicles needed to serve the customers. The objective is to minimize the total distance traveled. By the term "2-stage," we mean the following: in the first stage, the actual demands of the customers are not known, and only their lowest possible demands are known. In the second stage, the actual demands are revealed and the solution must be updated. It is assumed that the company has enough vehicles to serve the total forecasted demand, and therefore the number of vehicle used is not considered in the optimization. The routes used have an environmental effect by the carbon dioxide emissions from vehicles used—which are directly related to the distance covered.

Let $G = (L, A)$ be a graph with L being a set of locations and A a set of arcs connecting the L vertices. We assume that the graph is complete and in the set of locations 0 is always the depot. We also let V be the set of vehicles available for delivery and c_{ij} be the cost of traveling from location i to location j. We assume that each customer at location i has at least $\underline{d}_i$ amount of demand, and this amount of demand can probabilistically increase. In order to deal with probabilistic increases in the demands, we generate various scenarios and in each of them, the demands are perturbed in various ways. We let S be the set of scenarios and d_i^s the demand in location i in scenario $s \in S$. Our objective is to find a feasible solution x that minimizes the total travel distance and therefore the total carbon dioxide emissions. We let x^v be the route decided for vehicle $v \in V$ in x, $|x^v|$ the length of the route x^v, and x_k^v the kth visited place of the vehicle v in x. We assume that all the vehicles have the same capacity, denoted by Q. The objective function to be minimized is the cost sum of the preliminary tours (called base cost) and the average cost of the extra vehicle tours required to satisfy the customers who were not satisfied by the preliminary tours because of demand increases, simulated over various demand increase scenarios within S. The demand of a customer revealed in a scenario $s \in S$

is expressed as d_i^s. The function which calculates the travel cost of extra vehicle tours for a scenario $s \in S$ is $F_s(x)$ using a simple and fast greedy heuristic: the Nearest Neighborhood Heuristic (NNH; see Johnson and McGeoch 1997). The extra cost due to stochasticity averaged over various scenarios is computed in the objective function by the term $\sum_{s \in S} \left(\frac{F_s(x)}{|S|}\right)$. The problem can be expressed as:

$$\min \left[\sum_{v \in V} \sum_{k=1}^{|x_v|-1} \left(c_{ij} \middle| i = x_k^v, j = x_{k+1}^v\right) + \sum_{s \in S} \left(\frac{F_s(x)}{S}\right) \right]$$

$$\text{subject to } \mathrm{x}_1^v = x_{|x^v|}^v = 0 \quad \forall v \in V$$

$$x_k^v \neq x_{k'}^{v'} \quad \forall v, v' \in V$$

$$\forall k \in \{2, \ldots, |x^v| - 1\}$$

$$\forall k' \in \left\{2, \ldots, \left|x^{v'}\right| - 1\right\}$$

$$k \neq k' \text{ if } \mathrm{v} = v'$$

$$x_k^v \in (L \backslash \{0\}) \quad \forall v \in V, \forall k \in \{2, \ldots, |x^v| - 1\}$$

$$\sum_{k \in \{2, \ldots, |x^v|-1\}} \underline{d}_{x_k^v} \leq Q \qquad \forall V \in V$$

The fix function $F_s(x)$ can be explained as simulating the solution x over scenario s, getting a list of unsatisfied customers, heuristically finding tours for the extra vehicle(s) to revisit the unsatisfied customers using NNH and finally returning the total cost of these tours. The algorithmic explanation is as follows:

```
function F_s(x) is:
unsatisfied_customers ← []
for all v ∈ V do
   serving_capacity ← vehicle_capacity
   for all k ∈ {2, ..., |x^v| − 1} do
      if serving_capacity ≥ d_i^s then
         serving_capacity ← serving_capacity − d_i^s
      else
         add k to unsatisfied_customers
         missing_k ← d_i^s − serving_capacity
         serving_capacity ← 0
      end if
   end for
end for
SubGraph ← {0} ∪ unsatisfied_customers
SubVRP ← VRP problem on SubGraph where
      the demands are given by missing_k ∀k ∈ SubGraph
y ← solve SubVRP via nearest neighbour heuristic
return travel cost of y
```

An Ant Colony System Algorithm

For solving our problem in a heuristic way, the ACO meta-heuristic is used. The ACO is a probabilistic technique for finding solutions to difficult combinatorial optimization problems that can be reduced to finding good paths through graphs like TSP or VRP (Dorigo 1992; Dorigo et al. 1991). The main advantage for applying this method here is, on one hand the required possibility, to include probabilities into the overall calculation and on the other hand the advantage that it has been applied to VRP problems before. The ACO was inspired by the behavior of the ants in the nature: When an ant finds a path to a food source, it leaves that path using pheromones. These pheromones attract more ants, therefore the pheromones get reinforced. More convenient paths are traveled more and more, and their pheromones are further reinforced. In the end, one can observe that the best known path is the one with the highest amount of pheromones, and almost all the ants converge onto that path. In ACO, artificial ants are activated on the solution space of a combinatorial optimization problem. Each artificial ant "walks," constructing a solution in the end. According to the quality of this constructed solution, the decisions made by the artificial ants are marked by artificial pheromones. The ants of the future iterations of the algorithm, while making their decisions, are probabilistically attracted toward the more pheromoned options. In our study, we use a variation in ACO called the Ant Colony System (ACS), which is an *elitist* variation in the sense that only the ants who have improved the best known solution are allowed to leave pheromones. This allows the ants of the future iterations to consider converging only to best solutions. The ACS variation we use in this study is based on the study of Gambardella et al. (1999), for which the technical details can be found in Toklu et al. (2013).

The algorithm we propose will not treat the 2-Stage optimization problem directly. Instead, it will optimize a 1-Stage problem only where demand is increased with respect to the basic level in order to simulate the behavior of different real planners that following their reasons can be more or less conservative about the uncertain demand. Approximating objective function with these simplified scenarios makes the algorithm more efficient from a computational point of view. The solutions obtained by the different methods will be used in section "Operational Implications Facing Uncertain Demand" to discuss about the bullwhip effect connected to planner choices. Given a problem, the algorithm will be run on the following three scenarios: (i) Best-Case: all demands are at the standard (minimum) value, uncertainty is ignored. (ii) Average-Case: all demands are at an average level, medium protection against uncertainty is targeted. (iii) Worst-Case: all demands are at the highest possible level, full protection against uncertainty is targeted. It has to be recognized that the solutions obtained by the algorithm on these scenarios will be evaluated according to the real 2-Stage objective function presented in section "Formal Description of the Problem". In particular, 1000 scenarios will be sampled for each uncertain demand according to the given distributions through a Monte Carlo sampling technique to provide set S.

Experimental Results

Here, we present our results which were first reported in Toklu et al. (2013). After the analysis of the results, Sect. Operational Implications Facing Uncertain Demand will discuss further implications of the results and their role in the Green Bullwhip Effect.

For testing our approach, we used the CVRP instances provided by Taillard (2013), namely, tai100{a, b, c, d} and tai150{a, b, c, d}, which are instances considering 100 customers and 150 customers, respectively. Note that, these instances were originally created for the classical CVRP where the demands are deterministic. Since, in this study, we consider that there are probabilistic increases in the demands, we modified these instances. In more detail, within each considered problem instance, for each customer location $i \in (L \in \{0\})$, the following modifications were applied: (i) accept the demand at location i as the base demand $\underline{d}_i$; (ii) generate a random number r within $[0; \underline{d}_i \cdot R]$, where R is a parameter that we set as 0.2 in our studies; and (iii) declare that the demand at location i is stochastic according to the half-Gaussian distribution, with the base demand d_i and standard

Table 1 Result overview scenario calculations

Instance	Scenario	Total cost	
		Average	stDev
tai100a.dat	Best-case	2610.03	58.63
	Average-case	2267.09	30.64
	Worst-case	2371.36	39.19
tai100b.dat	Best-case	2413.99	40.63
	Average-case	2183.65	39.38
	Worst-case	2175.77	33.13
tai100c.dat	Best-case	1782.81	73.53
	Average-case	1546.38	36.42
	Worst-case	1618.03	21.02
tai100d.dat	Best-case	1954.59	87.44
	Average-case	1771.12	38.6
	Worst-case	1743.73	20.1
tai150a.dat	Best-Case	3793.40	55.12
	Average-case	3613.45	46.85
	Worst-case	3693.16	47.81
tai150b.dat	Best-case	3545.05	72.52
	Average-case	3228.53	90.93
	Worst-case	3356.87	94.12
tai150c.dat	Best-case	3391.10	51.72
	Average-case	2928.72	98.75
	Worst-case	2946.34	94.12
tai150d.dat	Best-case	3359.90	107.83
	Average-case	3064.09	95.21
	Worst-case	3061.22	33.01

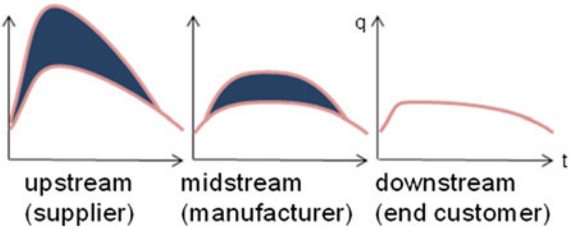

Fig. 1 Green bullwhip effect description

deviation r. Three ACS implementations were used: one which optimizes according to the Best-Case scenario, one according to the Average-Case, and one according to the Worst-Case. These were written in C programming and executed on a computer with Intel Core 2 Duo P9600 @ 2.66 GHz processor with 4 GB RAM. Each ACS implementation was executed on the considered modified instances. Of 9 runs (3 min each), the best ones are reported in Table 1. The costs are reported in terms of all three ant colonies working in different scenarios. If probabilistic demand increases are ignored by the optimizing algorithm (Best-Case), costs are higher, since a substantial part of the delivery is left for stage 2. Average-Case and Worst-Case variants produce solutions with lower travel times, since they try to cover uncertain demand already in the first stage. Between these methods, there is not a clear dominance, although the Average-Case seems to work slightly better in general. Explanations can reside in the fact that the Worst-Case is a very conservative approach that will tend to not use vehicle capacity properly in the first stage.

Operational Implications Facing Uncertain Demand

Facing the described uncertainty in demand and the subsequent possible cost increases, it can be assumed prudent for experienced logistics managers to try to *avoid* these cost developments induced by second tour deliveries. They may do so by ordering and/or sending higher lot size volumes in the first place. This can be indicated as an additional Green Bullwhip Effect as depicted in Fig. 1.

This view assumes decreased transport flexibility due to vehicle and interval restrictions—*implying* for logistics practice as a result from this simulation model that green logistics measures may indeed lead to an artificial increase of the established bullwhip effect with the connected excess costs as logistics managers try to avoid excess costs.

Outlook and Further Research

The last mentioned assumption how logistics managers would react to those cost increases in the face of uncertainty of demand and "ordered" green logistics measures shall also be the main directive of future research as well as the following points:

- In *decision experiment research set ups*, it would have to be established how logistics managers really react in operational contexts facing the described challenge of the 2-stage problem.
- Based on this a framework for *overall evaluation* of green logistics measures should be developed, including excess costs of the described green bullwhip effect.
- In case studies or other research, it has to be established in which *areas of the supply chain* (downstream as in this distribution example or also further upstream) as well as in which industries (food, FMCG, pharmaceutical, manufacturing, automotive, etc.) this applies.

Altogether, for the evaluation of green logistics measures, as well as the trend toward more and more flexible and agile supply chains, this research field has to be explored further in order to provide for a real-world measure of excess costs in terms of flexibility within distribution (and general supply chain) structures.

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References

Agrawal S, Sengupta RN, Shanker K (2009) Impact of information sharing and lead time on bullwhip effect and on-hand inventory. Eur J Oper Res 192:576–593

Aronsson H, Huge-Brodin M, Kohn C (2008) Logistics structures—drivers of environmental impact. In: Stentoft-Arlbjørn J, Halldórsen Á, Jahre M et al (eds) Northern lights in logistics and supply chain management, Gylling, pp 183–200

Beamon BM (1999) Designing the green supply chain. Log Inform Man 12:332–342

Bertsimas DJ (1992) A vehicle routing problem with stochastic demand. Oper Res 40:574–585

Bianchi L, Birattari M, Chiarandini M et al (2006) Hybrid metaheuristics for the vehicle routing problem with stochastic demands. J Math Model Algorithms 5:91–110

Campbell AM, Gendreau M, Thomas BW (2011) The orienteering problem with stochastic travel and service times. Ann Oper Res 186:61–81

Chatfield DC, Kim JG, Harrison TP, Hayya JC (2004) The bullwhip effect—impact of stochastic lead time, information quality, and information sharing: a simulation study. Prod Oper Manage 13:340–353

Chen F, Ryan JK, Simchi-Levi D (2000) The impact of exponential smoothing forecasts on the bullwhip effect. Naval Res Logistics 47:269–286

Coppini M, Rossignoli C, Rossi T, Strozzi F (2010) Bullwhip effect and inventory oscillations analysis using the beer game model. Int J Prod Res 48:3943–3956

Dorigo M (1992) Optimization, learning and natural algorithms (in Italian). Ph.D. dissertation, Dipartimento di Elettronica, Politecnico di Milano, Milan

Dorigo M, Maniezzo V, Colorni A (1991) Positive feedback as a search strategy, Tech. Rep

Erera AL, Morales JC, Savelsbergh M (2010) The vehicle routing problem with stochastic demand and duration constraints. Trans Sci 44:474–492

Forrester JW (1961) Industrial dynamics. Portland

Gambardella LM, Taillard E, Agazzi G (1999) New ideas in optimization. McGraw-Hill, London, pp 63–76

Gendreau M, Laporte G, Seguin R (1995) An exact algorithm for the vehicle routing problem with stochastic demands and customers. Trans Sci 29:143–155

Jaksic K, Rusjan B (2008) The effect of replenishment policies on the bullwhip effect—a transfer function approach. Eur J Oper Res 184:946–961

Johnson DS, McGeoch LA (1997) The traveling salesman problem: a case study in local optimization. Local Search Comb Optim 1:215–310

Klumpp M (2011) Green bullwhip effect simulation concept. In: Navais P, Machado J, Analide C, Abelha A (eds) The 2011 European simulation and modelling conference proceedings, University of Minho, Guimaraes, pp 263–265

Lee HL, Padmanabhan V, Whang S (1997) Information distortion in a supply chain: the bullwhip effect. Manage Sci 43:546–558

Metters R (1997) Quantifying the bullwhip effect in supply chains. J Oper Manage 15:89–100

Murphy PR, Poist RF (2000) Green logistics strategies: an analysis of usage patterns. Transp J 40:5–16

Özelkan EC, Lim C (2008) Conditions of reverse bullwhip effect in pricing for price-sensitive demand functions. An Oper Res 64:221–227

Paik S, Bagchi PK (2007) Understanding the causes of the bullwhip effect in a supply chain. Int J Retail Distrib Manage 35:308–324

Polonski MJ (2001) Green marketing. In: Charter M, Tischner U (eds) Sustainable solutions—developing products and services for the future, Sheffield, pp 282–303

Sharma S, Lote KS (2013) Understanding demand volatility in supply chains through the vibrations analogy—the onion supply case. Log Res 6:3–15

Sundarakani B, de Souza R, Goh M (2010) A sustainable green supply chain for globally integrated network. In: Wang L, Koh SC (eds) Enterprise networks and logistics for agile manufacturing, London, pp 191–206

Taillard E (2013) Vehicle routing instances, [Online]. http://mistic.heig-vd.ch/taillard/problemes.dir/vrp.dir/vrp.html. Accessed 27 Sept 2013

Tan K, Cheong C, Goh C (2007) Solving multi-objective vehicle routing problem with stochastic demand via evolutionary computation. Eur J Oper Res 177:813–839

Taylor DH (1999) Measurement and analysis of demand amplification across the supply chain. Int J Log Manage 10:55–70

Teodorovic D, Pavkovic G (1992) A simulated annealing technique approach to the vehicle routing problem in the case of stochastic demand. Trans Plan Tech 16:261–273

Toklu NE, Papapanagiotou V, Klumpp M, Montemanni R (2013) An ant colony approach for a 2-stage vehicle routing problem with probabilistic demand increases. In: Proceedings of FORS40—finnish operations research society 40th anniversary workshop, pp 5–8

Tripathi M, Kuriger G (2009) An ant based simulation optimization for vehicle routing problem with stochastic demands. In: IEEE Proceedings of the 2009 winter simulation conference, pp 2476–2487

Wright D, Yuan X (2008) Mitigating the bullwhip effect by ordering policies and forecasting methods. Int J Prod Econ 113:587–597

Challenges and Solutions Toward Green Logistics Under EU-Emission Trading Scheme

Fang Li, Hans-Dietrich Haasis and Irina Dovbischuk

Abstract Since climate change has already threatened the whole ecological environment worldwide as well as the living surroundings of human beings, positive actions and regulations from governments are proposed and put into practice before the situation reaches the extreme situation in the near future. Among them, the EU-emission trading scheme (EU ETS) offers probably one of the most cost-efficient solutions for companies to realize greenhouse gas emission reduction. In this context, manufacturers and other companies included in ETS are confronted with the trade-off between carbon abatement cost and carbon allowance purchasing cost. The logistics sector, maintaining close business relationships with almost every industrial sector, is not yet directly included into ETS so far but still faces to the challenge of green reformation required by its customers from the manufacture industry and so on. A new market competition is aroused not only in inclusive manufacture industry but also in the logistics sector. This paper is going to introduce the ETS-impacted logistics sections, to discern both challenges and opportunities for logistics providers, and finally to propose effective measures against the current dilemma.

Keywords EU-emission trading scheme · Green logistics · Trade-off · Abatement measure · Customers' green awareness

F. Li (✉) · H.-D. Haasis · I. Dovbischuk
Chair of maritime business and logistics, University of Bremen, Bremen, Germany
e-mail: lif@uni-bremen.de

H.-D. Haasis
e-mail: haasis@isl.org

I. Dovbischuk
e-mail: dovbischuk@isl.org

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Introduction

In response to climate change, the Kyoto protocol introduced various flexible mechanisms—emission trading scheme (ETS), the clean development mechanism (CDM), and Joint implementation (JI), through which different countries can cooperate to meet their emission reduction targets and decrease costs.

The ETS works on the "cap and trade" principle. A "cap," or limit, is set on the total amount of certain greenhouse gases (GHGs) that can be emitted by the factories, power plants, and other installations in the system. The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. In this context—a carbon market based on the commodity—carbon allowance is aroused, where the price is jointly decided by demand and supply. One carbon allowance gives the right to emit 1 tonne of carbon dioxide (CO_2) or an equivalent amount of GHG. They can also buy limited amounts of international allowance from emission-saving projects carried out under the CDM and JI around the world to offset a proportion of their emissions. The limit on the total number of allowances available ensures that they have a value. After each year, a company must surrender enough allowances to cover all its emissions, otherwise heavy fines as 100 € per tonne of carbon since 2013 (EC 2013) are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. The flexibility that trading brings ensures that emissions are cut, where it costs least to do so. By putting a price on carbon and thereby giving a financial value to each tonne of emissions saved, the EU-emission trading scheme (EU-ETS) has placed climate change on the agenda of company boards and their financial departments across Europe. A sufficiently high carbon price also promotes investment in clean, low-carbon technologies. Although only businesses covered by the EU-ETS are given allowances, anyone else—individuals, institutions, non-governmental organizations or whoever—is free to buy and sell in the market in the same way as companies do (EC 2013).

The EU ETS, the first and still by far the largest multicountry, multisector system for trading GHG allowances, accounts for about 45 % of EU GHG emissions, 40 % of EU CO_2, and covers all 27 EU member states as well as other non-EU nations, Iceland, Liechtenstein and Norway, Croatia. Up to now, more than 11,000 facilities are covered by the EU ETS (EC 2013):

- Power and heat generation
- Energy-intensive industry sectors including oil refineries, steel works and production of iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids, and bulk organic chemicals
- Commercial aviation:
  Those facing difficulty in remaining within their allowance limit have a choice between several options:

- Investing in more efficient technology or using a less carbon-intensive energy source
- Purchasing extra allowances and/or CDM/JI allowances on the market
- Combining the above-mentioned two measures

So far industries covered in ETS are mainly aimed at energy-intensive installations, such as power generation and energy-consuming manufacturing and plants. The logistics sector, although closely interrelated with almost every industrial sector, is not directly included into ETS so far but still cannot escape such a globally fierce situation. Logistics is the management of the flow of resources between the point of origin and the point of consumption in order to meet some requirements, e.g, of customers or corporations. The customers of logistics could be the end use product consumers as well as the contracted companies, for instance, logistics providers of paper manufactures could be affected more or less when paper manufactures are included into ETS.

In any case, meeting the requirements of customers based on minimization of the use of resources is the ultimate goal of logistics. Under ETS context, to attain a green logistics is the only sustainable way of development for the logistics sector.

Challenges of Logistics Providers

Since logistics outsourcing is a usual strategy adopted by most big manufactures, integrating logistics management and then cutting logistics cost would be one of the economical solutions for manufacturers under increasingly ETS-resulted cost pressure. In this context, logistics providers, as contract logistics service providers of manufactures, e.g., third-party logistics (3PL) service providers are indirectly facing challenges induced by ETS as well. Especially, such challenges would become more severe when logistics industry is integrated in a higher level.

Furthermore, as the concept of fourth-party logistics (4PL) is raised up currently, the provider of which functions as a general contractor essentially taking responsibility of a complete process for the customer, such a high-level integration of logistics service brought by 4PL, would avail a closer and more systematical interrelationship between manufacture industry and logistics industry.

In this context, trends are going to be that manufactures write logistics contracts directly with 3PL or 4PL providers who in return share the ETS-induced burden of manufactures. Hence, logistics sections, including procurement-, production-, distribution-, and reverse logistics, will be automatically affected by the EU-ETS context, and two quite possible results would be that the logistics sector is targeted reducing GHG emissions in line with related manufactures or even going to be included into EU-ETS.

Burden Share with Manufactures to Offset Their Trade-off Between Carbon Abatement Cost and Emission Allowance Cost

Under the EU-ETS context, usually companies can take two strategies into account, abatement measure adoption and carbon allowance purchasing. Abatement measure refers to adopting actions and resources for saving energy, which includes technological- and operational-efficiency improvements. Notably, purchasing carbon allowance is a reactive measure and will not reduce carbon emissions but will alleviate the impact of carbon allowance on the economic performance of companies directly. Conversely, abatement practices are a proactive measure as their effect on companies' performance is long term and sustainable, moving toward the goal of reducing GHG emissions. The third measure combining these two facilitates the characterization of short- and long-term competitive strategies of companies moving toward sustainable business development in the emerging ETS context.

Some abatement measures provide extremely high cost (called "abatement cost") and some provide revenue (negative costs) rather than cost. The trade-off between abatement measures and carbon allowance purchasing is the key for a companies' sustainable management. The optimal strategic combination is strongly related to the operational marginal cost. Sheu and Li (2013) analyzed the impact of EU ETS on aviation industry and indicated that additional cost that EU ETS will impose on airline operators should also differ by airline efficiency. When the trend comes to any other industry, it also becomes a challenge. Cost-efficient companies gain great profit once they implement an abatement measure strategy. As input increases, profit increases.

In this way, logistics, as a close partner of manufacturers occupying up a large amount of cost expenditure, would likely be an essential sector for manufactures to cut cost in order to attain the final cost-efficient goal. Accurately, the logistics sector maintains lots of weak sections that could be improved and modified under EU-ETS context.

Market Competition Affected by Customers' Green Awareness

Additionally, Sheu and Li (2013) connected green transportation with customer behavior via behavior economic theories, which concluded that customers' green awareness takes effect on shaping a new strategy of companies against carbon emission. It is proved that consumers' green attitude likely influences his or her willingness to accept more expensive green products or services. For logistics sector, the customers it faces mostly come from manufacture industry, which have a much higher green requirement than individual customers, especially those manufactures included in the ETS.

Generally, a growing number of environmentally conscious consumers increase the competition among firms to provide greener products and services and thus increase their market share. This trend changes the way companies manage their chain (Abdallah et al. 2012). They will have to find new and innovative means of optimizing the chain across all its stages to minimize their carbon footprint. Such customers' green awareness will take an important role in affecting the whole consumption environment and thus in some way increasing the market demand uncertainty. A new market competition is aroused not only in manufacture industry but also in logistics sectors that are confronted with the green requirements from related customers.

Huge Emissions from Transportation Section of Logistics

Transport, as the second biggest GHG emissions sector after energy, is responsible for around a quarter of EU GHG emissions. In the last decades, the sector of transport has positively responded to the green development and lots of measures have been undertaken to reduce CO_2 emissions including technological and organizational measures through which specific emissions CO_2/t km have been reduced significantly. However, CO_2 emissions from transport still increase due to the increase in transportation. The GHG emissions in other sectors decreased 15 % between 1990 and 2007 but emissions from transport increased 36 % during the same period (EC 2013).

Significant reductions in GHG emissions from transport are required if the EU is to achieve its long-term goals. The commercial aviation sector, as one main actor of transportation industry, is already being adopted into EU ETS in 2013, due to the increasingly civil aviation consumption as well as its large contribution on emission. Shipping, a large and growing source of the GHG emissions that are causing climate change is currently under discussion for a global approach to reduce emissions. As a first step, the European Commission (EC) has proposed that owners of large ships using EU ports should report their verified emissions from 2018.

Transportation is the biggest part in the logistics sector in function of realizing products' geographic movement. On one side, emission problems from transportation would prevent the logistics sector developing toward a sustainable goal for a long run. On the other side, since more and more attention from the government is placed and going to be placed in the transportation section, it is very likely that the logistics sector will, in the near future, go through another turn of ETS inclusion. A fast response in the logistics sector on green reformation is urgently needed.

Solutions Toward Green Logistics Under EU ETS

By putting a price on carbon and thereby giving a financial value to each tonne of emissions saved, the flexibility that trading brings ensures that emissions are cut where it costs least to do so. A company, whose unit emission reduction cost, by abatement measure, is lower than unit carbon price, would benefit from cutting even larger amount of emission and then selling the extra to others. Vice versa, companies, whose unit emission reduction cost, by abatement measure, is higher than unit carbon price, are offered with the more economical option, that is, to buy carbon permits from the carbon market. In any case, both kinds of companies get accurate benefit from ETS. The ETS offers exactly a solution that some firms can cut their emissions more economically than others. It relieves the pressure on companies to reduce carbon emissions throughout their operations, by allowing them to either invest in other economical emissions reduction projects by CDM/JI or purchase carbon permits. In any case, companies are now realizing that they will have to pay for their emissions and this will be adopted into their usual business strategies.

Going Ahead of the Game

Since green logistics has already become a necessary trend, the logistics sector has to make a fast response to current requirement in order to move to the sustainable business development in the long run. Positive actions for the logistics sector would be cutting possible GHG emissions along all of its stages to the most cost-efficient extent or investing into projects by CDM and JI in advance.

Taking an active participation into free-willing ETS market could also be one solution for logistics sector. Abatement measure can not only reduce carbon emission directly, the extra emission could then be traded as a product in the carbon market and bring avenue as a result. And from this prospective, it can even offer opportunities for creating a new industry, which especially takes revenue from emission trading, that is, a new industry would be shaped when abatement cost in certain emission reducing projects is not higher than the carbon price.

Green Procurement

Geffen and Rothenberg (2000) used three case studies of U.S. assembly plants to examine the role of strategic partnership between manufacturers and their suppliers to achieve their environmental performance targets. The study concluded that the manufacturers and suppliers with the strongest coordination achieved the greatest success. Thus, green procurement can provide a key competitive advantage for companies because it leads to eco-efficiency, cost-savings, and improved public perception for the products (Zhu and Geng 2006). Simpson and Power (2005) investigated the relationship between a supplier—firm's level of environmental management activity and the structure of the customer—supplier—manufacturer relationship. They concluded that the manufacturing process is where the greatest amount of pollution is generated and where the greatest amounts of resources are consumed. Hence, the supply–manufacture relationship has the potential to make significant strides toward a greener supply chain.

Under the trend to a sustainable chain, logistics providers of procurement have to aim at green development. Green procurement, also known as environmental sourcing, is one way of extending green initiatives to upstream suppliers. It is defined as the integration of environmental considerations into purchasing policies and supplier selection (Erdmenger 2003). The green procurement or sourcing decision affects the green supply chain through the purchase of materials that are either recyclable or reusable or have already been recycled (Sarkis 2003).

Multimodality

In this area, many studies focusing on how to design a sustainable supply chain within ETS context can be found based on different models, for instance, an integer multiobjective optimization model (Wang et al. 2011; Sadegheih et al. 2010), a mixed-integer linear programming (Chaabane et al. 2012; Ramudhin et al. 2008), fuzzy linear multiobjective model (Pishvaee and Razmi 2012), and a two-level multicommodity facility location model (Abdallah et al. 2012). With these kinds of models, the optimal solution of distribution logistics, e.g., route plan, plant location, transport mode choice can be attained.

As aforementioned, transportation occupies up a large part of distribution logistics as well as a large amount of GHG emissions. Considering different transport modes have different cost efficiency and GHG emissions, a multimodal transportation is highly encouraged under current conditions. On one side, the optimal combination of different transport modes on the aspect of GHG emissions could be realized via multimodality. On the other side, multimodality offers logistics providers with the largest flexibility to arrange products' delivery via transferring in freight terminal. Making the most use of freight village or dry port could also facilitate operational cost reduction and efficiency enhancement for logistics providers.

Reverse Logistics Integration

Reverse logistics indicates the section from the end use of product to the recycled materials, including recover, disassemble, disposal, and recycle (Hawks 2006). In a long run, a sustainable supply chain management has to integrate reverse logistics to realize a maximal profit and minimal cost. Sheu et al. (2005) formulated a linear multiobjective model that shows an increase in around 21.3 % in net profit by implementing the suggested integrated supply chain model.

Inspired from the research mentioned earlier, integrating reverse logistics could also be a possible solution for manufacturers to increase profit under ETS context. Besides, integrating reverse logistics into the whole supply chain management is undoubtedly beneficial to form a sustainably substantial loop. In such way, the recyclability of used products could be so effectively improved that material suppliers and manufacturers will be engaged into a larger second material market, the start of an eco-environmental chain.

Conclusion

This paper analyzes the challenges faced by the logistics sector under EU-ETS context from the prospective of customers' green requirement, and then proposes possible solutions and some managerial insights for logistics providers based on analyzed challenges and opportunities in the logistics industry. By summarizing the emission reduction assignments for logistics industry from a customer-based perspective, by giving the right motivation for industrial companies to join ETS, this work is of significance in decision-making support, not only of governmental policy but also of industrial practice.

No matter if the logistics sector will be included directly into EU ETS or not, green logistics is already the necessary trend in this industry. Besides, a quite practical and interesting research could be the ETS implementation on the whole supply chain. We propose a supply chain ranged carbon market would be formed, where the total carbon allowance is allocated to the whole supply chain instead of the only manufacturer, and members of the supply chain have to realize the final goal of emission reduction through strategic cooperation and coordination. The total carbon allowance is allocated to each member of the supply chain according to their historical emission data and the amounts of emission they are willing to cut in the future which is jointly decided by cost efficiency und the trade-off between carbon abatement cost and carbon allowance purchasing cost. It is obvious that there also exists beneficial contradiction among different supply chain members. How to allocate the carbon allowance among different members along supply chain in order to minimize the total emission as well as cost would be a problem in the aspect of operation research.

Based on the solutions advised in this paper, possible future research would also be followed in directions, for instance, reverse logistics integration into the supply chain management based on a multiobjective linear programming model, procurement logistics management considering the recyclability policy from government, freight transport mode choice based on ETS, market competition in logistics under ETS based on customer behavior economy, and so on.

References

Abdallah T, Farhat A, Diabat A, Kennedy S (2012) Green supply chains with carbon trading and environmental sourcing: formulation and life cycle assessment. Appl Math Model 36:4271–4285

Chaabane A, Ramudhin A, Paquet M (2012) Design of sustainable supply chain under the emission trading scheme. Int J Prod Econ 135:37–49

EC Climate Action (2013) The EU-emissions trading system (EU ETS). Available at http://ec.europa.eu/clima/policies/ets/

Erdmenger C (2003) Buying into the environment: experiences, opportunities and potential for eco-procurement. Greenleaf Publishing

Geffen C, Rothenberg S (2000) Suppliers and environmental innovation. Int J Oper Prod Manage 20(2):166–186

Hawks K (2006) What is reverse logistics? Reverse Logistics Magazine. Winter/Spring

Pishvaee MS, Razmi J (2012) Environmental supply chain network design using multi-objective fuzzy mathematical programming. Appl Math Model 36:3433–3446

Ramudhin A, Chaabane A, Kharoune M, Paquet M (2008) Carbon market sensitive green supply chain network design. In: IEEE international conference proceedings on industrial engineering and engineering management (IEEM), pp 1093–1097

Sadegheih A, Li D, Sribenjachot S, Drake PR (2010) Applying mixed integer programming for green supply chain management. S Afr J Ind Eng 21(2):13–24

Sarkis J (2003) A strategic decision framework for green supply chain management. J Clean Prod 11(4):397–409

Sheu JB, Li F (2013) Market competition and greening transportation of airlines under the emission trading scheme: case of duopoly market. Transp Sci. doi:10.1287/trsc.2013.0473

Sheu J, Chou Y, Hu C (2005) An integrated logistics operational model for green-supply chain management. Transp Res Part E: Logistics Transp Rev 41(4):287–313

Simpson D, Power D (2005) Use the supply relationship to develop lean and green suppliers. Supply Chain Manage: Int J 10(1):60–68

Wang F, Lai X, Shi N (2011) A multi-objective optimization for green supply chain network design. Decis Support Syst 51:262–269

Zhu Q, Geng Y (2006) Green purchasing in Chinese large and medium-sized state-owned enterprises. Greening the Supply Chain 173–187

Economic Ship Travel Speed and Consequences for Operating Strategies of Container Shipping Companies

Timm Gudehus and Herbert Kotzab

Abstract In this paper, we develop a model for the economic travel speed of container ships and show how the travel speed impacts the profit situation as well as the environmental sustainability. Thereby, we differentiate between a cost-optimal and profit-optimal travel speed strategy and show, based on model calculations, how both strategies lead to lower costs as well as lower emissions. Following the dynamic network aspect, we suggest that large container ship companies can adopt both strategies under specific market conditions which allow them to act profitable as well as environmental sustainable.

Keywords Maritime logistics · Cost-optimal speed · Profit-optimal speed · Sustainability

Introduction

The operative task of maritime logistics is to convey cargo with ships on rivers, channels and seas at minimal possible operating costs, fuel consumption and emissions. For this purpose, optimal shipping networks and maritime transport chains have to be designed, implemented and operated (see Gudehus and Kotzab 2012).

T. Gudehus (✉)
Strandweg 54, 22587 Hamburg, Germany
e-mail: TimmGudehus@t-online.de

H. Kotzab
Department of Logistic Management, University of Bremen,
Wilhelm-Herbst-Strasse 12, 28359 Bremen, Germany
e-mail: kotzab@uni-bremen.de

H. Kotzab
Glasgow Caledonian University, Glasgow, Scotland

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Besides ship capacity, optimality is driven by economic as well as environmental factors such as (see, e.g. Notteboom and Vernimmen 2008; Psaraftis and Kontovas 2010)

- extreme market volatility with regard to oil prices and freight rates thus leading to extreme demand up- and down-turns;
- high dependency of travel speed on fuel consumption leading to a high contribution of bunker costs to the total operating costs;
- huge GHG emissions.

Especially, travel speed is impacting on the economic as well as the sustainable optimality of maritime logistics (see Fig. 1).

The example of slow steaming shows that fuel consumption can be significantly decreased as well as emissions of GHG (see, e.g. Cariou 2011; Eyring et al. 2010; Faber et al. 2010; Song and Xu 2012). For this paper, we determine a cost-optimal speed and profit-optimal speed of ships that significantly differ in their economic as well as environmental results.

We identify fuel consumption and bunker costs, transport time and freight limit performance, harbour costs and ship utilization costs as the main parameters that affect the maritime logistic costs (see section "Influencing Parameters on Maritime Logistic Costs").

Minimizing these costs and putting them into relation with speed leads to our suggested cost-optimal speed. Furthermore, freight revenues and their derived operating profits can be taken into account too. Maximizing operating profits and putting them into relation with speed leads to our suggested profit-optimal speed. These two strategies will be discussed as economic ship travel speeds (see section "Fuel Consumption and Bunker Costs").

Our model calculations are based on the key data for a fleet of 5000 TEU-container ships (see Table 1) and their scheduling and operating data for a roundtrip with only two stops in Rotterdam and Shanghai (see Table 2).

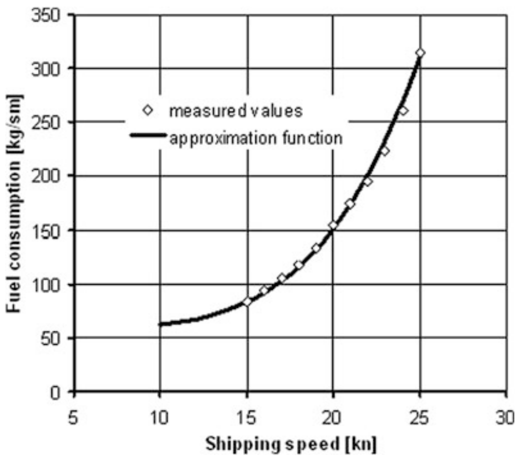

Fig. 1 Fuel consumption curve of a 5000 TEU-container ship. Approximation function: $c_F(v) = 58 + 0.00013 \cdot v^{4.5}$ (Gudehus and Kotzab 2012)

Table 1 Data of a container ship used for the model calculations

Key data	Characterization
Type	Panamax containership
Load units	20 ft container = 1 TEU
	40 ft container = 2 TEU
Maximal capacity	5,000 TEU
Ship utilization price P_S	23,000 US-$/d
Design speed	v_{min} = 12.5 kn
	v_{max} = 25.0 kn
Fuel consumption at v_{max}	320 kg/sm
Consumption rate $c_F(v)$	$c_F(v) = 58 + 0.00013 \cdot v^{4.5}$

Source (Münchmeier Petersen Capital 2003; Gudehus 2010)
Ship utilization price: Cost rate for own ships or charter rate for third-party ships

Table 2 Scheduling and operating data for the round tour of a container ship

Key data	Outward tour	Return tour
Driving length L_i (sm)	11,000	11,000
Bunker price P_B (US$/t)	500	500
Freight rate P_F (US$/TEU)	1050	630
Harbour stops N_H (per tour)	1	1
Stop time t_H (h/stop)	48	48
Stop price P_H (US$/stop)	42,000	42,000
Filling degree ρ_{max} (%)	95	95
Limit performance μ (TEU/year)	42,633	42,633

Based on a roundtrip with only two stops in Rotterdam and Shanghai

Influencing Parameters on Maritime Logistic Costs

Fuel Consumption and Bunker Costs

The crucial element for determining the optimal speed is the dependency of the mileage consumption on the travel speed of a ship (e.g. Ronen 1982; Notteboom and Vernimmen 2008; Eyring et al. 2010). The fuel consumption curve is assumed to increase from a basic consumption at minimal operating speed up to the highest consumption at maximal speed for which a ship has been designed. The slope of the bunker consumption curve then depends on the type, hull form, propulsion, capacity and other properties of the ship as well as on load, weather and sea conditions (see also Schneekuth and Bertram 1998; Faber et al. 2010).

It holds that the mileage consumption of a cargo ship increases with power 4–6 of the travel speed. In case a ship travels a tour, the consumption for fuel increases due to different speeds during the tour as well as accelerations. In order to save fuel, it is advisable to let a ship travel as constantly as possible in all sections with an average speed. Looking at the bunker costs, it is known that bunker quantities are purchased at different bunker prices during a tour. In case of constant bunker prices for the whole tour, the total bunker costs are proportional to the total fuel consumption and minimal when travelling with constant speed.

Transport Time and Freight Limit Performance

The transport time between two harbours is the sum of the harbour time spent at each so-called harbour and the travel time between these harbours. The harbour time is the sum of all times for decelerating, pulling in, landing, loading and un-loading, pulling out and acceleration, and of the waiting times (see, e.g. Notteboom and Vernimmen 2008). The times required for locking, channel passing and other interruptions can be taken into account similar to the harbour times. When scheduling a tour, the actual stop times at the different harbours and other interruptions must be known. However, these times do not alter the cost-optimal speed and have only minor influence on the profit-optimal speed.

Looking at travel speed, we can identify a dependency between the transport time and the travel speed where a reduction in travel speed prolongs transport time nearly in the same relation. Any significant increases of the transport time affect thereby the achievable freight rates. Especially when high-value cargo is shipped, we need to take—at least—additional interest costs into account.

In order to utilize a given ship capacity best, we need to consider a maximally achievable filling degree. This can be obtained by optimal stowage plans. However, due to the many stowing restrictions of container ships in practise the achievable filling degree can be much lower than 95 %, whereas for bulk carriers also higher filling degrees than 95 % are possible (see Gudehus and Kotzab 2012).

Model calculations have shown that a 20 % reduction of speed can reduce the freight limit performance of a ship, which is the theoretical maximal freight capacity, by 18 %. As long as the sum of the travel times is significantly greater than the sum of the harbour times, the freight limit performance of the ship increases and decreases in proportion with the travel speed.

Shipping Operating Costs and Shipping Freight Costs

The operating costs for a ship refer to the costs for bunker, the costs for utilizing the ship and the harbour costs (see, e.g. HSH Nordbank 2009). Bunker costs depend on the bunker costs per roundtrip, the cycle frequency and the operation time. The utilization costs are determined by the operation time and ship utilization price, which is for own ships the cost rate and for leased ships the charter rate.

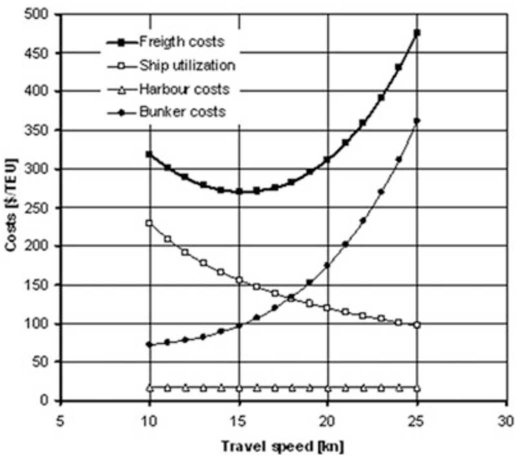

Fig. 2 Contributions and speed dependence of the shipping freight cost for full utilization of the effective capacity (data arises from Table 3)

The ship utilization price increases with the capacity and the installed maximal speed. As far as the technical utilization time of the ship and the lubricant consumption do not significantly alter with the speed, the utilization costs are independent from the current travel speed.

The harbour costs depend on operation time, number of stops per tour and the average harbour price which is the sum of the charges and dues for harbour facilities, pier utilization, tow boats, pilots, waterway utilization and other local services. Fees for channel passages, locks and other intermediate services can be treated like harbour prices. The harbour prices vary from stop to stop but do not depend on the travel speed. The shipping freight costs per load unit are the ship operating costs divided by the current freight performance of the ship. Their dependence on the shipping speed is shown in Fig. 2.

The freight costs are minimal at the cost-optimal speed, which in this example is 15.3 kn. As long as the freight demand for all segments of the tour exceeds the freight limit performance, the current freight performance equals the freight limit performance of the ship. Thereby, we need to acknowledge that freight costs decrease at first with increasing speed and, after passing a flat minimum at the cost-optimal speed, sharply increase.

Operating Profits

It is of course the goal when operating a shop to achieve a return which covers the business operating expenses of the shipping company and generates maximal profit. The operating profits of a single ship are the difference between the total freight revenues generated by the freight performance in the considered operation time and the operating costs (see also Corbett et al. 2009). We can thereby observe that a decrease in travel speed leads to an increase in operating profits as compared to a

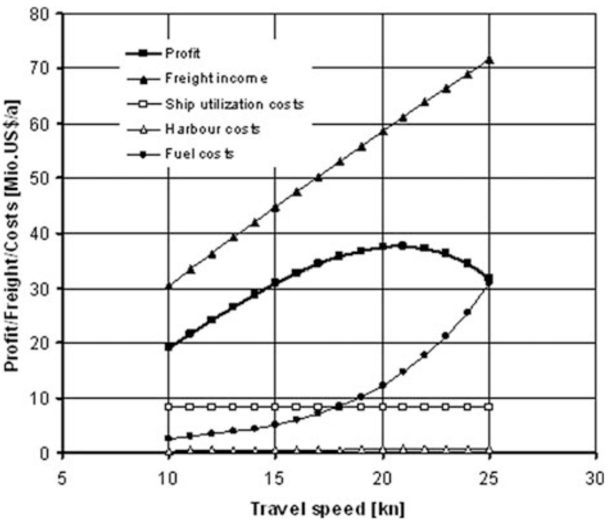

Fig. 3 Contributions and speed dependence of the operating profit for full utilization of the effective capacity (data arises from Table 3)

travel at maximal speed. The resulting influence of the shipping speed on the operating profit is shown in Fig. 3. In this case, the operating profit is maximal at the profit-optimal speed 20.7 kn.

Determination of Economic Ship Travel Speeds

Cost-Optimal Speed

The cost-optimal speed can be determined by looking at the ratio between ship utilization price and the bunker costs times the ascent parameters of the fuel consumption curve. It can be observed that the cost-optimal speed of a cargo ship increases with the (n + 1)-root of the ship utilization price and decreases inverse proportional with the (n + 1)-root of the bunker price. Furthermore, we can see that the cost-optimal speed is independent from the ship capacity and the tour length as well as from the number and costs of the harbour stops.

Profit-Optimal Speed

The determination of the profit-optimal speed considers the average freight rates, the effective ship capacity, the number of harbour stops, harbour prices and the average bunker prices times the ascent parameters of the fuel consumption curve.

Our calculations show that the profit-optimal speed decreases inversely proportional to the *n*-root of the bunker price, slightly faster than the cost-optimal speed. It is also independent from the ship utilization price and increases with the effective ship capacity. Thus, it is higher for large ships than for smaller ships as long as their capacity is fully used.

Profit-optimal speed also decreases with decreasing freight rate and reaches the cost-optimal speed if the achieved freight rate falls to the freight cost rate at full capacity utilization. It decreases only slightly with increasing number of harbour stops and longer harbour times and as far as the achievable freight rates do not depend on the distance, the profit-optimal speed is independent of the route length.

Comparison and Consequences

The model calculations were performed with a basic MS-Excel version developed by the authors. This spread sheet program consists of input-tables, such as Tables 1 and 2; output-tables, such as Table 3, backup sheets, where the different calculations are executed and tables, where intermediate data are stored.

Table 3 presents the result of three different scenarios for serving an outward and inward freight demand of more than 260,000 TEU/a between Hamburg and

Table 3 Fleet planning results for three scenarios with maximal speed, profit-optimal speed and cost-optimal speed and adopted number of ships

Key data	Maximal speed	Profit-optimal speed	Cost-optimal speed
Tour length (sm)	22,000	22,000	22,000
Service frequency per year	54	53 (−2 %)	57 (+6 %)
Travel speed (kn)	25.0	20.7 (−17 %)	15.3 (−39 %)
Transport time (days/dest.)	20	24 (+19 %)	32 (+57 %)
Fleet size (ships)	6	7 (+17 %)	10 (+67 %)
Fleet performance (TEU/a)	255,799	251,354 (−2 %)	271,268 (+6 %)
Freight rates outward (US$/TEU)	1050	1000 (−5 %)	950 (−10 %)
Freight rates return (US$/TEU)	630	600 (−5 %)	570 (−10 %)
Freight revenues (Mio.US$/a)	430	402 (−6 %)	412 (−4 %)
Operating costs (Mio.US$/a)	934	634 (−32 %)	522 (−44 %)
Operating profits (Mio.US$/a)	191	243 (+27 %)	271 (42 %)
Fuel consumption (t/a)	369,532	193,945 (−48 %)	107,880 (−71 %)
Fuel consumption/propulsion (t/a)	1.4	0.8 (−47 %)	0.4 (−72 %)
Carbon dioxide (CO_2, t/a)	1156,636	607,047 (−48 %)	337,665 (−71 %)
Sulphur Oxides (SO_x, t/a)	33,258	17,455 (−48 %)	9709 (−71 %)

Ship data from Table 1, operating data from Table 2

Shanghai by a fleet of 5000-TEU-container ships. The ship data are taken from Table 1, the operating data from Table 2.

The first column of Table 3 contains the results for a fleet of six ships travelling with the maximal design speed of 25.0 kn, the second column for a fleet of seven ships travelling with the profit-optimal speed of 20.7 kn and the third column for a fleet of nine ships travelling with the cost-optimal speed of 15.3 kn. In all three cases, the demand is served weekly with a total freight limit performance of the fleet around 255,000 TEU/a. Amazing are the resulting differences between operating costs, profits, fuel consumption and emissions. Our calculations have shown that despite the additional investment and the lower freight rates which have been assumed for compensating the longer transport times, the profits are increased by 28 % or 52 Mio. US$ when travelling with seven ships at profit-optimal speed, and increased by 34 % or 63 Mio. US$/a when travelling with nine ships at cost-optimal speed.

For the business case of Table 3, the reduction by travelling with profit-optimal speed is 45 % and saves annually 164,000 t fuel as well as 550,000 t CO_2 and 16,000 t SO_x; and with cost-optimal speed 70 % and saves annually 261,000 t fuel as well as 818,000 t CO_2 and 24,000 t SO_x.

Applying these saving percentages to the present global maritime fuel consumption and emissions of carbon dioxide, sulphur oxides, nitrogen oxides and soot, demonstrate the utmost importance of slow steaming in comparison to other means and measures which are tried or discussed presently in order to save fuel and reduce emissions (Bond 2008; Corbett et al. 2009; Faber et al. 2010; Meyer 2011).

Conclusion

Out of these results, we can see that cost-optimal and profit-optimal speeds can be used for the determination of optimal business strategies. Large operators following a cost-leader expansion strategy can reduce during times of decreasing freight demand and low freight rates, the travel speed of their fleets stepwise down to a cost-optimal value.

Limitations of the study refer to the narrow understanding of environmental sustainability due to reduction of GHG emissions, which is mainly due to reduction of bunker fuel due to a lower speed. Other issues of environmental sustainability have been excluded in our discussion.

By using the achieved cost savings, lower freight rates can be offered in order to attract additional freight and to ensure sufficient utilization. In times of increasing freight demand and high freight rates on the markets, the travel speed is increased up to the profit-optimal speed. The freight rates can be increased as long as the utilization is not affected. However, business practise has shown that the main motive for slow steaming is reduced costs.

References

Bond P (2008) Improving fuel efficiency through supply chain? And the ship management plan. http://www.intermanager.org/2008/11/improving-fuel-efficiency-through-the-supply-chain/

Cariou P (2011) Is slow steaming a sustainable means of reducing CO_2 emissions from container shipping? Transp Res 16D:260–264

Corbett JJ, Wang H, Winebrake JJ (2009) The effectiveness of speed reductions on emissions from international shipping. Transp Res 14D:593–598

Eyring V, Isaksen ISA, Berntsen T, Collins W, Corbett JJ, Endresen O, Grainger RG, Moldanova J, Schlager H, Stevenson DS (2010) Transport impacts on atmosphere and climate: shipping. Atmos Environ 44:4735–4771

Faber J, Freund M, Köpke M, Nelissen D (2010) Going slow to reduce emissions. Can the current surpluse of maritime transport capacity be turned into an opportunity to reduce GHG Emissions? Seas at Risk http://www.seas-at-risk.org/pdfs/speed%20study_Final%20version_SS.pdf

Gudehus T (2010) Optimale Geschwindigkeiten von Frachtschiffen, Forschungsbericht. Hamburg (Optimal freight ship speeds. A research report)

Gudehus T, Kotzab H (2012) Comprehensive logistics, 2nd revised and enlarged edn. Springer, Heidelberg

HSH Nordbank (2009) Betriebskostenstudie 2009. Untersuchung der Betriebskosten deutscher Containerschiffe—Kurzfassung (Study on operation costs 2009. Examining the operation costs of German container ships—Short version). Hamburg

Meyer J (2011) Slow steaming in der Contanerschifffahrt. TU Hamburg-Harburg

Münchmeier Petersen Capital (2003) Informationsbroschüre über die Beteilgungsgesellschaft Santa P Schiffe mit 6 Panamax-Containershiffen (Information leaflet for venture capital company Santa P ships with 6 Panamax-Containerships)

Notteboom T, Vernimmen B (2008) The effect of high fuel cost on liner service configuration in container shipping. J Transp Geogr 17:325–337

Psaraftis H, Kontovas C (2010) Balancing the economic and environmental performance of maritime transport. Transp Res 15D:458–462

Ronen D (1982) The effect of oil price on the optimal speed of ships. J Oper Res Soc 33:1034–1040

Schneekuth H, Bertram K (1998) Ship design for efficiency and economy, 2nd edn. Butterworth-Heinemann, London

Song D-P, Xu J (2012) An operational activity-based method to estimate emissions from container shipping considering empty container repositing. Transp Res 17D:91–96

A Five-Step Approach for Dynamic Collaborative Transportation Planning on Hard Time Horizon

Kristian Schopka, Xin Wang and Herbert Kopfer

Abstract Freight carriers are often confronted with customers demanding for quick execution of their transport requests. Especially for Small and Mid-size Carriers (SMCs), it is very difficult to deal with the uncertainness pertinent to dynamic planning. Horizontal collaboration may help SMCs to operate more efficiently in such situations by performing Collaborative Transportation Planning (CTP). As shown in the literature referring to static situations, SMCs are able to generate high cost savings due to the exchange of requests. To realize such synergy also in dynamic situations, approaches of CTP must be adapted for Dynamic CTP Problems (DCTPP). In this paper, a DCTPP of a coalition of freight carriers with the same hard planning horizon is presented. A stepwise approach using single event optimization is proposed to solve this problem. Computational studies are presented to identify the cost saving potential of the DCTPP against isolated planning. Furthermore, an analysis of the best times for a new planning is performed.

Keywords Dynamic collaborative transportation planning problem · Horizontal carrier collaboration · Request exchange · Periodic re-optimization

Introduction

Nowadays, freight carriers are confronted with more complex transportation problems. One main reason for this trend is the customer demand for transport solutions in nearly real time. Especially for Small and Mid-size Carriers (SMCs), it

K. Schopka (✉) · X. Wang · H. Kopfer
Chair of Logistics, University of Bremen, Bremen, Germany
e-mail: schopka@uni-bremen.de

X. Wang
e-mail: xin.wang@uni-bremen.de

H. Kopfer
e-mail: kopfer@uni-bremen.de

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is difficult to create efficient solutions, because of their small pools of resources for disposal. A possibility to realize the economies of scale like large forwarding companies may be found in the establishment of a horizontal cooperation with competitors.

By exchanging requests, SMCs can realize cost benefits up to 20 % (Ergun et al. 2007). Furthermore, the reduction of the total length of drives results in an additional ecological gain. In the proposed type of horizontal cooperation, the autonomy of all members is preserved, where the cooperation can be understood as a joint decision-making process (Stadtler 2009). This combination of conditions is defined as Collaborative Transportation Planning (CTP) (Wang and Kopfer 2014).

In the last decade, much research on the CTP was presented. It is shown that collaboration is able to reduce costs in static situations. Since problems in reality are often dynamic, Wang and Kopfer (2013) introduced a rolling horizon planning approach, which considers the process of collaboration in a dynamic way. The authors also define the class of Dynamic CTP Problems (DCTPP).

In this paper, a scenario of the DCTPP is presented and a Five-Step Approach (FSA) for solving the DCTPP is introduced. In the given dynamic situation, the FSA is solved repeatedly at defined planning times. This paper is structured as follows: in section "Literature Review", a literature review on the dynamic and deterministic vehicle routing and the CTP is given; section "Problem Definition" defines the basic problem; in section "A Five-Step Approach", the FSA is introduced; in section "Computational Study", the results of computational studies are shown; finally, section "Conclusion" concludes the paper.

Literature Review

The DCTPP is an extension of the CTP to dynamic situations. To our knowledge, the presented research of the DCTPP, apart from the approach of Wang and Kopfer (2013), is very rare. Therefore, in this section, a literature review on the two relevant topics, namely dynamic and deterministic vehicle routing and CTP, is given.

In the classical definition, routing problems are considered as being completely determined a priori. Several real world problems differ from this consideration in the dimensions of evolution and quality. The evolution defines, whether all information is known (static) or some is unknown (dynamic) at the beginning. The quality states, whether the data is deterministic or stochastic. An overview of all possible combinations and the dynamic routing problems is given in Pillac et al. (2013).

According to Pillac et al. (2013), the approaches of dynamic and deterministic routing problems are classified in the types of periodic and continuous reoptimization. Approaches of periodic reoptimization construct an initial solution for the current static problem. The initial solution is updated when input data change, for example when new requests arrive. This strategy is used in Psaraftis (1980) and Yang et al. (2004). Alternatively, the initial solution can be updated after a defined time interval, as seen in Wang and Kopfer (2013). Both methods imply the Single Event Optimization (SEO) shown in Bianchi (2000). The basic idea of the continuous reoptimization is to run an optimization routine and maintain good solutions in an adaptive memory. Whenever new pieces of information arrive, the current planning will be updated. Furthermore, for each vehicle only one request is planned. The next request is not planned before the current one is served. An example of continuous reoptimization is given in Gendreau et al. (1999).

A possibility to deal with the ambiguity of dynamic planning may be found in the establishment of horizontal cooperation. Some general opportunities and impediments of this type are revealed in Cruijssen et al. (2007). A possibility for the realization of cooperation can be found in exchanging requests among coalition members. To organize this, exchange mechanisms must be developed. These mechanisms should be (1) simple and implementable, (2) effective in terms of generating high benefits and (3) able to deal with distributed information and decision-making competencies (Özener et al. 2011; Wang and Kopfer 2014).

In literature, several approaches solving the static CTP have been presented. Most of these approaches use auction mechanisms to perform the CTP within. Here, the Vickrey auction (Vickrey 1961) and the combinatorial auction are identified as best auction strategies by Gomber et al. (1997). Furthermore, some approaches are presented that solve the CTP problem in several steps, like Krajewska and Kopfer (2006), Schwind et al. (2009), Berger and Bierwirth (2010). These stepwise approaches preserve the autonomy of each coalition member.

Problem Definition

In a horizontal carrier coalition, there are m independent carriers having the same planning horizon, e.g., a working day from 8:00 to 16:00. Each coalition member t, receives n_t, homogeneous requests that are denoted as R_t, where $R = \cup_{t=1}^{m} R_t$ is the set of all requests. Each request j generates a benefit b_j, if it is served. The aim of each member is to maximize his benefits. To achieve this, the members can exchange requests with others. Subcontracting requests to external carriers is excluded, which means that all requests must be served within the coalition. To guarantee a decentralized planning, each member is responsible for his own set of requests and decides, whether he self-fulfills a request or transfers it to his partners.

Each member possesses only one truck to serve his attached requests. The geographical position of a truck changes at every planning time. In the first planning period, the start position is the depot. In later planning periods, it is set to the geographical position of a current request. During the time horizon, some new requests appear implying the dynamics of the problem. Furthermore, a deadline (e.g., 14:00) is defined. It has to be guaranteed that all requests arriving before the deadline are served in the hard time horizon.

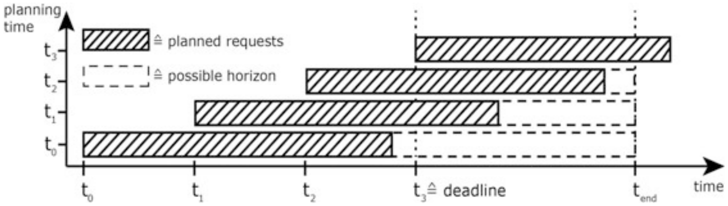

Fig. 1 Example for the planning points in hard time horizon

Joint planning times, at which all members have to plan the whole horizon, must be defined in advance. The first planning point is the beginning of the horizon and the last planning point is the time of the deadline. Between these fixed points, the members can define extra points (e.g., a new planning point every hour). Speculation to get more information is forbidden, so that all trucks must leave their current positions at the earliest possible time. Because of this regulation the number of requests served as early as possible is maximized, which results in more capacity in the following intervals. After the deadline, no new request arrives, so that only one static problem must be solved. If it is impossible for a member to serve his attached requests during the time horizon, overtime is allowed. On the other hand, if a planned route ends earlier, short-time is possible as well. An illustration of the planning horizon with its planning points can be found in Fig. 1.

A Five-Step Approach

To solve the problem defined in section "Problem Definition", an FSA is introduced. The FSA solves a given problem instance with the current database by identifying all requests that can be exchanged. These requests are assigned to the members via a modified Vickrey auction. Furthermore, the approach generates the scheduling with database for the current planning period. By repeating the static stepwise procedure at defined joint planning times, the given dynamic problem can be considered. Figure 2 shows the basic idea of the iterative process of our FSA.

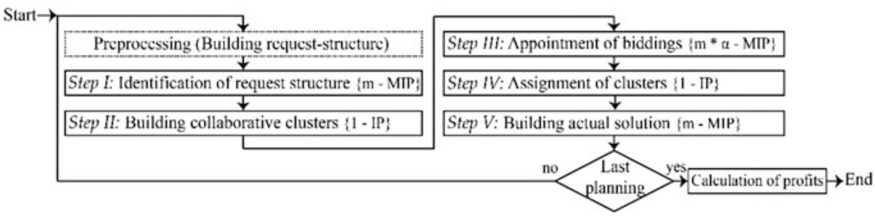

Fig. 2 Basic idea of the FSA

Static Solution Building

In this section, the five steps of the FSA namely Identification of Request Structure, Building Collaborative Clusters, Appointment of Biddings, Assignment of Clusters, and Building Actual Solution are presented. Here, a static situation, which is given at each joint planning time, is examined.

Step I Identification of Request Structure: In the first step, all members decide whether each of their own requests should be served by themselves or reallocated in the collaboration, this guarantees autonomy of each member. In reality, there are many possibilities of how members can decide about their self-fulfillment of requests. Theoretically, all members can use different criteria. In contrast, all members of our FSA use a Profitable Tour Problem (PTP). A formulation of the PTP is given by Feillet et al. (2005). After the PTP is solved for each member t, the values of the objective function are stored in the set $D1_t$. Furthermore, the requests must be sorted into two groups: self-fulfill requests (RS_t) and collaboration requests (RC_t) for each member t. A request i is stored in RS_t, when i is served in the PTP, otherwise i is stored in RC_t. After the classification, the sets RC_t of all members are combined to form the set RC, which represents the union set of collaboration requests.

Step II Building Collaborative Clusters: The goal of the second step is to reduce the computing complexity in the following steps by building wise clusters of requests in RC. Here, requests that have a geographical neighborhood relation are merged. The maximum size of this geographical neighborhood is given by N. Furthermore, as few as possible clusters should be generated. To achieve this aim, for each cluster a request is chosen, which represents the center of the cluster. Here, each request is able to present the center of a cluster. If a request has a neighborhood relation to several clusters, it is allocated to the nearest one. To generate the clusters, an Integer Program (IP) is developed. Here, the binary variable x_{ij} is introduced to identify which request belongs to which cluster. The rows j presents the possible clusters and the columns i give the requests. If x_{ij} has the value 1, a request i belongs to a cluster j; otherwise i is not a part of j. Furthermore, if a decision variable x_{jj} has the value 1, a cluster j is needed; otherwise there is no need of this cluster.

$$\min \sum_{j \epsilon RC} (M \cdot x_{jj} + \sum_{i \epsilon RC} x_{ij} \cdot c_{ij}) \tag{1}$$

$$\text{s.t:} \sum_{i \epsilon RC} x_{ij} = 1 \quad \forall j \in RC \tag{2}$$

$$x_{ij} \cdot c_{ij} \leq N \quad \forall (i,j) \in RC \times RC \tag{3}$$

$$x_{ij} \epsilon \{0, 1\} \quad \forall (i,j) \in RC \times RC \tag{4}$$

The objective function (1) minimizes the sum of used clusters and the distances between the requests of each cluster. In this function, the aim is to reduce the quantity of clusters (rated with big M). The distance between each request i and the center of each possible cluster j is given by c_{ij} and represents the second part of the objective function. Constraint (2) allocates each request to only one cluster. Constraint (3) settles that the neighborhood relation is observed. The number of used clusters can be identified by the sum of the rows of x_{ij} that are not equal to 0. For all used clusters α, the elected requests are stored into the set RB_α. In the next step, only these clusters are considered.

Step III Appointment of Biddings: In this step of the approach, the auction bidding for each combination of member and cluster are determined. Here, a member has also a lot of possibilities of how he can evaluate his cluster bidding. In our FSA, we solve a Traveling Salesman Problem (TSP) for every combination of each member t and each cluster α. The general definition of the TSP is given in Flood (1956). The union of requests for each combination is given by $(R =)R_t = RS_t \cup RB_\alpha$. In our TSP, the objective function of the general TSP must be extended by profits to get comparability between step I and III. To reach this goal, the cost minimizing function is changed to the profit maximizing objective function (5) of the PTP. Constraints (6)–(12) are well known from literature.

$$\max \sum_{(i,j)\epsilon R\times R} x_{ij} \cdot (b_j - c_{ij}) \tag{5}$$

$$\text{s.t}: \sum_{j\epsilon R\backslash\{0\}} x_{ij} = 1 \quad \forall i \in R\backslash\{\text{n}+1\} \tag{6}$$

$$\sum_{i\epsilon R\backslash\{n+1\}} x_{ij} = 1 \quad \forall j \in R\backslash\{0\} \tag{7}$$

$$\sum_{i\epsilon R} x_{ih} - \sum_{j\epsilon R} x_{hj} = 0 \quad \forall h \in R\backslash\{0, n+1\} \tag{8}$$

$$m_0 = 0 \tag{9}$$

$$m_i - M \cdot \left(1 - x_{ij}\right) \leq m_j - 1 \quad \forall (i,j) \in R \times R \tag{10}$$

$$x_{ij} \epsilon \{0, 1\} \quad \forall (i,j) \in R \times R \tag{11}$$

$$m_i \epsilon \mathbb{N} \quad \forall i \in R \tag{12}$$

After solving, the individual profit is stored in the set $D2_{t\alpha}$ for each combination of member t and cluster α. Now, the marginal contribution can be calculated for each combination by subcontracting $D2_{t\alpha}$ from $D1_t$. The results are stored in the set $D_{t\alpha}$. The marginal contribution gives the information of how much a member is willing to pay for a cluster or how much compensation a member must get to generate the same benefit as before.

Step IV Assignment of Clusters: In this step, each cluster is assigned to a member via Vickrey auction. The original Vickrey principle recommends that the bidder with the highest bid wins the auction by paying the second highest bid (Vickrey 1961). The best strategy is identified by bidding truthfully (Gomber et al. 1997). For the execution of the auction, we distinguish three situations: In the first one, where multiple positive bids for a cluster exist, the Vickrey principle is applied. In the second situation, only one positive bid exists, the bidder with a positive bid wins the auction but has to pay nothing, because all other members abdicate. In the remaining situation, all bids are negative. A member must be dictated who has to serve the cluster. The best strategy for the collaboration is to choose the member with the highest margin and to pay him this value as adjustment. After the assignment, all attributive requests of member t are stored into the set RD_t.

The result of the combination of requests from different members is that it is difficult to determine the payments among the members. For simplification, a collaboration account (CA) and accounts for all members (MA_t) are introduced. The identified auction payments of each winning member t are paid from MA_t to CA, respectively; all adjustment payments of t are taken from CA to MA_t. After the assignment of all clusters, the accounting balance of CA is distributed among the members. This treatment seems to be fair because, as described, all members submit the same request structure into the collaboration.

Step V Building Actual Solution: In the last step, the scheduling for each member t with requests RS_t and RD_t is generated. For this purpose, the constraints (9), (10) and (12) are extended with a time factor w_i, which defines the arrival time of request i. The new constraint (13) sets the factor w_0. It forces the leaving time of the start depot to be equal to the earliest possible time (a) and replaces constraint (9). In the first planning period, a is set to 0. Later on, a is given by w_r of a start request r. Constraint (14) is a modification of the subtour elimination constraint of Miller et al. (1960) and replaces constraint (10). Here, s_i represents the service time of a request i. Constraint (15) defines the range of w_i for each request i. The modified TSP together with its new constraints is solved for each member t to get the current tour scheduling and benefits. The benefits of each member t must be reduced or raised by MA_t to get a proper value.

$$w_0 = a \tag{13}$$

$$w_i + M \cdot \left(1 - x_{ij}\right) \geq w_j - s_i - c_{ij} \quad \forall\, (i,j) \in R \times R \tag{14}$$

$$w_i \epsilon\, \mathbb{R}^+ \quad \forall\, i \in R \tag{15}$$

Dynamic Planning

As constituted in section “Problem Definition”, not all requests are known at the beginning, which excludes a static planning. For a solution via FSA, the problem together with its current database is converted into a static model at every joint planning point. This method implies the periodic reoptimization or SEO. The general idea is shown in Fig. 2.

At every planning point, all members consider their current request structure, which results from the unattended requests of the last planning and the incoming requests since then. The incoming requests are planned in the current planning for the first time. This implies a fixed planning between a current and a following planning. Due to this knowledge, the best strategy is to plan as many requests as possible in this period, because there are no capacities for incoming requests necessary.

As described in section "Problem Definition", the position of the start depot changes in every planning phase and are only in the first planning phase the same as the end depot. To consider the different locations, all models of the FSA consider a Hamilton path. At each new planning point, the position of the start depot (r_0) and the earliest leaving time (a) must be identified. Here, we distinguish three possibilities: First, the truck serves a request i at the time of a new planning. In this situation, r_0 is defined as i and a is set to w_i. The second situation is obtained, when a truck is on its way to a customer j. Here, we define j as the new r_0 and set a to $w_j + s_j$. Alternatively, a truck is planned on the way to or at the end depot. In this situation, r_0 is set to be equal to the last served request and a is set to the current planning time. Here, we disclaim a return to the end depot at all planning points without the last one. As described, a return to the end depot is only allowed in the last planning phase. But the cost of this return has an influence on the scheduling. In early planning periods, the return to the depot is far away and its cost should not be rated as high as the traveling costs between the requests. For the evaluation of the return, a cost factor (d) is introduced. In the first planning phase, a value of 0 should be chosen for d. The value of d rises slowly, before it reaches the value of 1 at the last planning point. For the consideration of d, the objective function (5) must be changed to function (16) for all problems in steps I, III and V described in section "Static Solution Building".

$$\max \sum_{(i,j)\epsilon R \times R \setminus \{n+1\}} \left(x_{ij} \cdot (b_j - c_{ij}) - d \cdot x_{i,n+1} \cdot c_{i,n+1}\right) \tag{16}$$

For the accounting of the profits (P_{pt}) for member t in period p, the benefits and costs of the attended requests should be considered. A request i is attended, when i is identified as r_0 for the following planning point or when i is served before the new r_0. Only the profits and costs of the attended requests are added to P_{pt}. Afterward, P_{pt} must be reduced or raised by MA_t (see section "Static Solution Building"). After the planning at the last point, all values of P_{pt} of a member t are added to obtain the total profits of the whole horizon.

Computational Study

To evaluate the collaboration saving potential that can be realized through FSA, we generate four different types of instances (A–D). The instances differ in the number of members (m) and of requests (n_t), the geographical square of size (gs), the benefits (b_j) of each request j, the basic time of planning interval (τ), the grade of dynamic (δ) and the neighborhood size (N). Furthermore, we define six different functions for the evaluation of d that can be grouped into the type sharp jump (jum) and exponential increase (exp). An overview of the parameters is given in Table 1.

In the test cases, the depots of the members are positioned randomly over the considered square of size. The associated requests of a member are uniformly distributed in a circle around the depot. This situation induces an overlapping of requests in the gap among members. For each request j, a benefit b_j is randomly defined. In our tests, the requests of an instance type have a given preexisting order in which they arrive. By the modification of the factors τ, δ, N and the d-function, we generate 91 different test scenarios overall. The FSA is implemented in a Java program in which CPLEX is embedded to solve the MIP models. The instances are solved on a Windows 7 personal computer with Intel Core i7-2600 processor (3.4 GHz and 16 GB memory). In our computational study, we simulate for each of the given scenarios the Isolated Planning (ISO) and a collaborative planning by FSA.

As listed in Table 2, the FSA can generate high-cost savings compared to ISO. These savings result in profit gains for all members. The average savings of our dynamic instances range from 20 to 40 % and are thereby higher as the potential

Table 1 Types of instances

Type	m	n_t	gs	b_j	τ	δ	N	d-function
A	3	100	60 × 60	5–10	20–1200	0.4–0.8	1–20	jum/exp
B	4	60	40 × 40	3–8	15–600	0.5–0.83	1–20	jum/exp
C	2	120	40 × 40	3–8	20–1200	0.58–0.83	1–20	jum/exp
D	5	50	60 × 34	3–8	20–600	0.4–0.8	1–20	jum/exp

Table 2 Cost saving potential: FSA versus ISO

Type	Test–cases	ISO		FSA		∅ savings	In percentage
		∅ profit	∅ cost	∅ profit	∅ cost		
A	3	91.22	2087.78	770.57	1408.43	679.35	32.54
B	4	−130.17	1548.17	170.95	1247.05	301.12	19.54
C	2	259.32	1096.68	684.82	671.18	425.50	38.80
D	5	117.42	1235.58	416.03	939.97	298.61	24.17

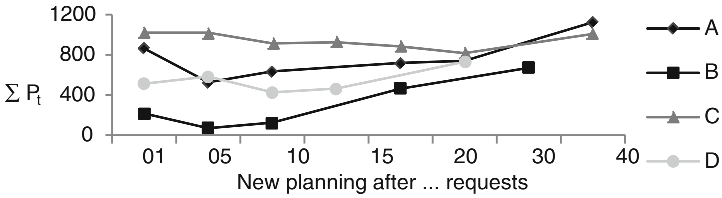

Fig. 3 Profits by changing planning times

given in Ergun et al. (2007). We can conclude that collaboration in dynamic situations has a higher potential. This can be explained with the imperative of quick reactions that are reached more effectively by applying a larger pool of resources for disposal in collaboration.

Through varying τ, we can generate different strategies for the selection of joint planning times. The general results of our study are shown in Fig. 3. Here, we can see that in scenarios with few planning points, the approach is able to generate the highest profits because they tend to be a static planning. A special feature in our study is that scenarios that generate immediately new planning obtain more profits than those that plan moderately often. This observation can be explained as such, that these scenarios have a higher average number of current requests per planning, which facilitates the building of promising clusters and results in cost savings. If it is necessary to plan more than two times, an immediate planning should be preferred against a moderately often planning in our FSA.

Conclusion

Through the establishment of horizontal coalitions, SMCs are able to improve their operational efficiency and realize high-cost savings. Particularly, in dynamic scenarios with uncertainness, the realization of this synergy for SMCs is necessary to save their competitiveness against large forwarding companies. In our paper, a DCTPP is presented in which several SMCs with the same hard time horizon perform CTP with request exchange. To solve this problem, an FSA framework is introduced that preserves autonomy for all members. Moreover, the presented mechanism confirms with the defined exigencies of CTP (see section "Literature Review"). How the FSA can deal with dynamic situations via periodic reoptimization is also shown. Computational studies are carried out. The identified cost saving potential of the FSA against ISO accounts up to 40 %. Another study presents strategies for the selection of joint planning times with the result that very low and high planning frequencies generate the highest benefits. Because of the identified potential, the future research of DCTPP should be expended. In this context, the focus should be laid to the development of more complex and realistic models. Moreover, a need of research is given by the adaptation of powerful metaheuristics for DCTPP. Especially, for stepwise approaches an improvement may be achieved by including instruments of game theory to guarantee a fair and long-living process of CTP.

References

Berger S, Bierwirth C (2010) Solutions to the request reassignment problem in collaborative carrier networks. Transp Res Part E Logistics Transp Rev 46(5):627–638

Bianchi L (2000) Notes on dynamic vehicle routing—the state of the art. Technical report IDSIA-05-01, IDSIA

Cruijssen F, Cools M, Fleuren W (2007) Horizontal cooperation in transport and logistics: a literature review. Transp J 46:22–39

Ergun Ö, Kuyzu G, Savelsbergh M (2007) Shipper collaboration. Comput Oper Res 34 (6):1551–1560

Feillet D, Dejax P, Gendreau M (2005) Traveling salesman problems with profits. Transp Sci 39 (2):188–205

Flood MM (1956) The traveling-salesman problem. Oper Res 4(1):61–75

Gendreau M, Guertin F, Potvin J-Y, Taillard E (1999) Parallel tabu search for real-time vehicle routing and dispatching. Transp Sci 33(4):381–390

Gomber P, Schmidt C, Weinhardt C (1997) Elektronische Märkte für die dezentrale Transport-planung. Wirtschaftsinformatik 39(2):137–145

Krajewska M, Kopfer H (2006) Collaborating freight forwarding enterprises. OR Spectrum 28 (3):301–317

Miller CE, Tucker AW, Zemlin RA (1960) Integer programming formulation of traveling salesman problems. J ACM 7(4):326–329

Özener Ö, Ergun Ö, Savelsberg M (2011) Lane-exchange mechanisms for truckload carrier collaboration. Transp Sci 45(1):1–17

Pillac V, Gendreau M, Guret C, Medaglia AL (2013) A review of dynamic vehicle routing problems. Eur J Oper Res 225(1):1–11

Psaraftis HN (1980) A dynamic programming solution to the single vehicle many-to-many immediate request dial-a-ride problem. Transp Sci 14(2):130–154

Schwind M, Gujo O, Vykoukal J (2009) A combinatorial intra-enterprise exchange for logistics services. Inf Syst e-Bus Manage 7(4):447–471

Stadtler H (2009) A framework for collaborative planning and state-of-the-art. OR Spectrum 31 (1):5–30

Vickrey W (1961) Counter speculation, auctions and competitive sealed tenders. J Financ 16 (1):8–37

Wang X, Kopfer H (2014) Collaborative transportation planning of less-than- truckload freight. OR Spectrum 36(2):357–380

Wang X, Kopfer H (2013) Dynamic collaborative transportation planning: a rolling horizon planning approach. In: Pacino D, Voß S, Jensen R (eds) Computational logistics. Springer, Berlin, pp 128–142

Yang J, Jaillet P, Mahmassani H (2004) Real-time multivehicle truckload pickup and delivery problems. Transp Sci 38(2):135–148

On Using Collaborative Networked Organizations in International Outbound Logistics

Kim Jansson, Iris Karvonen and Aino Vaittinen

Abstract This paper analyses if the Collaborative Networked Organizations (CNO) concept can bring advantages in organizing the international outbound logistics for SMEs. In the manufacturing domain, the European CNO research has identified benefits from using the concept in traditional supply chains, collaboration in various inbound networks and business eco-systems. Less focus has been made on outbound logistics for delivering products and related service to customers at remote locations. The analysis is based on the conducted company interviews. The interviewed companies have a good record of successful international operations. The used international delivery models are mapped into the taxonomy of well-known outbound logistics models. The paper proposes a customer interface network model, based on the CNO concept to tackle problems encountered.

Keywords International distribution · International outbound logistics · Collaborative networked organizations · SME · Delivery models

Introduction

The outbound logistics is an area of big concern for organizations seeking to expand from local to international markets. For an SME type company having limited resources, this is a real problem. The resources of SMEs, both as finance and as competent personnel, are lower than those of large enterprises. There are examples of companies that have made substantial efforts to sell to new market

K. Jansson (✉) · I. Karvonen · A. Vaittinen
VTT Technical Research Centre of Finland, P.O. Box 1000, 02044 VTT Espoo, Finland
e-mail: Kim.Jansson@vtt.fi

I. Karvonen
e-mail: Iris.Karvonen@vtt.fi

A. Vaittinen
e-mail: Aino.Vaittinen@gmail.com

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areas, but did not succeed and finally withdrew from the location. SMEs willing to extend to geographically new markets need to consider how and through which stages the entrance is made. For example, which operations are transferred to the target areas and which are kept in the home country or in the neighbourhood, how to build the distribution network, what kind of collaborative partners is needed and how to identify them?

The objective of this paper is to discuss the organizational forms of SMEs in global operations. The paper first presents the results from two qualitative research studies, based on interviews in SME companies. Both studies are motivated by the growth opportunities on the remote markets at the same time as the local European market is in change. The interviewed companies all have a successful history of internationalization. A summary of used outbound logistics delivery models has been collected and interview observations are presented.

Furthermore, the paper describes how the collaborative networked organizations concepts could be used to develop delivery models in international logistics. The long-term goal is to support European SMEs to produce goods and deploy efficient outbound logistics for international markets.

The first set of interviews was conducted within the marine industries. A large-scale FIMECC; Innovations and Network (I&N) research programme was launched in the beginning of 2009 with special focus on marine industries (FIMECC 2009). The "Net" project, being a minor project and a part of I&N programme, focuses on SME companies' direct international businesses and customer segments. The research work carried out generates explorative data, based on questionnaires and interviews. The Finnish marine industry branch is to a high degree networked, involving a large number of companies, mostly SMEs, having the local shipyards as the main customer. Due to the dramatically decreasing number of new building orders received by the shipyards, the companies now have to search for direct overseas international business, develop their international business processes and international delivery logistics operations.

In parallel, the "Industrial Global Logistics Value Networks" Tarvo project (Tarvo 2013) was started by VTT in 2012 with support from the national research funding organization Tekes (2013). In the project, the focus is on Finnish manufacturing SME companies who are either entering the global markets or increasing their volume of export. The objective is to create modern delivery logistics networks for SME companies to increase sales on the Asian markets.

In this context, the meaning of outbound logistics or international delivery logistics is broader than just transportation for order fulfilment to the customer. International delivery logistics cover also the identification and creation of sales channels, assembly, inventories, customer pick-up points, spare parts, repair and maintenance service, training, etc. at remote locations.

In both the mentioned projects, a number of industrial interviews have been carried out with representatives of the company management. The interviews give real world information on used models for customer value creation. This paper is based on the work carried out by VTT in the Tarvo project and in the Net projects together with Turku School of Economics at the University of Turku.

Section "International Distribution Network Models" describes the used international delivery network models and a summary of observations from the conducted interviews. Section "Results from Conducted Interviews" discusses European research results in the area of CNO and their application to distribution networks. Section "Application of CNO Approaches in Outbound Logistics" gives the conclusions and ways forward.

International Distribution Network Models

There are several possibilities to the entry of new markets, like using export company, agent, distributor or creating alliances with local companies or building an own company to new markets. Often, SMEs need to build their entrance to the market not only as sales channels but also as operational support and maintenance. To achieve sufficient volume in the market, also some manufacturing or engineering activities may need to be moved to the target area. Typically, the form of the presence on the distant market area does not remain the same. The partners and the organizational arrangement of the distribution network may evolve along the time.

In Fig. 1, taxonomy for international delivery networks is presented, based on a literature review. The network types have two main types: direct or indirect ways, depending on, if there are intermediate organizations involved between, the company and the customer. *Joint ventures*, *Franchising* and *Commissioning/Licensing* are drawn with dashed lines, as they were not seen as common for the industry branches in the interviews.

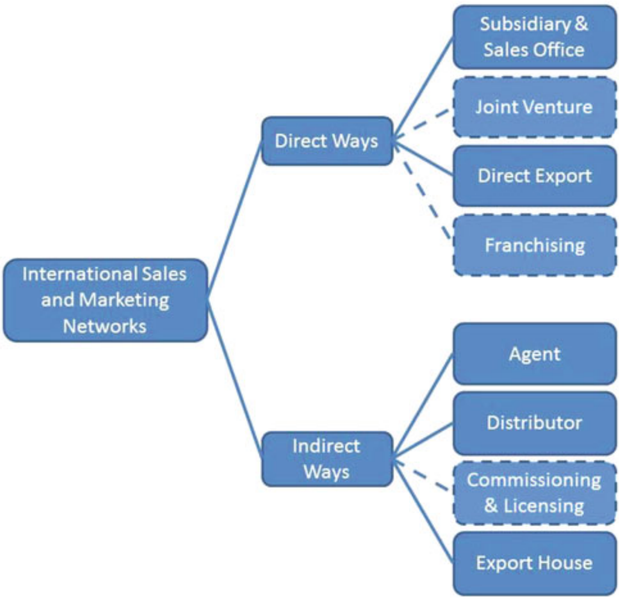

Fig. 1 Taxonomy of organization models in international distribution networks

The different options have different challenges regarding needed resources, identification and commitment of partners, contracting, pricing, and controlling the market and contacts to the customers. The following four graphs in Fig. 2, give an overview of the roles, information flows and contract relations of the most used organization models in the taxonomy. Table 1 gives an overview of the different features in organization models.

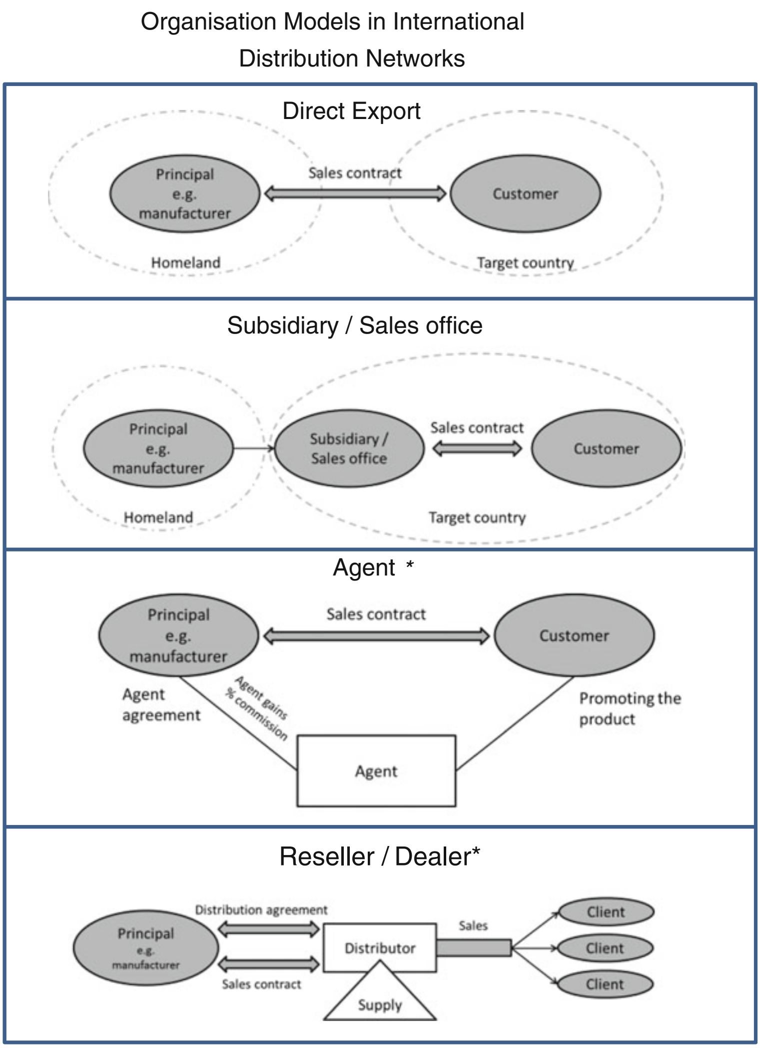

Fig. 2 Overview of the used organization models. *Source* Caraiani and Potecea (2010)

Table 1 Summary of features of the used models

	Description	Benefits	Challenges	When to apply?
Agent	Agent opens doors in export; sales contract between manufacturer and customer	Contact to customers. Knowledge of the agent area	Contractually difficult. Commitment of the agent. Takes more resources than direct export	Useful way to create contacts to customers when there are no contacts
Dealer	Dealer buys the products from the manufacturer and sells them to customers	The dealer takes the risk of sales. The dealer knows the area	No direct contact to the customers. Commitment of the dealer. Price setting. Requires more resources than direct export	For standard products and other situations when the contact to customers is not necessary
Direct export	Company has direct contact to customers	Direct contact to customers. No difficult contracts. Requires less resources than agent or dealer	Not continuous presence at the market. Travelling costs. It may be difficult to reach the customers	In cases when the number of customers is restricted and does not require too much travelling (short distances/not very often)
Subsidiary company/own sales office	The sales office or subsidiary company is in the same country or area as customers	Direct contact to customers. Commitment of employees. Using a subsidiary company some taxes can be avoided	Costs of creating the remote office of company. Recruiting the employees. Collecting needed knowledge	Not in the first phases of globalization
Partnership with a foreign company	Collaboration with a foreign company to market and sell the products together	Increased credibility and more business potential	How to build the relationship and identify proper partners?	The products or services of the partners complement each other
Export ring/export house	Companies with the same origin country collaborate for common export	The export house may support in export and market knowledge	No direct contacts to customers. Difficult to monitor the market	The company has low knowledge and resources for sales and export activities

Results from Conducted Interviews

The objectives of the Net project interviews are to get deep understanding of direct international business model characteristics in the SME marine sector. The purposes of the Tarvo project interviews are to review paths for setting up international delivery networks with special emphasis on the Chinese markets. Although the objectives of the two interview groups were slightly different, the used interview questions were quite the same. The researchers did the selection of the companies to be interviewed. The candidate companies were on forehand known to be involved in international business. Thus, only qualitative results are expected, while the sampling is biased for quantitative results.

Altogether 17 companies were interviewed, of which one was interviewed twice (once in both projects). Companies are kept anonymous in this paper. Together they represent ten equipment providers for the marine and process industry, two turnkey marine outfitting providers, one software provider, one automation provider, a mall shipyard and an engineering design company. Ten companies are involved in project type deliveries and the rest in assembly to order and standard product type deliveries. With the exception of the software provider and the engineering company, all the other companies deliver tangible products together with a varying degree of intangible services and software.

Table 2 shows the number of used models in the interviewed companies. As a summary of the interviews, we can state that

- All model types are used. The used model is depending on production volumes, maturity and time, geographical area and local legislation.
- Subsidiary company/Own sales office is the most used distribution network model within this group of companies.
- Direct export is the second most used model.
- Collaboration with international partners is an important channel to the international customers.
- When companies have production abroad, then it is mostly organized in own subsidiary companies.
- A majority of project type deliveries go by direct export.
- Joint venture is an unpopular model.
- A development pattern can be distinguished as the time passes and local presence mature. Dealer and Agent → Direct export → Subsidiary.

  The following list is a collection of success factors for sales and distribution. The comments have been collected from the interviews and grouped together.

Table 2 Number of used models

Direct export	Subsidiary company/own sales office	Reseller/dealer	Agent	Partner	Joint venture	Export house/ring
10	13	6	5	7	1	4

- *Suitability of products and service*: In direct sales, it is important to have the right customer contacts, knowledge about the customers. Ask the customers about their problems and needs and finding the decision maker. Understanding customer needs. Sales professionalism is needed.
- *Small services to customers can grow to large sales:* Start small and grow.
- *Joint R&D projects and technology development* with customer groups are important to strengthen customer relationships. Collaboration, communication and common understanding in service/delivery network are vital.
- *Partnership with another global company* with a connected product may be a successful path for entering a new market.
- *Sales- and marketing-partnerships* with joint products have been useful.
- The rule no. 1 in international business is to *respect local habits and customers*. The internal company processes and rules must guarantee this.
- *Trustworthy sales channels:* Communication and interaction is needed, personal relationships support the trustworthy cooperation between partners.

Research on Collaborative Networked Organizations

Much knowledge and understanding of CNOs has been acquired through European research during the last decades. There have been several research initiatives in Europe in the field of CNO (Camarinha-Matos et al. 2008), also in the context of global operation.

The research objects span from traditional supply chains, collaborative networks and business eco-systems to virtual organizations. In short: a Virtual Organization (VO) is usually created within a network composed of organizations committed to collaborate. To achieve efficient collaboration, some degree of preparedness and preparation is needed. This preparation takes place within a breeding environment. The concept of the breeding environment is used to characterise the network behind a VO. The Virtual Organization's Breeding Environment (VBE) represents a long-term "strategic" alliance, cluster, association, or pool of organizations that provides the needed conditions for collaboration, Fig. 3, (Camarinha-Matos and

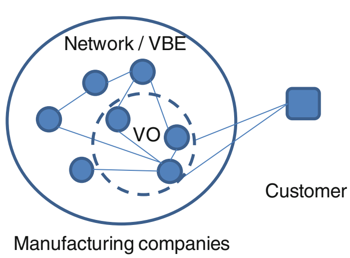

Fig. 3 The virtual organization's breeding environment (*VBE*) and virtual organization (*VO*)

Afsarmanesh 2008). Based on the above description, a VO has similarities with a distributed, inter-organizational project, and the business eco-system is a kind of a network. The level of preparedness within the networks may vary.

Most of the previous research has been focused on manufacturing networks and supply chains. Few examples have been studying networks in the distribution, sales, marketing or market opportunity identification. As an example, Anastasiou and Tsagkas (2003) developed tools and approaches to support the management of information in collaborative sales. In ECOLEAD project, (Camarinha-Matos et al. 2008) tools for collaboration opportunity identification and characterization were developed.

Application of CNO Approaches in Outbound Logistics

Much of the mentioned European CNO research work has centred around the question on how to organize work in the best way to deliver products and services to a customer in the most efficient and dynamic way. Here, the aim is to review the outbound logistics for SME type of organizations, using the CNO concepts established in previous and existing research results. In this context, the outbound logistics is used as a large concept. The meaning of outbound logistics is broad, as mentioned in the introduction. In this context, we call it a Customer Interface Network (CIN), Fig. 4, covering also the activities such as: final assembly, inventories, customer pick-up points, spare parts, repair and maintenance service and training.

Figure 1 introduces taxonomy of organization models in international distribution networks and Table 1 summarizes the features of the used models. The emphasis is on creation and using the best suitable and cost/resource efficient organization mode that increases sales and new order intake. The concept of VO is best suited for project type and project type deliveries. From an order fulfilment point of view, the delivery of a one-of-a-kind and project type delivery is quite different from a mass product or continuous supply chain. However, when we take

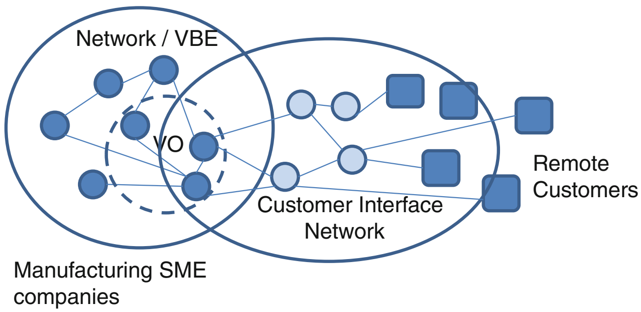

Fig. 4 Customer interface network (*CIN*)

the broader view involving life cycle services as well, then the difference is not so dramatic. All types of products need spare parts, maintenance, repair and potentially (software) updates. Support to the usage of a one-of-a-kind and project type delivery throughout its full life cycle is always needed. The CIN concept can respond all life cycle support needs and create the preparedness for delivering the product and service as well as on-going support. The CIN thus forms the correspondence to the VBE as mentioned above. The CIN can be long-term strategic alliance.

For a European SME, it is indeed very difficult to provide all the functions that are expected for an efficient outbound logistics system alone. Often, this requires proximity to the customer, speaking the customer's language, technical knowledge, spare part inventory, etc. The purpose of a customer interface network is thus to establish the necessary preparedness to serve a remote customer in a cross company and collaborative way, having sufficient time, costs and quality constraints. The following roles are needed in the

- CIN Manager
- Marketing and sales
- Transportation (overseas and local)
- Warehouse (final products, spares and consumables)
- Pick-up point (customer interface point)
- Final Assembly (customization, localization)
- Training
- Service and Maintenance
- IT systems provider
- Invoicing

The following Table 3 contains a set of required roles in the customer interface network and how the organization models from taxonomy in Table 1 could fulfil the different roles. Note, the *local logistics operator* is not a model in the taxonomy, but usage of a local logistics operator is a form of partnership. The local logistics operator is a local or international operator that can be included in the network but not sufficient alone as an international distribution network.

Table 3 Roles in a customer interface network and organization models

Roles	Possible organization models
CIN manager	Agent, dealer, own sales office
Marketing and sales	Agent, dealer, own sales office
Transportation	Local logistics operator
Warehouse	Local logistics operator
Pick-up point	Dealer, local logistics operator
Assembly	Own subsidiary company, partner
Training	Agent, dealer, own sales office
Service and maintenance	Dealer
IT systems	
Invoicing	Dealer, own sales office

From the organization model viewpoint, it can be stated that the selection of the organization model of the distribution network is always dependent on the context, environment and the development phase; and the model may evolve along time. Thus, there is no one recommended solution good for all. The different options have different challenges regarding needed resources, identification and commitment of partners, contracting, pricing and controlling the market, and contacts to the customers. Understanding the customer needs is essential. The understanding may be achieved through direct contacts, common development projects and collaboration, and communication in the distribution network.

Conclusion

It is very well known that the outbound logistics is a challenge for SME type of organizations seeking to expand from local to international markets. The conducted interviews have collected information on how this problem has been tackled. The paper presents taxonomy of used organization models in international distribution networks. The paper proposes approaches on how the currently used organization models in international distribution networks could be further developed based on the CNO concept to fulfil the requirements of efficient outbound logistics. Further research is needed for the different models to assess in more detail the roles and how to establish the appropriate preparedness to act in the roles. For practical feedback, more real case studies are needed.

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References

Anastasiou M, Tsagkas E (2003) Management of information in collaborative sales. In: Karvonen I, van den Berg R, Bernus P, Fukuda Y, Hannus M, Hartel I, Vesterager J (eds) Global engineering and manufacturing in enterprise networks, pp 207–217

Camarinha-Matos LM, Afsarmanesh H (2008) Collaborative networks: reference modeling. Springer, New York

Camarinha-Matos LM, Afsarmanesh H, Ollus M (2008) Methods and tools for collaborative networked organizations. Springer, New York

Caraiani G, Potecea V (2010) Agent and distribution agreements in international business. Metal Int 15(2):129–133

FIMECC (2009) Finnish metals and engineering competence cluster Ltd. http://www.fimecc.com. Accessed 26 Mar 2013

Tarvo (2013) Project WEB site in Finnish. http://interali.vtt.fi/tarvo. Accessed 18 Sept 2013

Tekes (2013) The Finnish funding agency for technology and innovation Finland. http://www.tekes.fi/en/community/Home/351/Home/473. Accessed 26 Mar 2013

Application of the Adapted SCOR Model to the Leather Industry: An Ethiopian Case Study

Fasika Bete Georgise, Klaus-Dieter Thoben and Marcus Seifert

Abstract Competitiveness and deregulation in the leather industry require new type cooperation among the supply chain members to increase the efficiency and profitability. The leather and leather products industry is a significant part of the developing countries' economy. Even though the sector contributes a considerable amount of income, the sector has a lot of challenges that can be improved to increase value for the firms. The application of the model is gaining importance in the current literature. The application of the model facilitates the mapping of business processes for better understanding the supply chain members. In this paper, the adapted SCOR model is applied to the leather industry to find processes with higher pains to further improve Ethiopian leather industry. Semi-structured interview and industrial visits have been employed as research methods. The case study has demonstrated how the firms in developing countries can be benefited with application of the SCOR.

Keywords Leather industry · Model · Adapted SCOR · Ethiopia

F.B. Georgise (✉)
International Graduate School for Dynamics in Logistics (IGS), University of Bremen, Bremen, Germany
e-mail: fasialem@gmail.com

F.B. Georgise
School of Mechanical and Electromechanical Engineering, Hawassa University, Hawassa, Ethiopia

K.-D. Thoben · M. Seifert
Bremer Institut für Produktion und Logistik GmbH—BIBA, Hochschulring 20, 28359 Bremen, Germany
e-mail: tho@biba.uni-bremen.de

M. Seifert
e-mail: sf@biba.uni-bremen.de

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Introduction

The leather and leather products industry is one of the top priority areas where the developing countries should go forward to engage for their competitiveness (Mulubrhan 2010; UNIDO 2002). From their large livestock potential and promising market for leather and leather products currently, the industry is trying to get advantages from the sector. However, the potential output is not realized due to poor animal husbandry, off-take rates which are low averaging at 14 % for cattle and 27 % for sheep and goats (Mulubrhan 2010). The low off-take rates plus decentralized slaughtering and poor collection implies that a considerable number of hides and skins did not enter to the market. In addition, the industry is highly fragmented. The presence of different actors were creating high price fluctuation and unstable market (Sonobe et al. 2007; UNIDO 2011).

The leather and leather products supply chain starts with the animal industry which produces its raw materials; hides and skins as by-products of slaughter-houses, which are transformed to various leather manufactured end-products. The supply chain has four processing stages; each performs different tasks with available resources. Hides and skins are recovered from dairy, beef, sheep, goats and other animals in the first stage. The second stage mainly focuses collection and procurement activities. Firms, at the same time, also sources chemicals, machineries and spare parts from international markets. The third stage involves leather tanning and finishing to either pickled, wet-blue, crust or finished leather types. The fourth processing stage is labour intensive and includes production of leather products (Mulubrhan 2010; Tegegne 2007; Sonobe et al. 2007; UNIDO 2011). Figure 1 demonstrates the leather and leather products industry supply chain.

This paper presents the implementation of the adapted SCOR model to the case study in leather and leather products industry. The previous works is presented in second section. The research methodology is explained in section three.

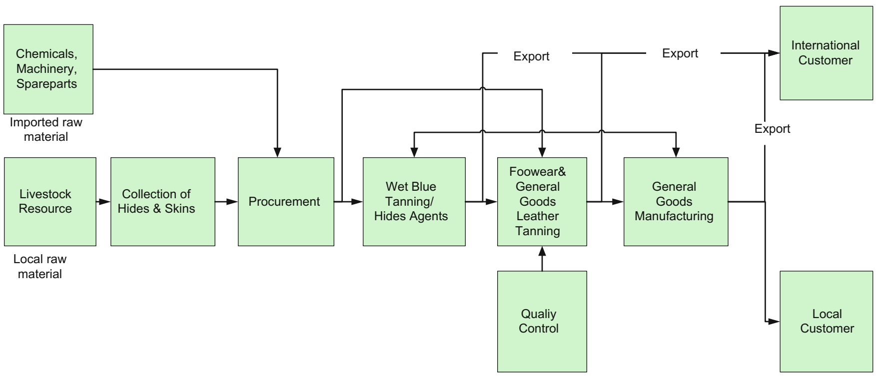

Fig. 1 The leather and leather products supply chain

Section four then discussed case study and implementation results. The fifth section is demonstrated as the "To-Be" and the proposed improvement initiatives. Finally, conclusions are discussed in section six.

Previous Works

Nowadays, enterprises have started to adopt and adapt SCOR model to map, evaluate and to address their improvement needs for the disjoint processes. The practical applications of the SCOR model have increased in recent times within different industries. Some of them were, for examples, manufacturing industries by Salman et al. (2012) (manufacturing firms), Irfan et al. (2008) (tobacco industry), Seifbarghy et al. (2010) (steel industry), Golparvar and Seifbarghy (2009) (oil industry), Goyal (2012) (E & ET companies); service industry by Di Martinelly et al. (2009) (hospital supply chain), and for forest industry by Audy et al. (2011); for construction industry by Persson and Bengtsson (2010); for biodiesel castor by Salazar et al. (2012). Although the practical application of SCM and SCOR model is still not matured in the developing countries, there is a need for adoption and adaptation to date and to scrutinize its applicability for further improvement.

Methodology

The research methodology is based on empirical data collected through the help of semi-structured interview questions. The objective of this field research is to examine the supply chain characteristics. The field research is carried out in two stages. The first stage of the fieldwork was based on an exploratory semi-structured interview which was focused on issues related to the supply chain characteristics of the leather industry. The main objectives of the stage were to ascertain the characteristics of the leather industry. The second stage was carried to map and evaluate the existing situations and propose the "To-Be" model through desktop analysis using the collected data. The duration of the interview was around two hours. Finally, the industrial visit is conducted after the interview activities.

Case Study in Leather and Leather Products Industry

The case study is conducted in two leather and leather products industries. The first one is operating to produce gloves and hides. The company has employed more than 500 workers. The company produces finished leather gloves sports from sheepskin. While employing conventional tanning process, the factory has installed an exemplary effluent treatment plant, an environmentally compliant project. The

Table 1 Clustering the challenges/pains areas

Process	Performance measures	ICT	Organization/relationship
• High operating cost • High inventory level • Production quality problem • Quality of hides and skins • Environmental pollution due to lack of facilities for treatment and disposal of hazardous wastes	• Inadequacy of performance measure • Lack of environmental measures	• Lack of information about supplier • Low-speed network connection • Low implementation status enterprise resource planning	• Unavailability of reliable suppliers • Lack of long-term contracts • Shortage foreign currency • Poor interaction between supply chain members • Presence of supply chain members without value adding activities • Poor and deteriorating physical infrastructure

factory's finished dress and sports gloves leather from sheep has penetrated the international market. The factory has also delivered products to its local leather, shoe and leather garments manufacturer to local markets. The other case study was conducted in garment industry. It is producing leather goods and garment products mainly for local markets and few leather articles for international markets. The company produces finished leather garments for men and women. Up to the time of interview, the company mainly produced for local market and with little foreign customer focusing on jacket, bags and some article depending on the customer request. The firm has around 250 employees. The firm uses make-to-order strategies for export market according to their initial agreement. On the other hand, the firm uses make-to-stock and make-to-order strategies for local market. Finally, these manufacturers further distribute finished goods throughout their own shop, by retailers and by wholesalers to consumers.

The researchers collected practical experience from case studies. The research analysis is based on the SCOR model processes: plan, source, make and deliver. In addition to the interviewed, the researcher visits companies' at the end. The interviewed manufacturers revealed some challenges in the supply chain. The firms are facing a lot of challenges or pains in the highly competitive and often from imported leather products. These pains in the case study are clustered into four groups. Table 1 shows the clustering of challenges/pain into four categories.

SCOR Model Mapping of the Leather Industry Supply Chain

The methodology for the application of the adapted SCOR model is based on the research result by Rollstorf and Rosenbaum (2003). The leather and leather products supply chain were mapped in level I processes focus on Source, Make, Deliver

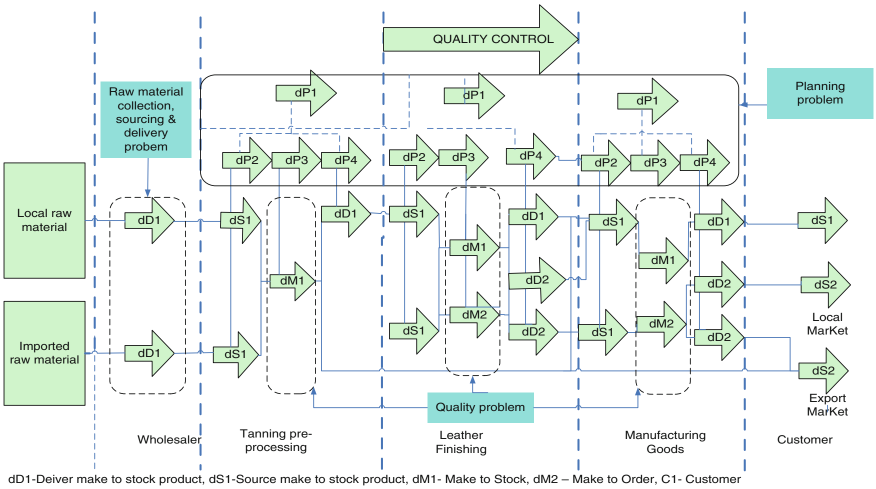

Fig. 2 The leather and leather products supply chain with level II business processes (As-Is)

and Plan processes. The supply chain starts from sourcing process from local and imported raw material suppliers. It includes the tanning and manufacturing (finishing) activities. The firms at both tanning and manufacturing level were exported to international market. For this case study, the tanning and manufacturing processes are performed within one enterprise premises. Mappings of the material flow starting from the local and imported raw materials have been performed with adapted SCOR model in level II. This step is identified to determine problem areas within the supply chain by interviewing, visiting and mapping the supply chain using an adapted SCOR model level II. Figure 2 gives the supply chain including the problem areas within the supply chain. The mapping is used to visualize and identify possible problems within the supply chain. The material flow for these raw material items, from local and imported raw material suppliers to the goods manufacturers, has been analysed in the SCOR methodology in level II. The major inefficiency observed areas are planning, quality, raw material sourcing and delivery.

Mapping the Level III SCOR Model

The manufacturing industry in developing countries is trying to achieve competitive advantages through different strategies. One area of interest would be cost reduction in raw material sourcing. In the current industry situations, the cost of raw materials, equipment and spare parts from local and imported suppliers constitutes the main part of the total product cost. For this reason, raw material sourcing is one of the most strategic tasks in the industry. In the manufacturing firm of developing countries, there is a large percentage contribution of imported materials both in terms of value and quantity. Most of the firms spend huge amount of their resources in purchasing. The imported raw materials and components are challenged with high uncertainty of delivery time and quality problem. In addition, the country is land-locked which makes it almost impossible to make quick respond in supply chain with minimum inventory cost. Therefore, due to this, keeping high inventory especially for imported items and seasonal raw material are highly practiced. The next step is to model the above supply chain at the process element (level III) level. An example of description of level III sourcing process has been given in this section. Figure 3 demonstrates local raw material sourcing process by manufacturer. Usually, the procurement process starts when procurement department receives a purchase requirement from customers, i.e. production department sends this requirement to the purchasing department.

These identified problems are then linked to those identified at the beginning of the process. This step aim is to use information captured at level III to address the problem correctly placed within the supply chain. A critical problem along the entire leather and leather products supply chain is the supplies of inconsistent hides and skins resulting from the lack of organized processing and poor veterinary practices. The identified problem is inconsistent supplies of local raw material, lack of supplier selection criteria and lower level relationship due to seasonality of the raw material and price fluctuation. In other words, the available suppliers cannot satisfy the manufacturer's requirements for demand, quality, delivery, etc. Despite the fact that Ethiopia is one of the largest producers of livestock in Africa, the livestock sector in Ethiopia is dominated by smallholder farmers, and virtually no

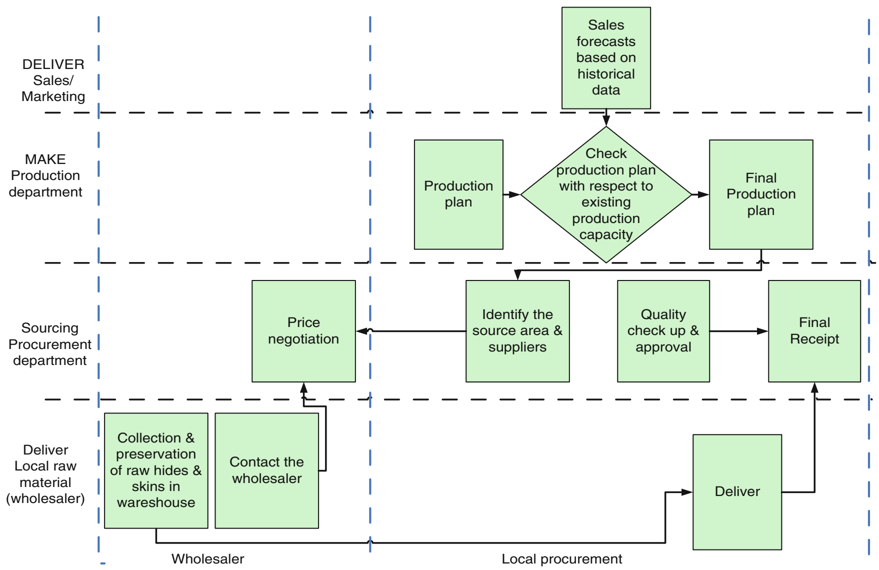

Fig. 3 Local raw material sourcing practice

commercial production of livestock exists in the country. The lack of the commercial livestock sector can be attributed to the absence of a continuous and reliable livestock supply chain. In this context, the problem can be categorized into two areas: raw material sourcing and quality limitations. The raw material availability and supplies are driven by meat consumption and financial shortfalls of the farmers rather than by the leather and footwear industry. There is an absence of strong backward linkage between suppliers of hides and skins and the value added sector, i.e. the leather and footwear industry. However, in recent years, the manufacturer is trying to establish a new partnership type of relationship with middle man (wholesaler agents). Manufacturer supplies salt for skins and hides preservation with appropriate training. Given the challenges associated with the supply of skins and hides, tanneries in Ethiopia are operating at an average capacity utilization of approximately 48 %. Different performance metrics are employed to gauge whether this organizational aims are performing well. Financial performances are most frequently used in the firm about the overall performance as a good indication whether the strategy is leading to an improved bottom line. The company has still been challenged by supplier of low quality and consistency of products. In short, manufacturers need to make contracts not simply on price, but other factors such as consistent quality and timely delivery for export market. For future, companies need to give adequate attention for these.

To-Be Model and Proposed Improvement Initiatives

The field analysis result and the As-Is model reveals the real practical situations. This will be the base to start the To-Be model for further improvement activities. There are different inputs that can be used to facilitate improvement activities. These are As-Is model, gap analysis and best practices. Based on the collected data, gap analysis and best practices, new level II business processes are designed by the researchers in order to improve the existing bottlenecks. Three main process changes are proposed in planning, sourcing and quality-related activities. Figure 4 demonstrate the “To-Be” level II processes. The first one is to extend the plan process that focus on the finishing manufacturing activities to involve other actors in early supply chain. The annual planning activities should involve the wholesaler and garment manufacturers also. The second proposed change is the quality control and assurance activities. The quality control and assurance activities need to extend its coverage up to the raw material suppliers (wholesaler). In addition to this, the manufacturer could have a new type of partnership in form of training, financial and technical support. From the field analysis, we have learnt that the manufacturers are working below capacity. The third proposed change is extension of the sourcing activities to the neighbour African countries.

The To-Be business processes mapping at III has been performed for the local raw material processes. In this industry, aggregate planning is driven by a sales history which consists of all major information necessary to plan the production. In

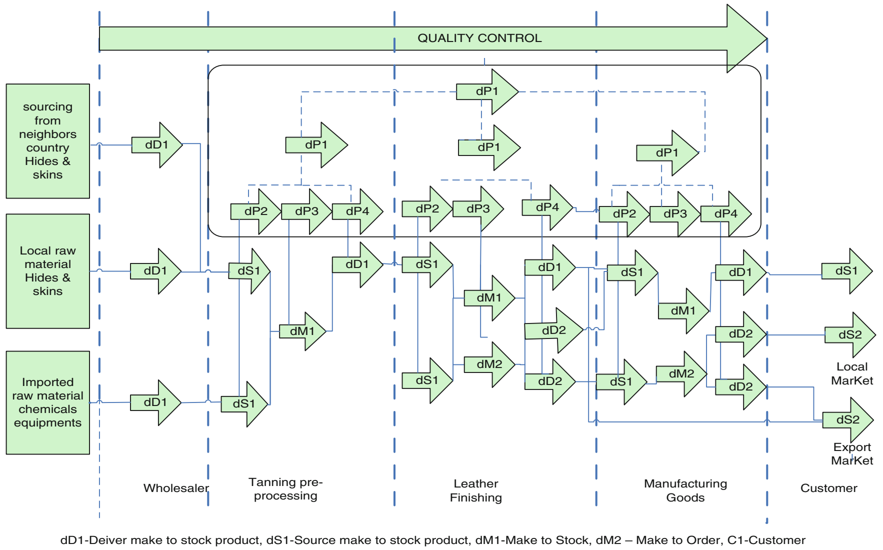

Fig. 4 SCOR model level II processes (To-Be)

the existing procurement practices, sales, marketing, manufacturing, production and purchasing, and supply departments were actively participating in imported raw material sourcing. When leather and leather products industry have got order for products, the process to develop a production schedule begins. The production schedule is based on spreadsheet data. As the manufacturing processes continue, work on preparation of production plans (dP3.1) takes place. The plan enables scheduling of production activities (dP1.2). The schedule of production activities (dP1.2) is used as a support for the next bidding preparation process. Another process that supports the procurement plan is the delivery plan (dP2.4). Purchase requirement for the imported are made through international bidding. Most of the time, the local agents deliver orders that are available on the stock which will be shipped directly from the warehouse. When the imported items arrive, the product is considered received (dS1.4). As the products are received, verification (dS1.5) is performed. After the verification, the products are transferred to the manufacturing processes. The invoice is then compared to the delivered quantity (dS1.6). Then, the imported raw material sent to the production department for further processing. Finally, planning: local raw material purchasing and make process was modeled using d-SCOR level III processes as shown in Fig. 5.

However, previous literature review and field results have shown that not all best practices are applicable to the manufacturing industries in developing countries (Georgise et al. 2013). The research will recommend a generic approach for the selection of different initiatives proposed by Xia (2006). On this generic approach, four major criteria have been identified to evaluate options of initiatives. These are revenue potential; cost saving; strategic fit and industrial partnership issues.

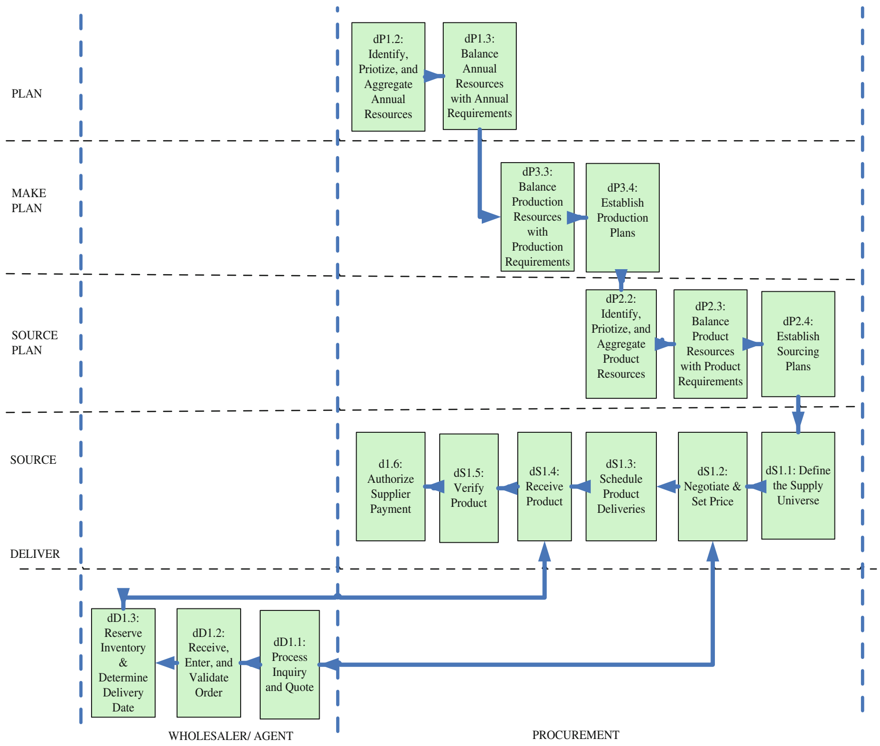

Fig. 5 SCOR model level III processes (To-Be)

Through the proposed initiatives selection process, finally the case study proposed the following major initiatives for the leather and leather products supply chain (see Table 2). From interview feedback and analysis of the challenges, further estimated qualitative benefits were gained for each of the major initiatives.

Table 2 Identified major initiatives

Major initiatives	Impacts
• Revising the current planning system • Develop collaborative and integration with suppliers • Revising the raw material and finished goods inventory control system • Sourcing the raw hides and skins from neighbour African countries • Integrating the different departments using IT and enable internet based procurement • Designing the system of suppliers identification, selection and performance evaluation system	• Reducing uncertainty in the firms and increasing the accuracy of plans • Enabling continuous raw material supply and utilize the full capacity • Decreasing the inventory system cost • Enabling continuous raw material supply and utilize the full capacity • Facilitate data exchange and information sharing • Decreasing supply costs and increasing the reliability of supply chain

Conclusion

In this paper, a comprehensive case study has been presented describing the leather and leather products industry supply chain in developing country. The case study demonstrated the feasibility and comprehensiveness of the model to suit the developing countries' scenarios. These analyses suggest that leather and leather products manufacturers in Ethiopia can take advantage of the high-quality skins available in the local market. Initial gains from the implementation of the model are evident in the accurate depiction of business operations at both a strategic and tactical level. So, this case has demonstrated practical implementation example. The case study explains how the adapted model can improve supply chain performance with its effective implementation. In particular, this study discusses the results of using the adapted SCOR model in the design of the "As-Is" system and the analysis of the leather and leather products industry supply chain processes for future "To-Be" processes. This case study demonstrates how the adapted model helps managers of the local manufacturers to model and improve their SC successfully.

References

Audy JF et al. (2011) A SCOR-based framework to portray wood supply systems—preliminary results from the United-States, France and Chile, 34th Council on Forest Engineering

Bolstorff P, Rosenbaum R (2003) supply chain excellence: a handbook for dramatic improvement using the SCOR model. AMACOM, American Management Association

Di Martinelly C, Riane F, Guinet A (2009) A Porter-SCOR modeling approach for the hospital supply chain. Int J Logistics Syst Manage 5(3–4):436–455. doi:10.1504/IJLSM.2009.022506

Georgise FB, Thoben K-D, Seifert M (2013) Implementing the SCOR model best practices for supply chain improvement in developing countries. Int J u- e- Serv Sci Technol 6(4):13–26

Golparvar M, Seifbarghy M (2009) Application of SCOR model in an oil-producing company. J Indus Eng 4(2009):59–69

Goyal P (2012) SCOR implementation in E&TC compaies. Int J Res Eng IT Social Sci 2 (5):99–117

Irfan D, Xiaofei X, Shengchun D (2008) A SCOR reference model of the supply chain management system in an enterprise. Int Arab J Inf Technol 5(3):285–295

Mulubrhan F (2010) Integrating supply chain for improved export market of Ethiopian leather product, Graduate project (unpublished), Addis Ababa University

Persson F, Bengtsson (2010) Construction logistics improvements using the scor model—tornet case. In: Vallespir B, Alix, T (ed) Advances in production management systems, 2009. Bordeaux, France, 21–23, 211–218. doi:10.1007/978-3-642-16358-6_27

Salazar F, Caro1 M, Cavazos, J (2012) Final review of the application of the SCOR model: supply chain for biodiesel castor—Colombia case. J Technol Innovations Renew Energy 1:39–47

Salman M, Iqbal SA, Khalid R (2012) Implementing SCOR (Supply Chain Operation Reference) model in manufacturing firm of a developing country, 978-1-4673-2460-1/12, IEEE, 465–469. doi:10.1007/978-3-642-38445-5_108

Seifbarghy M, Akbari RM, Sajadieh MS (2010) Analyzing the supply chain using SCOR model in a steel producing company, computers and industrial engineering (CIE), 40th international conference on 25–28 July 2010, pp 1–6. doi: 10.1109/ICCIE.2010.5668328

Sonobe T, Akoten JE, Otsuka K (2007) The development of the footwear industry in Ethiopia: how different is it from the East Asian experience? prepared for the global development network annual conference. Beijing, China, January 2007

Tegegne G-E (2007) Impacts of Chinese imports and coping strategies of local producers: the case of small scale footwear enterprises in Ethiopia. J Modern African Studies 45(4)

UNIDO (2002) A blueprint for the african leather industry a development, investment and trade guide for the leather industry in Africa, 2002

UNIDO (2011) Technical assistance project for the upgrading of the Ethiopian leather and leather products industry, progress report covering January–December 2011

Xia LXX (2006) Supply chain modelling and improvement in telecom industry: a case study. In: (ed) Industrial informatics, 2006 IEEE international conference on 2006, pp 1159–1164

Operational Supply Chain Planning Method for Integrating Spare Parts Supply Chains and Intelligent Maintenance Systems

Eduardo Francisco Israel, Enzo Morosini Frazzon, Ann-Kristin Cordes, Bernd Hellingrath and André Albrecht Lopes

Abstract A lack of spare parts and ineffective maintenance lead to low service levels and high production costs. Intelligent maintenance systems (IMS) have been intensively considered for supporting a better performance of maintenance service. For achieving high supply chain performance, it is also necessary that the information provided by IMS is integrated into the operational planning of the spare parts supply chain. Thus, this paper proposes a procedure for the integration of the spare parts supply chain operational decision level and the IMS. A framework comprising a heuristic approach along with a simulation model and a mathematical model is proposed.

Keywords Spare parts · Supply chain · Intelligent maintenance systems · Planning and scheduling

Introduction

Insufficient maintenance services and lack of spare parts can lead to negative effects in complex production systems. Proper maintenance and the availability of needed spare parts directly influence the production systems effectiveness and efficiency. In this context, one of the most used maintenance approaches is the predictive approach. It aims to forecast the lifetime of components based on classical statistical

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E.F. Israel · E.M. Frazzon (✉) · A.A. Lopes
Departamento de Engenharia de Produção e Sistemas, Campus Universitário João David Ferreira Lima, Universidade Federal de Santa Catarina, Trindade, Florianópolis, Brazil
e-mail: enzo.frazzon@ufsc.br

E.F. Israel · E.M. Frazzon · A.A. Lopes
CTC—UFSC, CEP, 88040-900 Florianópolis, Brazil

A.-K. Cordes · B. Hellingrath
Chair for Information Systems and Supply Chain Management, Leonardo Campus 3, University of Münster, Westfälische Wilhelms-Universität, 48149 Münster, Germany

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models, thus allowing their replacement before a failure occurs. However, sporadic spare parts' demand and the wide variety of system components do not allow for generating accurate predictions. In order to solve this problem, the adoption of intelligent maintenance systems (IMS) was suggested in the literature (Djurdjanovic et al. 2003). IMS are embedded diagnostic/prognostic systems that can forecast failures, supporting the optimization of maintenance processes. The IMS monitors a machine's or a part's gradual degradation status and, through these inputs, can estimate the probability rate and date of breakdowns.

In order to achieve higher levels of effectiveness (i.e., adequate level of maintenance services and spare parts' availability) and efficiency (i.e., low costs of maintenance service and spare parts' provision), it is also necessary that the information provided by the IMS is integrated with the planning activities of the spare parts supply chain (Espíndola et al. 2012). Thereof, the information becomes available and, consequently, it is possible to achieve more accurate supply chain plans. This paper will propose a tailored operational supply chain planning method for the integration of the spare parts supply chain and IMS. First, a generic spare parts supply chain structure considering classical approaches and in contrast with an IMS will be presented. Second, the existing literature related to spare parts and supply chain planning and scheduling will be reviewed. Third, based on the literature search and review, an operational supply chain method for integrating spare parts supply chains and IMS will be proposed. The paper ends by stating specific conclusions and proposing next steps for further research.

Spare Parts Supply Chain and IMS

According to Muckstadt (2005), it is possible to describe the general taxonomy of service parts inventory systems. To repair the failed equipment, a repair technician normally performs a diagnosis and if needed, the broken part can be replaced for a new one. The technical staff receives the ordered parts from the local stock of the service centers, which are responsible for feeding this demand. The service centers subsequently are resupplied from the responsible regional warehouse. Consequently, the regional warehouse is also replenished, but it receives its products from the central warehouse according to the previously planned stock replenishment polices. The central warehouse likewise receives replenishment stocks from the production (Muckstadt 2005). Moreover, the material flow is directed from the manufacturer to the costumers and a logistics service provider normally provides the transport of the goods. The information flow is a reverse path of the material flow. It crosses the supply chain backwards from the costumer to the manufacturer, consisting of customer orders, sales forecasts, internal orders for warehouse replenishment, production orders, as well as purchasing orders to the suppliers, etc. (Stadler and Kilger 2008). Furthermore, the information flow is also given in the vertical direction; downward flows coordinate subordinate plans by obtained results of the higher levels (Stadler and Kilger 2008). In this context, many spare parts supply chain's structure designs are possible, some systems have more echelons, and others have fewer. It mostly depends on strategic decisions based on control characteristics of serviceable parts such as criticality of the product, specificity of the components, demand pattern, value of the parts, joint geographic and product hierarchies (Muckstadt 2005).

Regarding the spare parts supply chain management, for improved planning activities in each supply chain's domain, the decision levels can be split in three interdependent components: strategic, tactical, and operational. Strategic are long-term decisions (over several years) and they typically concern the design and structure of the supply chain. Tactical are mid-term decisions (months up to one year) regarding to rough regular operations for the flows and resources (Stadler and Kilger 2008). Operational spare parts' planning corresponds to the short-term (days up to one month) decision-making time horizon. Here, the interconnections to the tactical planning layer have to be considered. The main focus of this approach lies on short-term production, inventory, transport, and maintenance planning and scheduling. The goal is the best utilization of existing structures (e.g., communication, buildings, transportation, and machines) restricted by the tactical decisions.

In the literature, it was not found a reasonable description of a spare parts supply chain containing an intelligent maintenance system. However, from these studies one can assume that the structure, the processes, and the flows of this specific supply chain will be different from a final product's one. First, the demand appears by providing forecasted failure information through an IMS in manufacturing devices and machines. The forecasted failure information is sent to an integration layer, responsible to integrate shop floor devices and machines to the spare parts supply chain entities. The suppliers and manufacturers receive the information, through specific information system mechanisms of an integration layer. The information layer receive the notification about *which*, *when,* and *where* the part will fail and share it to the specific decision levels. Furthermore, before the breakdown happens, the technical staff receives the required parts from the stock suppliers, which is responsible for feeding this demand. Thus, in order to reach adequate processes effectiveness, and efficiency, spare parts supply chain actors also have to cope with the IMS approach. The development of improved spare parts *planning* methods, integrating IMS information, is essential for the supply chain's performance. The main spare parts supply chain operational level tasks in a spare parts supply chain with IMS can be seen in Fig. 1.

With respect to Fig. 1, while the tactical level is resupplied with information about the actual condition of processes and machines and consequently forecasts the monthly aggregated potential failures, the short-term sales planning particularizes these forecasts in weekly and daily quantities for single spare parts. At the same time, the daily inventory management and transport quantities for single products are controlled and managed; taking into account previously agreed (in contract) lead times and service levels. Another important task of the inventory domain is the parts, categorization for creating a manageable number of spare part groups (Jouni et al. 2011). In order to carry the daily ordered goods, it is necessary to plan the detailed transportation capacities (e.g., available trucks) and the route

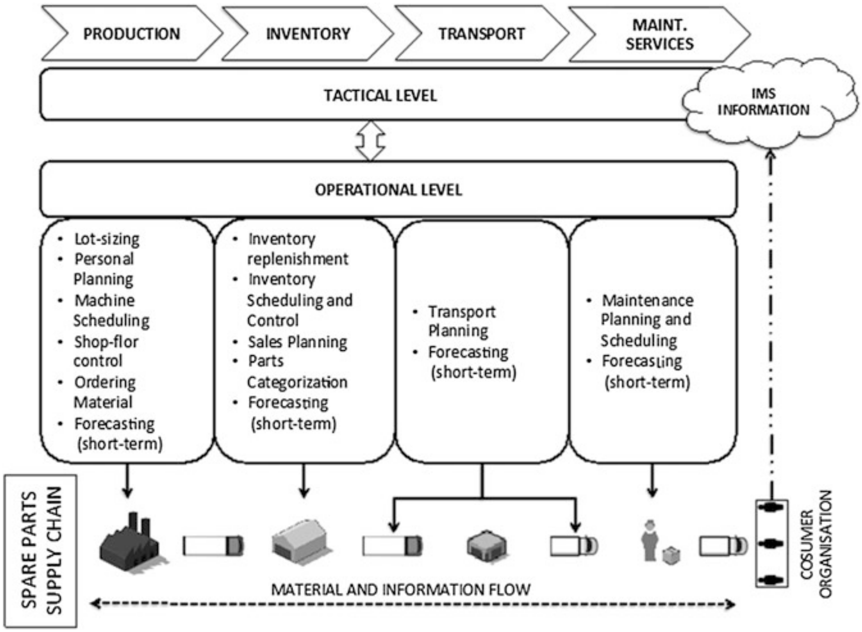

Fig. 1 Operational planning of main tasks in the spare parts supply chain

planning for optimizing the trade-offs between time, services, and costs. Therefore, the production (shop floor control, determination of lot-sizes, and their sequences on the machines, personnel scheduling) needs to be scheduled and controlled. All of these tasks are connected by information flows that also may be organized and processed by the operational level.

The service personal is another important task in the operational decision level (e.g., personal scheduling and maintenance scheduling). The planning of maintenance follows the elimination of downtimes and near zero breakdown times (Djurdjanovic et al. 2003). The maintenance scheduling regards an optimization of time and costs (e.g., through mathematical models); taking also into account the previously agreed lead times and service levels.

Spare Parts Supply Chain Planning Methods and Concepts

Spare parts logistics comprises different areas, such as service management, inventory control, production and transportation planning, as well as supply chain management, etc. However, the target of this chapter is not to review all these aspects, but to *review methods, which could be tailored to the integrated planning of operational decisions in the spare parts supply chain, regarding specific service* *level and costs*. Some tactical methods are also reviewed, because the discussion of those methods and concepts are relevant, as some of them might also be applied for the short-term decisions, by redefining variables and a new planning horizon. A classification of spare parts supply chain planning methods is presented below. This classification is based on the results obtained by the proposed search and review methodology[1] and authors' interpretation.

Spare Parts Inventory Management in Multi-echelon Supply Chains

The majority of planning methods, which have being implemented in the spare parts supply chains, according to the conducted research, is focused on *inventory management and control* (12 works). "Due to the sporadic need of a spare part, a vast inventory level in different places is required" (Kutanoglu et al. 2009). As a consequence, an extensive costumer's service must be developed. One of the most current network problems is where to place spare parts in a multi-echelon inventory system. For dealing with this issue, Sherbrook developed a landmark mathematical model, METRIC (A Multi-Echelon Technique for Recovered Item Control); "since that time many extensions and modifications in his model have been proposed" (Muckstadt 2005). One of these extensions is the VARI-METRIC (Improved Approximations for Multiple-Indenture and Multi-Echelon Availability Models) model (Sherbrook 1986). The VARI-METRIC system objectives describe the logistics relationships between assembly and subassemblies and compute stock levels for each component and inventory echelon that minimize backorder costs of reparable parts. Sleptchenko et al. (2002) shows that the used assumption of infinite capacity, of the VARI-METRIC, can seriously affect the stock allocation, if the repair capacity utilization is high (see Sleptchenko et al. 2002). As a result, the authors suggested modifications with the assumption of finite repair capacity. Furthermore, Sleptchenko et al. (2004) suggested a further extension to the VARI-METRIC by using repair priorities to reduce stock investment in spare part networks (see Sleptchenko et al. 2004). Another important issue in this area was pointed out by Sherbrook et al. (1992), Krannenburg and van Houtum (2009) and Tiacci and Saetta (2011). They presented the reducing of mean spare parts supply delay by using *lateral transshipments policies*. This subject has been intensively studied in the multi-echelon spare parts inventory system literature. By lateral transshipment high stock levels can be moved to other facilities, which have low

[1]The first keyword chosen for the review were "*spare parts supply chain*". After obtaining the results, the literature was filtered in order of relevance, considering works with the keywords "*spare parts*" and "*supply chain*". Firstly, 3.218 references were obtained. Nevertheless, many of them were not suitable to the proposed subject; by that, 23 articles have been chosen and they serve as basis for the literature review. The works date from 1978 to 2013.

stock levels, in the same echelon, for reducing supply chain delays through better parts distribution inside the inventory network systems.

Synetos and Keyes (2008) Jouni et al. (2011) and Bachetti and Saccani (2012) research the effects of *parts categorization in the spare parts inventory management*. The classification of components is necessary to establish service requirements for different parts classes because it gives greater accuracy to forecast and stock control processes. Bachetti and Saccanni (2012) performed a literature review about the categorization methods and found out that most of the papers used multi-criteria categorization methods. The most applied techniques (quantitative and qualitative) were ABC and AHP (Analytic Hierarchic Process).

Last but not least, Kalschmidt et al. (2003) presented the results of a case study, where an integrated system for managing inventories in a multi-echelon structure was supposed. The paper shows how combining *demand information and inventory management* can guarantee a substantial improvement of performance. The performance was measured taking into account the "*inventory* level/service *level*" trade-off curves for four different scenarios.

Spare Parts Supply Chain Optimization and Planning

In the present literature review, the *Spare Parts Optimization* is covered with 11 works. These papers generally consist of mathematical models and software aiming to find the optimum balance between costs and benefits such as service levels, delivery times, etc. It is a well-known area for *planning and scheduling spare parts and maintenance processes* as showed in the works of Dekker and Scarf (1997) and Garg and Deshmukh (2006).

According to Mula et al. (2010), the vast majority of the studies reviewed about mathematical programming for supply chain production and transport planning opted mixed integer linear programming models (MILP). Regarding to present an *integrated planning method* of different domains in a spare parts supply chain Goel et al. (2003) and Kutanoglu and Lohiya (2008) worked in the same direction. Goel et al. (2003) developed a new mathematical model for planning the design, production, and maintenance in multipurpose process plants. The aim is to create a schedule for suggesting maintenance policies that optimizes the balance between benefits and costs. Kotanoglu and Lohiya (2008) present a model to minimize costs and ensure service level in an integrated inventory and transportation problem.

Furthermore, Tysseland (2009) analyzed how the spare parts optimization process was conducted in the Norwegian defense procurement projects. The Norwegian defense was recommended to start using the *multi-echelon, multi-item, and multi-indenture optimization software tool* (OPUS10). In this context, Wu and Hsu (2008) pointed out the possibility to calculate an optimum BOM (bill of material) configuration through OPUS10. However, it might be, according to the authors, formidably time-consuming. With the aim of remedy, the time-consuming problem, they proposed a GA-neural network approach to solve the BOM configuration design. Extending the same approach in a new work, Wu et al. (2010) solved a design problem for spare parts logistics system encompassing part vendors and transport modes selection. Two approaches and five algorithms were proposed to find a near-optimal logistics network and an optimal combination for part vendor and transportation modes selection (see Wu et al. 2010).

Sarker and Haque (2000) proposed a *system optimization of maintenance and spare parts provision*. A model has been developed for a manufacturing system with preventive maintenance, continuous review inventory policy, and stochastic item failure. The paper showed, in its specific case, that a jointly optimal policy (regarding continuous review inventory and preventive maintenance interval per unit time) determines better cost effective results than combinations of separately and sequentially optimized policies. Zamperini and Freimer (2005) analyzed optimization procedures through simulation. They performed an analysis of the optimization method for inventory management VARI-METRIC, in the context of the American Cost-Guard fleet. The study illustrated the benefits of using simulation to validate other optimization methods. Last but not least, Chen and Popova (2002) and Barata et al. (2002) used Monte Carlo simulation to minimize the service costs and modeling deteriorating systems.

Operational Spare Parts Supply Chains Planning Whit IMS

The research mentioned above generally discuss the rather unexplored problem of managing multi-echelon, multi-item, and multi-modal supply chains with high demand uncertainties. In order to find solutions for this problem, the spare parts literature has focused major attention on forecasting lumpy demand (e.g., statistical classical approaches, CBM, etc.) and also on inventory management and control for multi-echelon supply chains (METRIC models, parts categorization, etc.). Minor attention has been devoted for planning integration and information exchange. Recent investigations show that a supply chain's domain integration (e.g., production, inventory, transport, and maintenance) can lead to additional information and reliability, which can enhance the performance of planning methods and consequently the whole supply chain (Chen and Popova 2002; Goel et al. 2003; Kutanoglu 2009; Wu et al. 2010). Most of these works use mathematical programming models as integration method.

The aim of suggesting a methodology for the operational planning of spare parts supply chains, considering information provided by IMS is to improve the supply chain's performance by minimizing costs while ensuring service level regarding the delivery of the orders in a predefined time. In this way, scientific studies as Chen and Popova (2002), Goel et al. (2003), Kutanoglu (2009), and Wu et al. (2010) showed that it is possible to plan and schedule multi-echelon supply chains with high demand uncertainties through an integrated planning, using optimization methods. Furthermore, Zamperini and Freimer (2005) illustrated the benefits of using simulation to validate optimization methods. In that work, the simulation

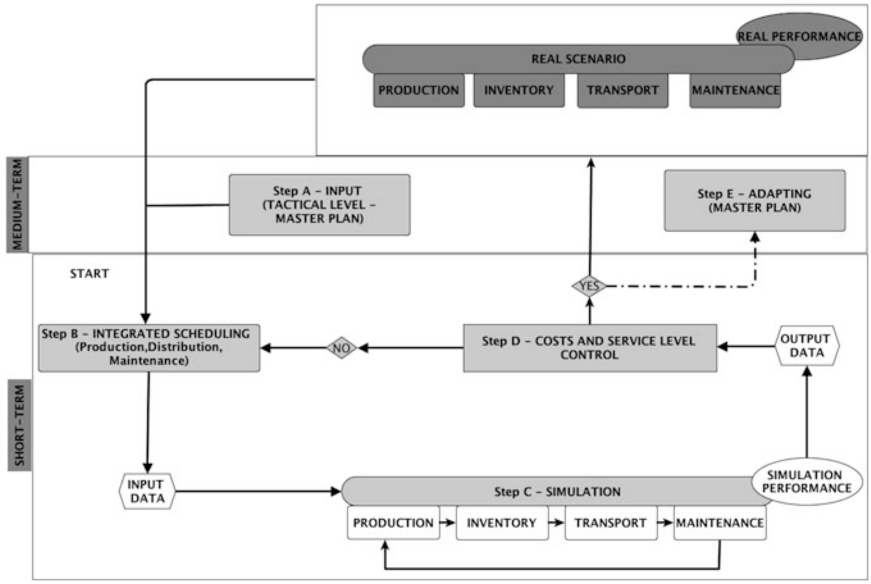

Fig. 2 Framework for spare parts supply chain with IMS

allowed examining the efficient frontier for maximizing spare parts availability while minimizing total costs in the U.S. coast guard.

Based on these scientific works and considering the present research problem, a heuristic is suggested for supporting the integrating process and, consequently, improving the planning and scheduling of spare parts supply chain along with an IMS. Figure 2 sketches the concept of the framework, which aims to find a feasible solution by minimizing costs while ensuring service levels.

An introduction of a scheduling entity along the supply chain will be proposed, which can perform the integrated scheduling for "production-distribution-maintenance" (Step B), using mathematical programming. The scheduling will be based on the capabilities, forecasts, order delivery dates, etc., provided by the master plan on the tactical level (Step A). After that, the obtained scheduling will be taken as model input, a sensitivity analysis, using a simulation-based model, will support the evaluation and the validation of the scheduling results (Step C). The simulation can resemble the behavior of complex systems and enables the estimation of their performance by taking into account stochastic variables (Banks 2009). Through this method, it is possible to integrate chain's actors in a dynamic way and to study their behavior. In Step D, the simulation output data has to be checked, whether satisfactory costs and service levels are met. Changes (e.g., a new scheduling) can be suggested in the real scenario and the tactical master plan can be adapted (Step E). Furthermore, if the simulation outputs indicate undesirable results, Step B would need to be rerun, i.e., a new schedule would need to be created and reevaluated (Step C). This interactive and iterative scheme would provide the capability of dynamically integrating spare parts supply chains and IMS.

Conclusion

According to the literature, the integration of spare parts supply chain with information provided by IMS can provide better performance, because the planning and scheduling of the supply chain can consider the actual condition of production components. This approach is a good alternative for the problem of sporadic/lumpy demand of spare parts. Nevertheless, it still imposes enormous challenges for the logistics management. It is necessary that the information provided by IMS is available for production, inventory, transport, and service management domains, so that they can plan their activities. The literature review showed that most of current research concentrates their efforts in the areas of inventory management and spare parts supply chain optimization, using mathematical models. Nevertheless, identified analytical methods are not suitable to the proposed integration case. Therefore, a framework is suggested in the present paper, in order to improve the operational performance by minimizing costs while ensuring service level, in terms of delivering orders in time. The framework is composed by a heuristic approach along with simulation and mathematical models. The framework will be further developed and applied to a test case and a real-world case study.

References

Bachetti A, Saccani N (2012) Spare parts classification and demand forecasting for stock control: investigating the gap between research and practice. Omega 49:722–737

Banks J et al (2009) Discret-System event simulation. PHI Learning, New Delhi

Barata et al (2002) Simulation modeling of repairable multi-component deteriorating systems for on condition maintenance optimization. Reliab Eng Syst Safety 76:255–264

Chen T, Popova E (2002) Maintenance policies with two-dimensional warranty. Reliab Eng Syst Safety 77:61–69

Dekker R, Scarf P (1997) On the impact of optimization models in maintenance decision making the state of the art. Reliab Eng Syst Safety 60:111–119

Djurdjanovic D, Lee J, NI J (2003) WA: an infotronics-based prognostic approach for product performance degradation assessment and prediction. Adv Eng Info 17(3):109–125

Espíndola D, Frazzon EM, Hellingrath B, Pereira CE (2012) Integrating intelligent maintenance systems and spare parts supply chains. 14th IFAC, 1017–1022

Garg A, Deshmukh SG (2006) Maintenance management: literature review and directions. J Quality Maintenance 12(3):205–238

Goel H et al (2003) Integrated optimal reliable design, production and maintenance planning for multipurpose process plants. Comput Chem Eng 27:1543–1555

Jouni P, Huiskonen J, Pirttilä T (2011) Improving global spare parts distribution chain performance through part categorization: a case study. Int J Prod Econ 133:164–171

Kalschmidt M et al (2003) Inventory management in a multi-echelon spare parts supply chain. Int J Prod Econ 81:397–413

Krannenburg AA, van Houtum GJ (2009) A new partial pooling structure for spare parts networks. European J Oper Res 199:908–921
Kutanoglu E, Lohiya D (2008) Integrated inventory and transportation mode selection: a service parts logistics system. Trasport Res 44:665–683
Kutanoglu E, Mahajan M (2009) An inventory sharing and allocation method for a multi-location service parts logistics network with time-based service levels. Europ J Operat Res 194:728–742
Muckstadt JA (2005) Analysis and Algorithms for service parts SC. Springer, New York
Mula J et al (2010) Mathematical programming models for supply chain production and transport planning. European J Oper Res 204:377–390
Sarker R, Haque A (2000) Optimization of maintenance and spare provisioning policy using simulation. Appl Math Model 24:751–760
Sleptchenko A et al (2002) Effects of finite repair capacity in multi-echelon, multi-indenture service parts supply system. Int J Prod Econ 79:209–230
Sleptchenko A et al (2004) Using repairs priorities to reduce stock investments in spare part networks. European J Oper Res 163:733–750
Sherbrook CC (1986) Improved Approximations for Multi-indenture. Multi-Echelon Availability Models Oper Res 34(3):311–319
Sherbrook CC (1992) Multi-Echelon inventory systems with lateral supply. Naval Res Logistics 39:29–40
Stadler H, Kilger C (2008) Supply chain management and advanced planning. 4th edn. Springer Berlin Heidelberg, Berlin, Heidelberg
Synetos AA, Keyes M (2008) Demand categorization in a European spare parts logistics network. Int J Oper Prod Manage 29(3):292–316
Tiacci L, Saetta S (2011) Reducing the mean supply delay of spare using lateral transshipments policies. Int J Prod Econ 133:182–191
Tysseland EB (2009) Spare parts optimization process and results: OPUS10 cases in the Norwegian Defence. Int J Physical Distrib Logistics Manage 39:8–27
Wu M-C, Hsu Y-K (2008) Design of BOM configuration for reducing spare parts logistics costs. Expert Syst Appl 34:2417–2423
Wu M-C et al (2010) An integrated approach to the design and operation for spare parts logistic systems. Expert Syst Appl 38:2990–2997
Zamperini MB, Freimer M (2005) A Simulation of the VARI-METRIC repairable inventory optimization procedure for the U.S. coast guard. In: Winter simulation conference 2005

Macro-institutional Complexity in Logistics: The Case of Eastern Europe

Frederic Wessel, Aseem Kinra and Herbert Kotzab

Abstract In this paper, the interlink between the concept of macro-institutional complexity in logistics and the dynamics in the logistics practice of Eastern Europe will be examined. Referring to the importance of different authors having ascribed to the external environmental uncertainty on organizational structure and transactional costs, the concept of environmental complexity is applied to the logistics management perspective. Thereby, the impacts which a given framework on a macro-institutional level might have on the situation and leeway in decision-making at the firm (micro) or the supply chain (meso) levels will be analysed. Furthermore, a quantitative modelling approach will be presented and exemplified by using the case of logistics infrastructure in Eastern Europe.

Keywords Environmental complexity · Global supply chain operations · Macro-institutional perspective · Analytic hierarchy process (AHP) · Multi-Criteria decision-making · Eastern Europe

Conceptual Background

Most existing research focuses on the measurement and optimization of logistics systems at a micro-level (e.g. Caplice and Sheffi 1995). Nevertheless, there are some papers, which extend the micro-level view to a meta-level perspective as described in Beamon (1999), and sometimes even to a macro-level perspective (e.g.

F. Wessel
Dipl.-Kfm., Department of Logistic Management, University Bremen, Bremen, Germany

H. Kotzab (✉)
Department of Logistic Management, University Bremen, Bremen, Germany
e-mail: kotzab@uni-bremen.de

A. Kinra
Department of Operations Management, Copenhagen Business School, Frederiksberg, Denmark

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Kinra and Kotzab 2008a, b). Nevertheless, the foundation for analysing the interlinks between macro-level institutional constraints and micro-level or meso-level logistics actions is rather still limited. Especially the applicability of the theoretical findings in the managerial practice using quantitative modelling is scarcely treated.

The purpose of this paper is to exemplify these important interlinks in the Eastern European context. Eastern Europe is an important logistics region for the upcoming decades, not just as a new selling market for Western European companies with the accompanied logistics challenges but also as a potential new logistics interlink between Europe and Asia. Existing studies in the Eastern European context often concentrate on the logistics situation in one specific country and mostly from the isolated perspective of a company on the micro-level. A structured comparison of the effects, the situation at a macro level might be at a micro- or meso level in the different countries of Eastern Europe, is not available. The paper is structured as follows. First, a brief description about logistics in Eastern Europe, and an overview of the existing literature is provided. Next, a short definition of the necessary theoretical concepts will be given, and our analysis framework will be presented. Afterwards, we apply the framework on Eastern Europe by exemplifying our analysis using the countries of Poland, Russia and Romania. Furthermore, Germany will be used as a benchmark country in terms of all factors considered. Finally we will present our findings and a discussion based on these findings.

Logistics Infrastructure in Eastern Europe

Since the fall of the iron curtain, Eastern Europe is being regarded as a region of great potential for the logistics industry. Prerequisite for a well-operating logistics industry is a logistics infrastructure of high quality. As we will see below, logistics infrastructure in this context is not limited to physical infrastructure like the road network or harbours. Also all surroundings, which are of importance for efficient and economical logistics operations, e.g. tax burdens for logistics activities or the availability of skilled employees, have to be considered. In the years after the system change, the maintenance or even extension of the existing macro-level logistics structures have not taken place in the needed way so that many authors report severe problems in using the existing logistics market potential. Examples can be found in Hall (1993), Augustyniak (2003) or Waters (1999). Existing research in this context has often concentrated on the transport-related aspects like road pavements or harbour accessibility. The above-mentioned broader perspective of environmental complexity for assessing macro-institutional impact on micro-logistic decisions has often not been sufficiently taken into account. Our paper on the other hand aims at showing that logistics performance of a nation is significantly impacted by the macro-institutional complexity related to its logistics system. Especially in the context of Central and Eastern Europe, Meyer and Peng

(2005) emphasize that an institutional view is required to successfully manage operations. This can affect the decision-making of multinational firms when structuring their supply chain network or countries when planning the development of their logistics infrastructure to support their domestic economy and to attract foreign direct investments.

Eastern Europe is highly a diverse area, which comprises a large variety of different economic, cultural and social structures. The definition of its boundaries in a geographical, economic and social dimension is a complex research question as several authors like Halecki (1957) and Korhonen (1997) have acknowledged. The paper at hand uses the cross-case technique as described by Gerring (2007) to achieve a certain representativeness of the findings by covering the whole extent of potential variation in the examined elements. Three countries are chosen as representatives for the Eastern Europe region: Poland as an already quite highly, economically developed country, Russia as an intermediate country of high logistics importance and Romania as a representative for the group of Eastern European countries which are still at early stage of logistical development.

The Concept of Macro-institutional Complexity in a Supply Chain Logistics Context

The concept of macro-institutional complexity in a supply chain logistics context is similar to the one presented in Kinra and Kotzab (2008a, b). For this, one has to first conceptualize the supply chain as a complex organizational form, facing a complex environment. In order to conceptualize a supply chain's environmental complexity, one has therefore to look at organizations, their environments and institutions. We thereby follow North (1990) and take his suggestion of geovalent components, which comprise all other environmental forces that impact the firm but are not themselves organizations: Institutional rules, regulations, cultures and exchange rates, for example (Guisinger 2001). Following this perspective, a supply chain is understood as an interorganizational arrangement embodying a high level of "structural complexity" (see Kinra and Kotzab 2008a, 330). Next, the environmental complexity of the supply chain has to be contextualized within particular task (industry/sector) environments like logistics, and how then organizational and managerial decision-making is taking place within these task environments with respect to this complexity. The logistics system environment is important because of the structural and strategic contingencies (Ketokivi and Schroeder 2004) it imposes on logistics decision-making (Kinra and Kotzab 2008b). The external environment affecting supply chain logistics operations and strategy are then the "geovalent components" and represent macro-institutional factors such as econography, culture, legal systems, political risks, government restrictions, etc. (Guisinger 2001). This leads to the overarching conceptual framework for analysing environmental complexity with respect to supply chain logistics operations, which implies taking into consideration macro-level institutional constraints while designing supply chain logistics processes, flows and activities. Similarly, at a logistics strategy level, we understand the incorporation of these constraints into decision-making as the choice and selection of best alternatives under uncertainty. Firms, their supply chains and their processes are embedded in a macro-institutional context (geovalent components). The consequence of such a conceptualization for logistics is to focus on the macro or "super-constraints," which impact the constraints on a micro-logistics level. The super-constraints have consequences for managers as the macro-institution determines the output of the micro-institution, which in the business logistics literature has constituted the notion of systems thinking (Pfohl 2004). Similarly, assuming this institutional perspective also has consequences for policy makers as they influence the provision of supply chain infrastructure. This approach is now applied to understand the Eastern European logistics environment. For this we will use factors and measures based on the set developed by Kinra (2009). We will simulate a managerial decision-making scenario where managerial choices on complexity will be recorded.

Application: An Analysis of Eastern Europe

Background

As mentioned earlier, existing research in the logistics context of Eastern Europe has often been concentrated on the transport-related aspects like road pavements or harbour accessibility without taking sufficiently into account the above-mentioned broader perspective of environmental complexity for assessing macro-institutional impact on micro-logistic decisions. Thus, the case aims at showing that logistics performance of a nation is significantly impacted by the macro-institutional complexity related to its logistics system. All three countries in our study have experienced severe changes in the logistics sector since the fall of the iron curtain, of which many were connected to the effects of macro-institutional complexity. The effects of the so-called "Balcerowicz-plan" in Poland are a good example for this. In order to fight the grasping hyper-inflation, the newly appointed Polish finance minister Balcerowicz announced a radical reform plan towards a free and market-oriented economy (see Bak et al. 1991). As a consequence, the formerly strictly limited number of privately owned trucks grew massively. As a consequence, the neighbouring countries in Western Europe faced a tough economic competition and also had to cope with the unprecedented side effects due to missing qualifications, bad truck equipment, etc. To improve the situation, a legal reform requiring the fulfilment of much higher commercial and operational preconditions for the logistics sector was issued already two years later (see also Rydzkowski and Spraggins 1994 and Waters 1999). Besides these mode-specific issues, also general state policy can lead to long-lasting effects on the macro-institutional complexity.

This can also be seen with regard to cultural effects of the socialist system on the education situation and business mentality. The change from the sellers' market to the buyers' market after the end of the socialist system often required new management skills. As Kisperska-Moron (2005) states, only ~15 % of all examined companies had a clear set of criteria to assess customer service quality in 1993 compared to more than 35 % in 2001. Also logistics as a subject for higher education faced a completely changed environment: According to (Olaru 1998), around 80 % of the examined employees working in managerial positions in Romania in the late 1990s had an engineering background, while only 20 % had been trained in business administration and managerial concepts.

Assessing Macro-logistical Performance for Meso-/Micro-operational Needs

The existing publications (e.g. Worldbank 2012 or Bagchi 2001) often lack a clear methodological reasoning what aspects to be taken into account and how these are assessed, compared and incorporated to come to an overall conclusion on the logistics performance. We therefore want to build on the foundations laid by Kinra (2009) in order to overcome these shortcomings and apply the developed model for the Eastern Europe area. In this context, the relevant location factors are grouped into three categories: (a) Physical infrastructure (e.g. traffic network, communication infrastructure), (b) public infrastructure (e.g. fiscal aspects of logistics operations, education sector etc.) and (c) human factor (e.g. social and cultural aspects of relevance for logistics operation). Next, an approach is needed for comparing and assessing the different location factors, in order to come to a conclusion on the logistics performance with regards to the macro-institutional complexity as a whole. Developing such a model structure, which can take into account this variety of factors while at the same time remains focused on aspects of logistical relevance and operational applicability, requires a flexible and effective modelling approach. This is made possible by employing the Analytic Hierarchy Process-approach (Saaty 1980) in our paper.

Using AHP for Modelling Logistics Complexity in Eastern Europe

In this section we have constructed a model of logistics complexity for Eastern Europe, using a factor selection based on the most important factors from Kinra (2009). The structure of the resultant hierarchical framework (model) is presented in Fig. 1. Here, the AHP has been used to structure a hypothetical managerial problem. This problem involves a logistics manager to select the country in Eastern Europe,

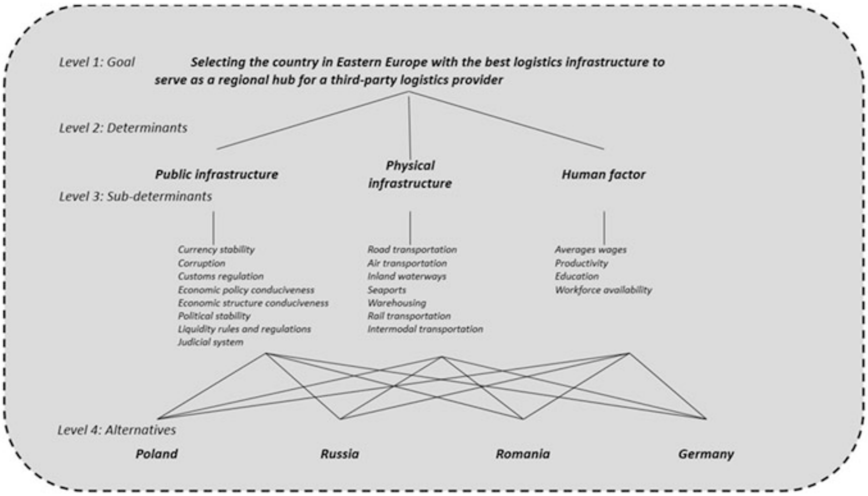

Fig. 1 Exemplary model framework for assessing logistics complexity in Eastern Europe

which offers the best logistical infrastructure to serve as a regional distribution hub. The AHP analysis was conducted by using Expert Choice Comparion Suite (2013, v 5.10.2). In this tool environment, the decision problem was modelled, the hierarchies were designed, and the collected data were analysed to allow the synthesis of the results.

Findings

After having calculated the weights for the three main determinants as well as the weights for the various sub-determinants per factor, the aggregated priority values are defined as shown in Table 1. Here, it can be seen that the quality of the physical infrastructure is regarded to have the greatest impact on the overall quality of the logistics infrastructure of an alternative with a relative value of 37.55 %. It must be noted that the other two main determinants public infrastructure and human factor are relatively close, and almost identical, with an overall priority of 31.22 % and 31.23 %. These priority values were the basis for the following evaluation. In this evaluation, for each of the determinants (here: Public infrastructure, physical infrastructure and the human factor) pairwise comparisons have been conducted. The pairwise comparisons have been based on the classical 1–9 ratio scale of the AHP process (Saaty 1990). Via these pairwise comparisons, the priorities of the different determinants with subject to the goal have been derived. The same kind of pairwise comparisons have been conducted for all sub-determinants with respect to their individual main determinants. To assess the relative preference of each alternative with respect to its lowest level sub-determinant, a different approach has

Table 1 Overview on priorities of determinants with respect to the goal and of sub-determinants with respect to the goal (global priority) and their covering main-determinant (local priority)

Determinants	Sub-determinants	Local priority (%)	Global priority (%)
Public infrastructure		31.22	31.22
	Currency stability	6.40	2.00
	Corruption	25.14	7.85
	Customs situation	21.19	6.62
	Economic policy conduciveness	18.34	5.73
	Economic structure conduciveness	3.62	1.13
	Political stability	13.44	4.19
	Liquidity rules and regulations	3.65	1.14
	Judicial system	8.22	2.57
Physical infrastructure		37.55	37.55
	Road transportation	28.89	10.85
	Air transportation	4.86	1.82
	Inland waterways	3.95	1.48
	Seaports	11.97	4.49
	Warehousing	24.81	9.32
	Rail transportation	11.58	4.35
	Intermodal transportation	13.96	5.24
Human factor		31.23	31.23
	Averages wages	38.05	11.88
	Productivity	23.20	7.24
	Education	25.67	8.02
	Workforce availability	13.08	4.09

been taken. Especially in case of many alternatives and many determinants/sub-determinants in the model, the number of required pairwise comparisons can proliferate. Therefore, alternative measurement approaches are necessary to facilitate the usage in the managerial practice.

For the illustrative AHP described in this paper, an absolute measurement method in form of ratings scale has been applied. Here, a relative ranking of the different alternatives with respect to its sub-determinants has been used. To achieve the local and global priorities, an evaluation matrix of the different comparisons has to be created. Then the sums of the columns are generated and the matrix is normalized. For the normalized matrix the sums per line are calculated and divided by the number of items to achieve the local priority. For calculating the global priority, this local priority is multiplied by the local priority of the related

Table 2 Logistics Complexity Index of Eastern European Countries and Germany

Determinants	Sub-determinants	Alternatives			
		Russia (%)	Poland (%)	Romania (%)	Germany (%)
Public infrastructure		9.57	29.43	20.59	40.41
	Currency stability	15.42	23.82	23.82	36.93
	Corruption	2.20	30.58	19.80	47.41
	Customs situation	1.94	33.51	22.68	41.86
	Economic policy conduciveness	13.84	26.52	26.52	33.13
	Economic structure conduciveness	15.69	20.36	20.36	43.59
	Political stability	15.85	30.37	15.85	37.94
	Liquidity rules and regulations	12.51	33.33	12.51	41.64
	Judicial system	15.59	29.88	11.22	43.41
Physical infrastructure		21.80	24.85	14.64	38.71
	Road transportation	14.94	28.63	14.94	41.49
	Air transportation	32.38	15.08	2.33	50.20
	Inland waterways	26.82	22.53	17.37	33.29
	Seaports	36.35	13.65	13.65	36.35
	Warehousing	19.30	29.81	13.89	37.00
	Rail transportation	27.76	18.79	18.79	34.67
	Intermodal transportation	20.27	26.30	14.58	38.85
Human factor		27.37	23.77	28.33	20.54
	Averages wages	33.51	22.68	41.86	1.94
	Productivity	21.66	21.66	16.70	39.98
	Education	21.98	21.98	21.98	34.07
	Workforce availability	31.04	31.04	26.75	11.17
Total		19.89	25.90	21.06	33.15

determinant. For example, the sub-determinant “currency stability,” the global priority of 2.00 % is achieved by multiplying the local priority of 6.4 % with the priority of the related determinant “Public infrastructure” (31.122 %).

For the illustrative AHP-application described above, Table 2 gives an overview on the results of the assessment of the different alternatives. From the three Eastern European countries in the sample, Poland has with a value of 25.90 % the best fit for being the new regional distribution hub for Eastern Europe for the logistics manager of the case description. The other two alternatives, Russia and Romania achieve a quite similar result with 19.89 and 21.06 %.

When having a look at the values of the different determinants and sub-determinants, for some reasons these differences quickly become apparent: Especially for the factor “Public infrastructure,” the results of the different alternatives significantly differ. With rather bad results for the sub-determinants of “Corruption” and “Customs situation,” Russia significantly, negatively impacts its overall result.

This provides some insights into potential levers for further improvement of the countries logistics competitiveness. For Romania, especially the factor “Physical infrastructure” shows substantial relative weaknesses to the other countries of the test sample: Especially for airfreight and sea transportation, the results are significantly weaker than of the other sample countries.

Poland achieves, after the standard comparison country Germany, the overall best results especially due to a quite balanced overall performance with the strongest results for the factor of “Public infrastructure” and fields for further improvements especially in the sub-determinants of air transportation and seaport infrastructure.

Conclusion

The analysis exemplified in this paper shows the importance macro-institutional complexity in logistics can have for the situation on a micro-logistical managerial level. As shown above, the levers for further improvements can be very different in the examined Eastern European countries so that a detailed analysis of the interlinks of the various determinants could also allow to take more focused action on a macro-logistical level to improve the overall logistical competitiveness.

As described above, the model presented in this paper is only of an illustrative character. To allow a comprehensive examination of the situation in the Eastern European market, future research needs to be elaborate methodology described in this paper to ensure that all relevant determinants and sub-determinants are taken into account and prioritized appropriately. Furthermore, the robustness of the results needs to be validated by appropriate tests on alternative cases to further develop and extend the indicator set used.

Especially the effects of other prioritization approaches apart from pairwise comparison, e.g. the usage of absolute measurement scales like ratings scales or utility curves on the robustness and consistency of the results as well as the methodology to choose the appropriate approach for the actual decision-making problem should be further examined. For dynamic economic environments like Eastern Europe with a sometimes quite limited availability of complete and comparable statistical time series information on logistics topics, this research field will probably provide additional value to assess the macro-logistical complexity and the related logistics competitiveness of a country.

References

Augustyniak G. (2003) Logistics strategies for Central and Eastern Europe. In D. Waters: Global Logistics and Distribution Planning. London, Kogan Page Limited

Bagchi PK (2001) Measuring the supply chain competency of nations: the case of India. Supply Chain Forum 2:52–59

Bak H, Pysz P, Scharff R (1991) Das Balcerowicz-Programm: Konzept, Realisierungsschritte, Zwischenergebnisse. Deutsche Gesellschaft für zeitgeschichtliche Fragen e.V, Erlangen

Beamon BM (1999) Measuring supply chain performance. Int J Oper Prod Manage 19:275–292

Caplice C, Sheffi Y (1995) A review and evaluation of logistics performance measurement systems. Int J Logistics Manage 6:61–74

Gerring J (2007) Case study research: principles and practices. Cambridge University Press, London

Guisinger S (2001) From OLI to OLMA: incorporating higher levels of environmental and structural complexity into the eclectic paradigm. Int J Econ Bus 8:257–272

Halecki O (1957) Europa, Grenzen und Gliederung seiner Geschichte. Darmstadt, Wiss. Buchges

Hall DR (1993) Transport and economic development in the new Central and Eastern Europe. Belhaven Press, London

Ketokivi MA, Schroeder RB (2004) Strategic, structural contingency and institutional explanations in the adaption of innovative manufacturing practices. J Oper Manage 22:63–89

Kinra A, Kotzab H (2008a) Understanding and measuring macro-institutional complexity of logistics systems environment. J Bus Logistics 29:327–346

Kinra A, Kotzab H (2008b) A macro-institutional perspective on supply chain environmental complexity. Int J Prod Econ 115:283–295

Kinra A (2009) Supply chain (logistics) environmental complexity. Ph.d. dissertation. Copenhagen Business School, Copenhagen

Kisperska-Moron D (2005) Logistics customer service levels in Poland: changes between 1993 and 2001. Int J Prod Econ 93–94:121–128

Korhonen P (1997) Regional boundaries: Europe and Asia. In Dag ANCKAR und Lars NILSSON: politics and geography: contributions to an interface, 245–280

Meyer KE, Peng MW (2005) Probing theoretically into Central and Eastern Europe: transactions, resources, and institutions. J Int Bus Stud 36:600–621

North DC (1990) Institutions, institutional change, and economic performance. Cambridge University Press, Cambridge, UK

Olaru A. (1998) The attitude towards change of Romanian managers in the transition to market economy. In: R Lang, C Baitsch, P Pawlowsky, Führungskräfte im osteuropäischen Transformationsprozeß. Mering, Rainer Hampp Verlag, pp 313–320

Pfohl H (2004) Logistiksysteme: Betriebswirtschaftliche Grundlagen. 7th edition, Springer

Rydzkowski W, Spraggins HB (1994) Restructuring privatization and deregulation of transport in Poland: new transport policy implications. Int J Physical Distribution Logistics Manage 24:23–29

Saaty TL (1980) The analytic hierarchy process. McGraw Hill, New York

Saaty TL (1990) How to make a decision: the analytic hierarchy process. Eur J Oper Res 48:9–26

Waters C (1999) Changes to road transport in Poland during a period of economic transition. Int J Physical Distrib Logistics Manage 29:22–137

Worldbank (2012) Connecting to compete. The World Bank, Washington

Collaborative Carry-Out Process for Empty Containers Between Truck Companies and a Port Terminal

Sanghyuk Yi, Bernd Scholz-Reiter and Kap Hwan Kim

Abstract A container port is a crucial interface between the maritime and the hinterland transportation. In order to improve this interface, joint efforts between truck companies and a port terminal operator are necessary. However, a port terminal operator should transfer containers onto inland trucks responding to unexpected arrivals of them. It causes that handling equipment often have to relocate containers in order to pick up a desired one under them. These container-rehandling operations result in the waste of energy and the long waiting of inland trucks with greenhouse gas emissions. This paper addresses the inbound carry-out process for empty containers where a port terminal operator carries out them onto inland trucks at a port. The objective of this paper is to reduce the number of container-rehandles during this process, which leads to decrease in waiting time for inland trucks and increase in productivity of handling equipment. This paper applies the policy of the category stacking to the inbound containers. According to the predefined categories of containers, a port terminal operator is able to stack containers on the top of those in the same category. Truck companies can issue pickup orders of empty containers by specifying only the category instead of specifying container numbers. Based on this strategy, this paper proposes a collaborative process between a port terminal operator and truck companies. Simulation experiments are done to validate the strategy in this paper.

Keywords Port terminal · Category stacking · Container rehandling · Inbound empty container

S. Yi (✉) · B. Scholz-Reiter
International Graduate School for Dynamics in Logistics, University of Bremen, Hochschulring 20, 28359 Bremen, Germany
e-mail: ysh@biba.uni-bremen.de

B. Scholz-Reiter
e-mail: bsr@biba.uni-bremen.de

K.H. Kim
Department of Industrial Engineering, Pusan National University, 30, Jangjeon-dong, Geumjeong-gu, Busan 609-735, Korea
e-mail: kapkim@pusan.ac.kr

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Introduction

The growth of world container throughput resulted in a higher congestion in storage yards and a higher traffic of inland trucks at a port terminal. This demand for high capabilities of the ports has caused considerable waiting of inland trucks at port terminals with larger greenhouse gas emissions. One of the major causes of truck waiting is that arrival times of trucks are extremely uncertain. In order to retrieve a desired container beneath another at a storage yard, the rehandling movements of handling equipment are unavoidable, which eventually results in long truck waiting. However, this transfer operation may be improved only by joint efforts between truck companies and a port terminal operator, but not only by either side.

For cooperative operations between truck companies and a port terminal operator, it is essential to share related information with each other. Actually, truck companies hesitate to reveal their information related to sales in practice. In many cases, they tend to be small-sized or individual businesses with small quantities of orders. However, in the case of empty containers at an export-oriented port, a truck company hauls the empties in large amounts towards off-the-dock container yards (ODCY) or inland container depots (ICD) for temporary storage before deliveries to their consignees. Thus, a port terminal operator is more likely to collaborate with large-sized truck companies by sharing information about empty containers which are not directly related to sales. Moreover, storage yards for only empties are separately allocated in port terminals, which means that this type of collaboration can show effects in flows of empties separate from the other flows of full containers.

This paper focuses on the process for inbound empty containers including the flow of information between truck companies and a port terminal operator as well as the flow of containers from container ships onto inland trucks within a port terminal, which is called as the inbound carry-out process for empty containers. This process is divided into three operations: unloaded containers from a container ship are stacked on storage yards; handling equipment rearranges them for quick retrieval after receiving information about containers to be retrieved from truck companies, called as a rearranging operation; containers are retrieved onto inland trucks, called as a retrieval operation. The detail process is described in the next section.

In this inbound carry-out process for empty containers, the container-rehandles by handling equipment often occur when a container under another is to be picked up. This is because the sequence of retrievals of containers is unknown. This rehandling activity causes the waiting of inland trucks with greenhouse gas emissions and the delay of deliveries on the container logistic network. Hence, the objective of this paper is to reduce the number of container-rehandles in the inbound carry-out process for empties, which leads to decrease in the waiting of inland trucks.

This paper applies the policy of the category stacking to the inbound carry-out process. Dekker et al. (2006) studied the category stacking where containers on the same category are stacked on top of the other and can be exchanged for the loading operation with a container ship. In terms of the inbound carry-out process, inland trucks can pick up any empty container of the same destination in practice. Thus, those containers can be grouped into the same category and stacked on top of the other by the category stacking. By using this policy, the collaborative process for inbound empty containers is proposed to reduce the number of container-rehandles during this process, especially during the retrieval operation which is the bottleneck of inland container logistics. The simulation study provides the effects of collaboration by showing the decrease in the number of container-rehandles.

There have been many researches about stacking containers to reduce the rehandling movement of cranes at a container port (Stahlbock and Voß 2008). Dekker et al. (2006) discussed the simulation study about stacking policies considering several variants of category stacking to reduce the workloads of cranes and the number of container-rehandles. Park et al. (2011) suggested the stacking policy considering various criteria such as the category of the container, the stack height, or the workload of cranes. However, these researches about the stacking policies considered only operations within a port without cooperating with hinterland truck companies. Some works addressed the collaboration between a port terminal operator and truck companies by sharing information about truck arrivals. Port retrieval operations with the use of truck arrival information revealed reducing container-rehandles in storage yards (Zhao and Goodchild 2010). Unlike these real-time operational methodologies, this paper proposes the strategic or tactical process including stacking policy and the flow of information between them. Many researchers have mathematically analyzed the container-rehandling problem (Jang et al. 2013). Kim et al. (2000) studied the problem of locating the incoming outbound containers by using certain group information based on the weights of the containers. They formulated the model for estimating the expected number of rehandles for the future loading operation with a containership. Kim and Hong (2006) suggested the algorithms to determine the locations of relocated blocks during the pickup operation. Hence, most of these researches dealt with the decision on the location of the incoming containers to storage yards or the relocated containers during the retrieval operation. On the contrary, this work considers the relocation of rearranging containers which are already stacked on the storage yard.

Carry-Out Process for Inbound Empty Containers

This paper targets a port terminal which is based on the electronic communication (e.g., Electronic Data Interchange) with truck companies and handles the rearranging operation in stacking strategies. Figure 1 illustrates the flow of inbound empty containers within a port terminal. At first, these empty containers are unloaded from a container ship and temporarily stored on a storage yard by using a simple stacking policy. In this work, it is assumed that the lowest stack policy is applied to stack unloaded containers. A container will be placed on the lowest possible stack. Then, a truck company notifies a port terminal operator that an

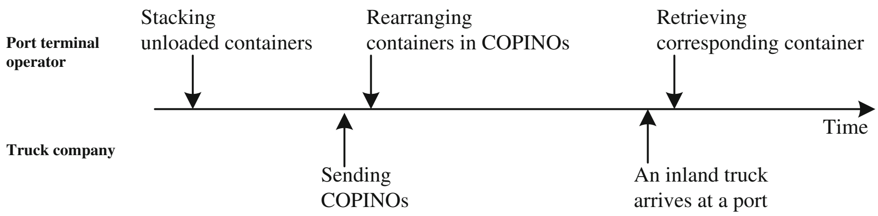

Fig. 1 Carry-out process for inbound empty containers

inland truck will arrive to pick up a container by sending a message, "container pre-notification message" (COPINO). A COPINO includes the information about a container identification number and a truck identification number, which means that this truck should deliver this container. A COPINO is only valid for 24 h, thus it is sent to a port terminal operator a day or several hours before an inland truck arrives at the gate of a port. Next, a port terminal operator rearranges the containers according to the information of COPINOs to smoothly retrieve them onto inland trucks. Finally, when an inland truck arrives at the storage yard, handling equipment picks up and loads the corresponding container onto the inland truck. The paper assumes that there are spaces separated for the rearranging operation. Unloaded containers cannot be stored on these spaces. Containers informed to be retrieved through COPINO from truck companies are relocated onto these spaces. In general, a port terminal operator easily manages their storage yard to locate empty containers in this way in practice. In the case that this separated space is fully filled with relocated containers, they are allowed to be stored on the other space for unloaded ones.

During these carry-out operations, handling equipment may have to rehandle containers to pick up a desired one which is located beneath others. In this work, it is assumed that the rehandled container is relocated on the lowest stack of the same bay. These additional rehandling activities can result in increase in waiting time for inland trucks as well.

Collaborative Carry-Out Process

This work applies two concepts: first, category stacking at storage yards; second, postponement of the decision on which container is assigned to which inland truck until the truck visits a port. Figure 2 illustrates the collaborative process for inbound empty containers through a port. In general, a truck company transports the empties in large amounts towards the same destination (e.g., ODCY, ICD) at the same day. Actually, these containers can be delivered by any inland trucks from the same truck company. Thus, in this process, the category of containers can be defined according to a truck company, destination of a container and carry-out period. The carry-out period means the duration of time in which an inland truck will visit a port

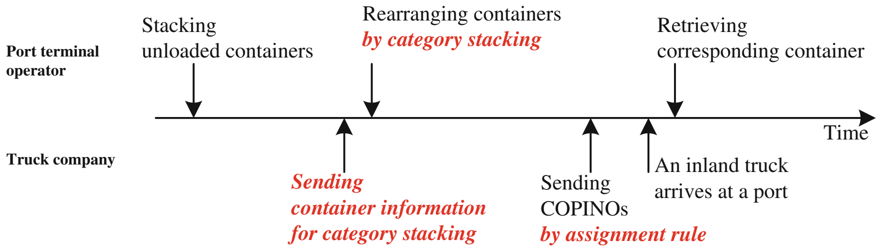

Fig. 2 Collaborative process for inbound empty containers

to receive the container. Hence, containers of the same truck company, the same destination and the same carry-out period are grouped into the same category. Then, a truck company sends information of containers except information of inland trucks which will deliver containers. Based on this advanced information on retrieval containers, handling equipment is able to rearrange them by the category. The handling equipment picks up a container with the minimum container-rehandles and piles it on top of a stack with containers of the same category. Next, when a COPINO is sent to a port terminal operator right before an inland truck arrives at a port, considering the situation of the storage yards, the specific container with the minimum container-rehandles in the same category is assigned to the inland truck. Hence, the proposed process can significantly reduce the number of container-rehandles during the rearranging and retrieval operations, which results in decrease in waiting time for inland trucks at a port.

A simple heuristic staking policy is suggested for the rearranging operation and subsequently the assignment rule of a container to an inland truck. For the rearranging operation, after receiving the information of retrieval containers from truck companies, the category-stacking policy is triggered and determines the position of relocated containers. Among the containers informed to be retrieved through COPINO from truck companies, a container with the minimum container-rehandles is selected and is preferably relocated on the stack of the same category. The algorithm for the rearranging operation is described in detail below.

Step 1: Check the number of container-rehandles for each container informed to be retrieved through COPINO from each truck company. Choose the container with the minimum number of container-rehandles. If there are several candidates with the same number of container-rehandles, then select the nearest one from the current location of handling equipment. Go to Step 2.
Step 2: Check the category of the selected container and search for a stack of the same category. If such a stack exists, then select it. If the selected stack is fully filled, then select an empty stack randomly. If there is no empty stack, then select the lowest stack of different categories. If the space separated for the rearranging operation is fully filled, then select a stack near this space and this stack is restricted to store unloaded containers. If all containers in the information from a truck

company are rearranged, then stop. Otherwise, rearrange the selected container onto the chosen stack and go to Step 1.

As a truck company arrives at a port, the assignment rule is triggered and a specific container is selected considering the current situation of the storage yard. The container on top of the stack in the same category is assigned to the inland truck. The algorithm is described below.

Step 1: Check the category assigned to the inland truck and search for candidate stacks having containers of the same category. Go to Step 2.
Step 2: Select the stack having the containers of the same category on top. In this case, a stack mixed with different categories is preferred to one of the same category considering expected container-rehandles on the mixed one. If there is no container of the same category on top of candidate stacks, then select the stack with the minimum container-rehandles to pick it up. Assign the container on top of the selected stack to the inland truck. Stop.

Simulation Experiments

Simulation experiments have been performed to evaluate the effects of the collaborative process for inbound empty containers. The simulation model was developed with the help of Tecnomatix Plant Simulation. The test data set is randomly produced where six containerships arrive for 2 weeks. After a containership come alongside a berth, unloaded containers are randomly generated for 1 day. Then, after the unloading operation is finished, inland trucks to pick up containers are randomly generated within 7 days based on the distribution of dwell time of inbound containers in a real port terminal, which is illustrated in Table 1. A COPINO is randomly generated within 24 h before the arrival time of an inland truck, and then is transmitted to a port terminal operator. For the collaborative process, the entire simulation time (3 weeks) is firstly divided by the defined carry-out period (e.g., 0:00–12:00 and 12:00–24:00 for a day in the case of 12 h of carry-out period). Then, the information about all retrieval containers which inland trucks will deliver at a specific carry-out period is collected and transmitted to a port terminal operator right before these divided simulation times. After that, a port terminal operator rearranges the containers by the stacking policy. For each test data, the simulation has been repeated 30 times, and the results have been averaged.

The storage yard is the area in the port where containers are temporarily stored. The storage yard is usually separated into several bays which are divided into stacks

Table 1 Percentage of retrievals of inbound containers on each day after unloading

*n*th day	1	2	3	4	5	6	7
Percentage (%)	19	26	20	14	9	7	5

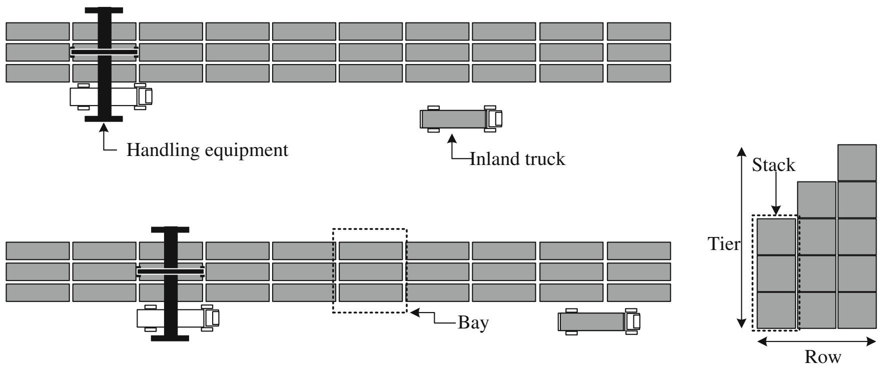

Fig. 3 A storage yard for empty containers

with rows and tiers as shown in Fig. 3. Often stacks are separated into areas for export, import, special, and empty containers. This paper considers specific storage yards dedicated to only empties. This simulation model assumed the storage yard which consists of 20 bays with 5 rows and 7 tiers. It is assumed that this model considers the same size (20 ft.) of a container and a gantry crane handles containers on a storage yard.

Table 2 illustrates the effect of the collaborative process with the category stacking by varying the number of inbound empty containers. This experiment additionally considers the conventional process without the rearranging operation. Simulation results illustrates that category-stacking policy helps to decrease the number of container-rehandles during the rearranging operation. In addition, the postponement of the assignment decision of a retrieval container for an arriving inland truck highly decreases the number of container-rehandles during the retrieval

Table 2 The effect of the category-stacking policy according to the number of containers

The number of containers	Conventional process			Collaborative process	
	The number of rehandles during RT (The case without RA)	The number of rehandles during RA	The number of rehandles during RT	The number of rehandles during RA	The number of rehandles during RT
550	212.87	235.57	120.83	203.87	12.03
600	261.03	303.57	165.60	262.87	19.07
650	322.23	382.23	202.47	307.67	29.30
700	378.40	451.60	251.07	366.87	41.83
750	455.37	537.90	307.97	424.03	54.33
800	538.17	622.90	345.90	489.37	71.40
850	629.43	713.03	409.73	552.17	88.37
900	713.30	817.80	478.17	621.77	112.40

Note: *RA* ReArranging operation, *RT* ReTrieval operation

Table 3 The sensitivity analysis on batching the categories

Carry-out period	The number of destinations	The number of truck companies	The number of rehandles during the RA	The number of rehandles during RT
6 h	5	5	548.83	124.63
12 h	5	5	525.20	114.70
1 day	5	5	489.37	71.40
2 days	5	5	386.40	24.57
3 days	5	5	403.07	17.53
Carry-out period	The number of truck companies	The number of destinations	The number of rehandles during the RA	The number of rehandles during RT
1 day	3	5	486.70	2.25
1 day	4	5	486.10	12.83
1 day	5	5	489.37	71.40
1 day	6	5	495.27	133.80
1 day	7	5	485.73	180.37

operation as well. Although the rearranging operation requires additional movements of cranes to relocate containers, it is effective in the interrelated retrieval operation between players. The collaborative process significantly reduces the number of container-rehandles compared with the conventional ones.

Table 3 analyzes the sensitivities on batching the categories. In this experiment, containers are categorized according to the carry-out period in the first table and the number of truck companies in the second table. The longer carry-out period means that more advance information about retrieval containers is transmitted and more containers can be grouped into the same category. Hence, during the rearranging and retrieval operation, the number of container-rehandles can be considerably reduced. Truck companies can cooperate with others for delivery of containers towards the same destination. In this case, more containers can be batched into the same category, which results in decreases in the number of container-rehandles during the retrieval operation. Thus, the collaborative process can be more effective when more information is certain and shared in advance.

In this experiment, the ratio of spaces separated for the rearranging operation is a measure of how many bays are allocated for the rearranging operation. If this ratio is higher, then more bays are assigned for rearranged containers but fewer bays are allocated for unloaded containers. Consequently, as the ratio of these spaces is higher, the number of container-rehandles decreases during the retrieval operation and increases during the rearranging operation in Table 4. In a port terminal with rearranging operation, this ratio should be considered when an operator determines the stacking strategy regarding the space allocation.

Table 4 The dependency of the ratio of spaces separated for the rearranging operation

The ratio of spaces separated for RA (%)	The number of rehandles during the RA	The number of rehandles during RT
10	433.53	498.83
15	463.20	281.37
20	489.37	71.40
25	535.90	4.41
30	574.30	0

Conclusion

This paper targets on container rehandling problem in the inbound carry-out process for empty containers. The category-stacking policy is applied to this inbound carry-out process. The category of containers is defined according to a truck company, destination of a container and a carry-out period. By the category stacking, containers of the same category can be piled on top of the other. Truck companies can exchange containers on the same category for carry-out operations by postponing the decision on which inland truck delivers which container until the truck arrives at a port. Based on this policy, this paper proposes collaborative process between a port terminal operator and truck companies to reduce the number of container-rehandles. In this process, the rearranging operation requires additional handling movements of cranes to relocate containers in advance. However, the simulation experiments demonstrate the effects of the collaboration by showing considerably decrease in the number of container-rehandles, especially during the retrieval operation which is the bottleneck of inland container logistics network. In addition, the simulation results explain that if a port terminal operator knows more information of retrieval containers earlier by sharing it with truck companies, it should be more effective to improve this process. Therefore, this paper expects to encourage interrelated stakeholders to reveal their information for the carry-out process through a port and cooperate with each other.

For the further research, it is assumed that all information about the retrieval containers within a carry-out period is known in advance. However, some carry-out orders can urgently occur even within a carry-out period in reality. For this dynamic situation, this work will conduct the simulation study in which container information can be transmitted to a port within a carry-out period. In addition, this research assumes that all the containers should be relocated to the separated space for the rearranging operation, which inevitably requires additional movements of cranes. Thus, the stacking algorithm for the rearranging operation will be developed considering total handling movements of cranes including container-rehandles.

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References

Dekker R, Voogd P, Asperen E (2006) Advanced methods for container stacking. OR Spec 28(4):563–586

Jang D, Kim SW, Kim KH (2013) The optimization of mixed block stacking requiring relocations. Int J Prod Econ 143:256–262

Kim KH, Hong GP (2006) A heuristic rule for relocating blocks. Comput Oper Res 33(4):940–954

Kim KH, Park YM, Ryu KR (2000) Deriving decision rules to locate export containers in container yards. European J Oper Res 124(1):89–101

Park T, Choe R, Kim YH, Ryu KR (2011) Dynamic adjustment of container stacking policy in an automated container terminal. Int J Prod Econ 133:385–392

Stahlbock R, Voß S (2008) Operations research at container terminals—A literature update. OR Spectrum 30(1):1–52

Zhao W, Goodchild AV (2010) The impact of truck arrival information on container terminal rehandling. Transp Res Part E 46:327–343

Optimization of Container Multimodal Transport Service Based on Segmented Procurement

Hualong Yang and Di Liu

Abstract This paper proposed the double optimization objectives including minimization of total transport cost and total transport time in container multimodal transport from the perspective of multimodal transport operators. Based on the routes selection and convergent combination of transport time, space, and volume, an optimization model of segmented procurement in container multimodal transport was established with regard to the elements constraints of shippers' orders, organization forms of container multimodal transport, container delivery location, transportation road and mode, transportation time, and freight rate. The natural constraint language (NCL) was employed to establish algorithm procedure for searching and solving the problem. Numerical examples show that the model and its searching algorithm are not only prone to implement and solve the problem, but also are quite good at the application results, and the goal of seamless integrated container multimodal transport is achieved.

Keywords Container multimodal transport · Segmented procurement · Convergent combination · Optimization model

Introduction

In recent years, the problem of transport service procurement has caught the attention of many scholars. Ledyard et al. (2002) first proposed the concept of combined-value auction for transportation services and reported that Sears Logistics

H. Yang (✉) · D. Liu
Transportation Management College, Dalian Maritime University,
Dalian 116026, China
e-mail: hlyang@dlmu.edu.cnLiu

D. Liu
Transportation Management College, Dalian Jiaotong University,
Dalian 116028, China
e-mail: liudi@djtu.edu.cn

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Services had been saving $165 million annually on outsourced transportation costs with the successful use of it. Later, many researches (Caplice and Sheffi 2003; Song and Regan 2003, 2005) examined the perspective of auctioneers or shippers and focused primarily on the design of auctions and methods to solve the winner determination problem.

In the field of container transportation and multimodal transport services procurement, Caris et al. (2013) indicated that the intermodal research topics include policy support, terminal network design, intermodal service network design, intermodal routing, drayage operations, and ICT innovations. Chang et al. (2010) studied an optimization model of international container intermodal transportation in South Korea, with the objective of minimizing the total logistic costs, that is, shipping and land transportation costs, as well as external costs such as air pollutants and greenhouse gases. Wang and Wang (2012) formulated a mathematical model for obtaining the optimal container type and transport modes for multimodal transport based on the fuzzy demands and the transportation cost minimization, and presented the improved particle-ant colony optimization algorithm to solve the model. Iannone (2012) presented an optimization model of port-hinterland container logistics systems with minimizing the sum of all container-related generalized logistic costs throughout the entire multimodal port-hinterland network. The logistic costs include transportation costs (by road and railway), terminal handling and storage costs, customs control costs, in-transit inventory holding costs, and container-leasing costs.

From what has been discussed above, most of the literature focuses on a single attribute—cost, the non-cost attributes as delivery time, service quality, etc., have not been taken into account. Zhang et al. (2011) took both road and rail chains in international container transportation between port and hinterland as the research object, and set the nested logit model by selecting the sea lines density, customer clearance procedure convenience, transportation time, transportation cost, and reliability as the variables of the transportation chain utility function.

In the reality, transportation cost, transportation time, the network accessibility and the integrated seamless connection are all the important attributes for container multimodal transport services procurement. The multi-attribute should be taken into account (Chen et al. 2005). Thus, this paper establishes a segmented procurement optimization model of container multimodal transport services based on route selection with the dual objectives of minimizing total cost and total time, and designs the corresponding algorithm based on the natural constraint language (NCL), so as to enrich and perfect the theory and practice of the container multimodal transport organization.

Procurement Optimization Model

Problem Description

The process of container multimodal transport service procurement can be divided into two phases in general. The first stage is that the shippers purchase transportation services from the multimodal transport operators (MTO). The second stage is that the MTO purchase the transportation services segmented from the actual carrier of water/land transportation service. From the perspective of the MTO, the problem in the second stage can be described as: it is assumed that n waybills should be completed through m sections within the stipulated period of time to submit the corresponding containers to the designated place. There are several frequencies from the starting to the end on each section every day. On each section, the mode of transport, transport mileage, transport time, transport capacity (TEU) and the transport rate are all fixed. Now, the MTO need to regard minimizing the total transport cost and total transport time as the objectives, and make a reasonable transport arrangement to determine the transport route (the combination of transport sections) and the transport time of the n waybills, so that completing all waybills within the stipulated period of time.

When the MTO make arrangements for multimodal transport service in each section, they take transport cost into consideration first, and then total time efficiency. Therefore, the first optimization objective is the minimum total cost of multimodal transport routes, and the second optimization objective is the minimum total transport time.

There are four main constraint conditions in procurement optimization of container multimodal transport service problem:

1. Spatial constraints: When deciding on transport routes for waybills, for one specific waybill, the starting and destination points of each section in the route must be connected. Besides, the starting and destination points of waybills are exactly the same as those of the route.
2. Time constraints: Feasible solutions of an optimization problem should be applied to the restraints of a time window, and a transport plan for a single waybill should consider constraints in chronological order.
3. Capacity constraints: All the waybills in a frequency have capacity constraints, that is to say the total number and the total weight, which is less than the maximum transport capacity in this specific frequency, in each waybill.
4. Implicit constraints: There is a section combination set that combines all the waybills, thus one section is different from its next section. Besides, in this section combination set, different sections cannot share one previous section, and different frequencies in one section cannot use the same waybill.

In the design of the spatial and time link, the variables of the former section and the latter section are introduced in this paper. We set place orders and time orders in one section and its neighbor sections by logic programming. The destination of a

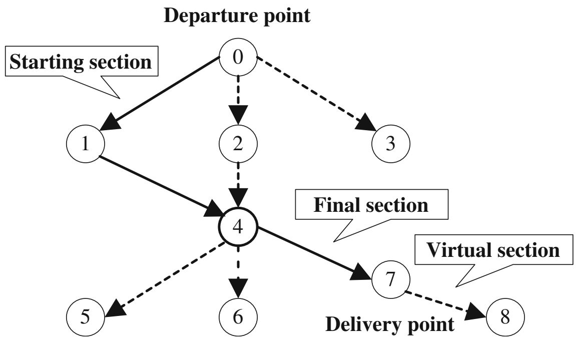

Fig. 1 The increased virtual section

section must be the starting point of the next section and the departure time of the latter section must be later than the arriving time of the former section. Particularly, the starting point of a section is the same as the departure point of a waybill and the starting time of a section is the same as the departure time of the waybill. Accordingly, the destination of a section is the same as the places of receipt of a waybill and the delivery time of a section is the same as the delivery time of the waybill, in a delivery time window.

In addition, in order to make the final section of a waybill to meet the above spatial and time link constraints we need to make a special management, which adds a virtual section in any waybill after the final section as its next section. In this way, the actual final section in a waybill has its next section, enabling the final section meet the spatial and time restraints as well. The starting point of the added virtual section is the destination of the actual final section and the starting time is earlier than the arriving time of the final section, as Fig. 1 shows.

Model

We assume that there is a MTO who has to complete n waybills through m optional sections. For a specific section j, there are k_j different starting frequencies with transport cost c_j and transport time t_j. The maximum package quantity is CQ_j, and the maximum load capacity is CW_j. For a specific waybill i, its shipping time is chosen from $\sum_{j\in\{1,m\}} k_j$ starting frequencies through m sections. Quantity shipped in this waybill is q_i, total weighing for w_i, and the origin depot is O_i with the place of receipt D_i. It is required that the containers arrive on time at exact destinations in the time window $[t1_i, t2_i]$, whose floor of delivery time is $t1_i$ and ceiling of delivery time is $t2_i$, the total amount of starting frequencies is $k = \sum_{j\in\{1,m\}} k_j$.

In this procurement problem of multimodal transport service, we assume that the unknown number of sections of waybill i is L_i, and apparently it is clear that $L_i \le m$. The actual departure time and actual arriving time of waybill i are also unknown, namely $T1_i^*$ and $T2_i^*$. Besides, the transport routes are uncertain, therefore, the starting point, destination, time of departure and arriving time are all unknown. Thus, we need to set the starting point $S1_{i,l_i}$, destination $S2_{i,l_i}$, time of departure $T1_{i,l_i}$, and the arriving time $T2_{i,l_i}$ in the $l_i(l_i \in \{1,\ldots,L_i\})$ section. This segmented procurement optimization of service modal can be described as follows:

Objective function of the first level

$$\min \sum_{t=1}^{k} \sum_{j=1}^{n} \sum_{i=1}^{m} c_j \cdot q_i \cdot x_{ijt} \tag{1}$$

Objective function of the second level

$$\min \sum_{i=1}^{m} (T2_{i,l_i} - T1_{i,l_i}) \tag{2}$$

$$x_{ij} = \begin{cases} 1, & \text{the waybill } i \text{ is transported through section } j \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

$$y_{ijt} = \begin{cases} 1, & i \text{ is transported at the } t\text{th starting time of section } j \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

$$x_{ij} = \sum_{t=1}^{k_j} y_{ijt}, \quad \forall i \in \{1,\ldots,n\},\ j \in \{1,\ldots,m\} \tag{5}$$

$$\sum_{j=1}^{n} x_{ij} = L_i, \quad \forall i \in \{1,\ldots,n\} \tag{6}$$

$$S1_{i,1} = 0_i, \quad \forall i \in \{1,\ldots,n\} \tag{7}$$

$$T1_{i,1} = T1_i^*, \quad \forall i \in \{1,\ldots,n\} \tag{8}$$

$$S2_{i,l_i} = D_i, \quad \forall i \in \{1,\ldots,n\} \tag{9}$$

$$T2_{i,l_i} = T2_i^*, \quad \forall i \in \{1,\ldots,n\} \tag{10}$$

$$S1_{i,j} \neq S1_{i,j+1}, \quad \forall j \in \{1,\ldots,L_i\},\ i \in \{1,\ldots,n\} \tag{11}$$

$$S2_{i,j} \neq S2_{i,j+1}, \quad \forall j \in \{1,\ldots,L_i\},\ i \in \{1,\ldots,n\} \tag{12}$$

$$T1_{i,j} \neq T1_{i,j+1}, \quad \forall j \in \{1,\ldots,L_i\},\ i \in \{1,\ldots,n\} \tag{13}$$

$$S1_{i,j+1} = S2_{i,j}, \quad \forall j \in \{1,\ldots,L_i\},\ i \in \{1,\ldots,n\} \tag{14}$$

$$T1_{i,j+1} \geq T2_{i,j}, \quad \forall j \in \{1, \ldots, L_i\},\ i \in \{1, \ldots, n\} \tag{15}$$

$$T2_{i,j} = T1_{i,j} + t_j - 1, \quad \forall j \in \{1, \ldots, L_i\},\ i \in \{1, \ldots, n\} \tag{16}$$

$$t1_i \leq T2_{i,L_i} \leq t2_i, \quad \forall i \in \{1, \ldots, n\} \tag{17}$$

$$\sum_{i=1}^{n} q_i \cdot y_{ijt} \leq \mathrm{CQ}_j, \quad \forall t \in \{1, \ldots, k_j\},\ j \in \{1, \ldots, m\} \tag{18}$$

$$\sum_{i=1}^{n} w_i \cdot y_{ijt} \leq \mathrm{CW}_j, \quad \forall t \in \{1, \ldots, k_j\},\ j \in \{1, \ldots, m\} \tag{19}$$

where Eq. (1) represents the first optimizing objective which is the minimum total transport cost of the multimodal transport. Equation (2) represents the second optimizing objective which is the minimum total transport time of all sections. In Eq. (3) x_{ij} is 0–1 variable, representing that whether waybill i chooses section j. In Eq. (4) y_{ijt} is 0–1 variable, representing that whether waybill i chooses t starting time of section j. In Eq. (5) logical relationship between 0 and 1 variable x_{ij} and y_{ijt} are defined. It means that if waybill i chooses section j, waybill i must chooses a starting time k_j which is unique in section j. Equation (6) represents the amount of sections which are assigned to waybill i. Equation (7) represents that starting point of origin section in waybill i is the same as the origin depot of waybill i. Equation (8) represents that starting time of origin section in waybill i is the same as the time of delivery in waybill i. Equation (9) represents that destination of the end section in waybill i is the same as delivery points of waybill i. Equation (10) represents that arriving time of the end section in waybill i is the same as delivery time of waybill i. Equation (11) represents that for waybill i, different transport sections have different starting points. Equation (12) represents that for waybill i, different transport sections have different destinations. Equation (13) represents that for waybill i, different transport sections have different starting time. Equation (14) represents that in waybill i, for one section, its destination is the starting point of the next section. Equation (15) represents that in waybill i, for one section, its delivery time is earlier than the starting time of next section. Equation (16) represents that in waybill i, for one section, its delivery time is equal to the starting time adding to transport time, then minus 1. Equation (17) represents a restraint that in waybill i, any arriving time of end sections should meet the demand of time window. Equation (18) represents that package capacity should be less than load capacity in any sections at any time. Equation (19) represents that load capacity should be less than the maximum capacity in any sections at any time.

Algorithm Design

By analyzing the problem, we can conclude that the segmented procurement optimization model of container multimodal transport service has not only the characteristic of nonlinearity but also links-style order. When solving the problem, we should combine the knowledge of shortest path problem with links-style order on space and time, forming the objective *string*. It's fairly hard to solve a problem which involves space links and time links by using general software, yet the solution efficiency of such nonlinear problem is low. Above all, artificial intelligence logic is used for finding solutions.

This paper uses NCL (Zhou 2009) to solve the problem. Searching steps of natural constraint algorithm program is shown in Fig. 2.

In the optimization model, 0–1 variable x_{ij} represents whether waybill i chooses section j, expressing as RouteOrder, a collection variable in the algorithm model. y_{ijt} represents that section j is chosen to transport on t starting time of waybill i, and as the selected starting time is unique, a numerical variable which is called shiftRouteOrder is used in the algorithm model. The algorithm design is based on mixed set programming on path selection algorithm model of multimodal transport.

Searching strategy 1: Searching for lastRouteOrder which is the end section of variable waybill with the nature of a bottleneck.

The non-set variable lastRouteOrder is searched in the light of follow steps: (1) waybills of more containers, (2) waybills with less uncertainty of section set, (3) waybills with less optional end sections among section set, (4) waybills of which the time window demand is tense, (5) sections of which the destination is the same as the waybill's, (6) sections with lower freight rate, (7) sections with less total package quantity of containers, (8) sections with less transport time needed,

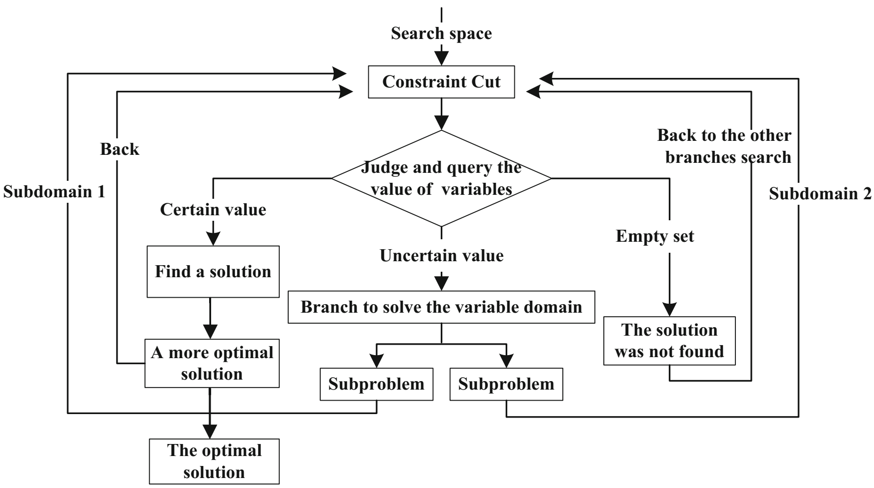

Fig. 2 Framework of solving steps

(9) sections with less mileages, (10) the first starting time in each section, (11) sections with less transport frequencies, (12) sections with the least uncertainty of the frequency actually used.

Searching strategy 2: searching for the core variable RouteOrder.

The set RouteOrder is inquired and searched according to the steps below: (1) waybills whose uncertainty is the least among all the sections set, (2) waybills whose ceiling of time window is the least, (3) waybills with larger amount of containers, (4) sections which can be the end section, (5) sections with less freight rate, (6) the first starting time of a section, (7) sections with less quantity of total package capacity of containers, (8) sections with less transport time, (9) sections with less mileages, (10) sections with the least uncertainty of the transport frequency actually used, (11) sections with less optional frequencies.

Searching strategy 3: finding the core variable shiftRouteOrder.

The non-set shiftRouteOrder is inquired and searched according to the steps below: (1) waybills with larger transport demands, (2) waybills with less transport links, (3) sections with less transport orders, (4) waybills with lower level of regret, that is, the principle of least regret level which searching for the biggest branch in function range, (5) frequencies with less uncertainty in the range of waybills.

Numerical Examples

It is assumed that a MTO gets 30 waybills from shippers. The global picture of routes, waybills, and sites is shown in Fig. 3.

Using the information data of mileages, transport time, carriers, and freight rate from present transport network which includes 16 highway sections (A001-A016), 17 waterway sections (B017-B033) and 77 railway sections (C034-C110), the

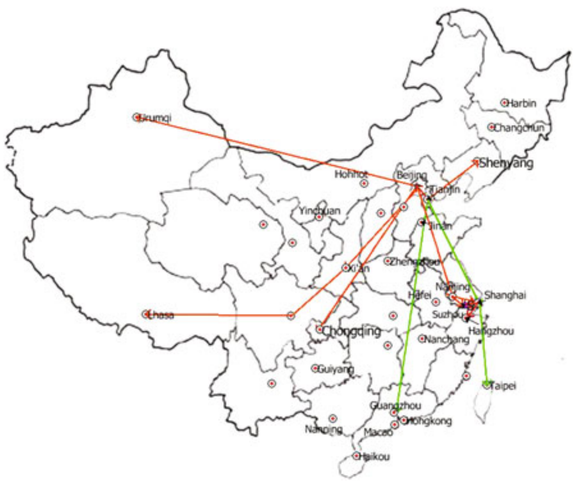

Fig. 3 The global picture of routes, waybills, and sites

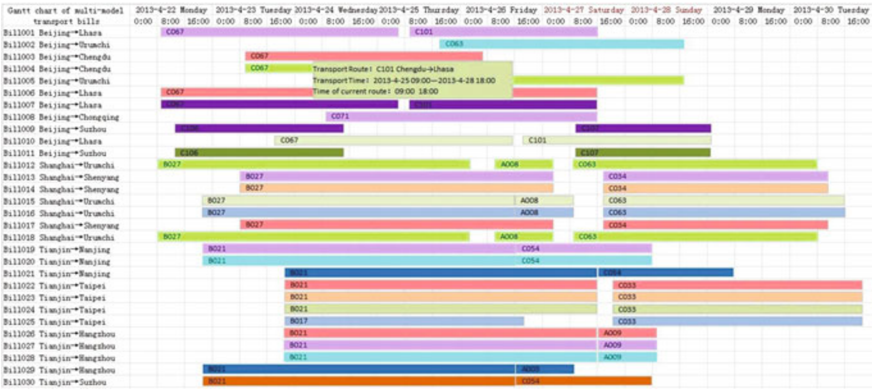

Fig. 4 Gantt chart of waybills

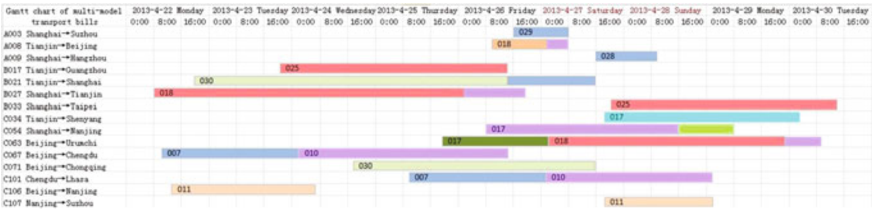

Fig. 5 Gantt chart of transportation route

programs are solved through the optimization model together with NCL established in this paper, and the Gantt chart of waybills is shown in Fig. 4.

The Gantt chart of transportation route is shown in Fig. 5.

From Figs. 4 and 5, we can see that the MTO have segmented procurement transport service combined efficiently, intensively arranging all the waybills into 5 days, from April 22–26, 2013. The procurement plan of segmented transport service is distributed based on convergent combination; it not only achieves the minimum total transport cost, but also arranges transport capacity intensively, saving more time. There are 59 sections needed to purchase, and after optimization combination, the total number of transport routes is 15, which meets all the demands of waybills. Courier missions are completed in the time period from April 22–30, 2013, achieving the goal of seamless integrated container multimodal transportation.

Conclusion

From the perspective of MTO and based on the routes selection and convergent combination of transport time, space and volume, this paper established an optimization model of segmented procurement in container multimodal transport with regard to the elements constraints of shippers' orders, organization forms of container multimodal transport, container delivery location, transportation road and mode, transportation time, and freight rate. The NCL was employed to establish algorithm procedure for searching and solving the problem. Numerical examples show that the model and its searching algorithm are prone to implement and solve the problem. In comparison with relevant papers on procurement of transport service, this paper has a breakthrough, not focusing on single mode of transport service, but proposing the double optimization objectives including minimization of total transport cost and total transport time in container multimodal transport. Thus, theories and practices on container multimodal transport operation are enriched and improved. There are two stages in the container multimodal transport service procurement. The first stage is that the shippers purchase transportation services from the MTO and the second stage is that the MTO purchase the transportation services segmented from the actual carrier of water/land transportation service. Next research is to focus on the cooperation of MTO and shippers, putting two stages together.

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References

Caplice C, Sheffi Y (2003) Theory and practice of optimization-based bidding for motor carriers transport services. J Bus Logistics 24(2):35–47

Caris A, Macharis C, Janssens GK (2013) Decision support in intermodal transport: a new research agenda. Comput Ind 64(2):105–112

Chang YT, Lee PTW, Kim HJ et al (2010) Optimization model for transportation of container cargoes considering short sea shipping and external cost. Transp Res Rec J Transp Res Board 2166:99–108

Chen J, Huang H, Kauffman RJ (2005) A multi-attribute combinatorial auction approach to electronic procurement mechanism design

Iannone F (2012) A model optimizing the port-hinterland logistics of containers: the case of the Campania region in Southern Italy. Marit Econ Logistics 14(1):33–72

Ledyard JO, Olson M, Porter D et al (2002) The first use of a combined value auction for transportation services. Interfaces 32(5):4–12

Song J, Regan A (2003) Combinatorial auctions for transportation service procurement: the carrier perspective. Transp Res Rec J Transp Res Board 1833

Song J, Regan A (2005) Approximation algorithms for the bid construction problem in combinatorial auctions for the procurement of freight transportation contracts. Transp Res Part B 39:914–933

Wang H, Wang CX (2012) Selection of container types and transport modes for container multi-modal transport with fuzzy demand. J Highw Transp Res Dev 29(4):153–158
Zhang R, Guo YJ, Yan ZB et al (2011) Study on international container transportation chain choice behavior based on nested-logit model. J China Railway Soc 33(7):8–13
Zhou JY (2009) Natural constraint language. Science press, Beijing

Comparative Analysis of European Examples of Freight Electric Vehicles Schemes—A Systematic Case Study Approach with Examples from Denmark, Germany, the Netherlands, Sweden and the UK

Tessa T. Taefi, Jochen Kreutzfeldt, Tobias Held, Rob Konings, Richard Kotter, Sara Lilley, Hanna Baster, Nadia Green, Michael Stie Laugesen, Stefan Jacobsson, Martin Borgqvist and Camilla Nyquist

Abstract E-Mobility is a hot topic, in the public policy area as well as in business and scientific communities. Literature on electric freight transport is still relatively scarce. Urban freight transport is considered as one of the most promising fields of application of vehicle electrification, and there are on-going demonstration projects. This paper will discuss case study examples of electric freight vehicle initiatives in Denmark, Germany, the Netherlands, Sweden and the UK and identify enablers and barriers for common trends.

Keywords Electro mobility · Electric vehicles · EVs · Urban freight · Commercial transport

T.T. Taefi (✉) · J. Kreutzfeldt · T. Held
Faculty of Engineering and Computer Science, Department of Mechanical Engineering and Production Management, Hamburg University of Applied Sciences, Berliner Tor 5, 20099 Hamburg, Germany
e-mail: research@taefi.de

R. Konings
Delft University of Technology, Delft, The Netherlands

R. Kotter · S. Lilley
Northumbria University, Newcastle upon Tyne, UK

H. Baster · N. Green · M.S. Laugesen
FDT—Association of Danish Transport and Logistics Centres, Aalborg, Denmark

S. Jacobsson · M. Borgqvist · C. Nyquist
Lindholmen Science Park AB, Gothenburg, Sweden

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Introduction

The issue of e-mobility deployment for freight vehicles has so far not gained substantial attention despite electric freight fleet usage for city distribution being most mature in North America and to some extent in Europe. A number of studies and pilot tests have been conducted in Europe, as private initiatives, within regional or federal projects, as well as the European Union's framework programs. Using findings and research gathered for the North Sea Region Electric Mobility project, this paper discusses electric freight vehicle pilot initiatives in Denmark, Germany, the Netherlands, Sweden and the UK.

Background

With dwindling fossil resources, concerns for climate change, urban air pollution and public health concern, the deployment of electric vehicles (EVs) is becoming more central to the European Union (EU) and a range of Member States. Within the EU, the road transport sector produces 20 % of the total CO_2 emissions and it is the only major sector where CO_2 emissions are still increasing. Cars and vans (up to 3.5 tonnes) contribute to 15 % of EU's road CO_2 emissions; trucks and buses produce approximately 25 % of the road CO_2 emissions (European Commission 2012; AEA/Ricardo 2011). The EU's 2011 White Paper supports research and outlines a long term strategy for transport development in the EU. The European Green Cars Initiative (including long-distance truck innovation) follows the European Green Vehicle Initiative, with the objective of energy efficiency of vehicles and alternative power trains. Regional initiatives include the Interreg IVB program's North Sea Region Electric Mobility Network (e-mobility NSR) project (which contains the CUFLOS initiative, a forum for Clean Urban Freight Logistics Solutions) and ENEVATE, the Interreg North-West Europe region; play an active role in promoting e-mobility solutions. Other project examples include:

ELCIDIS (Electric Vehicle City Distribution) project trialling hybrid electric trucks and electric vans for urban goods distribution in Europe;

CITELEC (the European Association of cities interested in electric vehicles) disseminate the idea of electric mobility.

FREVUE (Freight Electric Vehicles in Urban Europe) project (FREVUE 2013) is running urban freight EV demonstration projects in Amsterdam, Lisbon, London, Madrid, Milan, Oslo, Rotterdam and Stockholm.

Deutsche Post DHL's pilot project deploying electric delivery vehicles in its fleet, mid-2013 in Bonn city centre and the surrounding region (Cars 21 2013).

There is increasing guidance for and research into fleet EV usage, including vans (EV20 et al. 2012). Element Energy (2012) outlines the total cost of ownership of low and ultra-low emission plug-in vans (fully electric, hybrid, hydrogen, under 3.5 t gross weight). The results highlight the 'strong potential for ultra-low emission vehicles in the light commercial vehicle market in the medium term, as rising fuel costs and falling battery and fuel cell costs cause ownership costs to converge. They also highlight the short term cost challenge for ULEVs, where high battery costs (particularly in larger vans) are likely to restrict widespread deployment beyond fleet trials and early adopters without strong policy support.'

Methodology

A comparative case study methodology aims to compare multiple subjects. As a cross-country study, the aim here is to identify, analyse and explain similarities and differences across countries whilst identifying key issues and trends (Yin 2009). Issues seen as most relevant as enablers and barriers to introduce new transport technologies successfully (University of Antwerp 2012; Binsbergen et al. 2013), namely Environmental Factors, Technical and Logistics Factors, Financial and Regulatory Factors, Energy Supply and Infrastructure, ICT factors and Human Factors, were identified and applied consistently by researchers in their respective countries as a common analytical framework to the case study examples. The method of data collection has been based on secondary data collection, largely internet based searches. The information gathered was analysed to draw out the important and active actors in the adoption of EVs. Semi-structured telephone interviews and e-mail correspondence were used for data validation and verification.

Results

Environmental Factors

The outstanding performance of the EVs in terms of tailpipe emissions and noise is a strong focus for the application of electric freight vehicles where local air quality and noise production are perceived most problematic, i.e. in city centre shopping areas. The good environmental performance of EVs means that their application in residential areas, such as garbage collection and home delivery of packages, are emerging markets for electric freight vehicles. Many initiatives are driven by company's awareness of regulations for less environmentally friendly vehicles becoming more restrictive in the future, companies are anticipating future policy and getting involved in EV experiments. It is difficult to assess the total environmental benefits for cities, because reducing emissions depends on the extent to which conventional urban freight transport can be replaced by its electric counterparts, let alone the issue of upstream emissions depending on electricity source. Calculations of CO_2 emissions reductions in the case studies are summarized in Table 1.

Table 1 CO_2 emission reduction calculated in cases

UK	Germany	Denmark	Netherlands
5–12 tonnes per truck and year[a]	35–70 %[b]	36 %	1–2 Megatons p. a. in 2050

[a]Office Depot, Dainsbury's, Speedy Hire, Tesco
[b]Project colognE-mobil

Reducing local air pollutants such as nitrogen dioxide or particular matter were named as benefits throughout the cases, but a detailed calculation of emission savings was not provided. The more silent operation of the EVs was perceived positively by residents, passengers and drivers.[1] For the operation of EVs in park and cleaning public spaces, EVs were on the one hand perceived advantageous with regards to noise, but on the other hand humans and animals did not notice the vehicles until they were close by.[2] A warning indication, i.e. a manually switchable sound, was recommended in pedestrian areas.[3]

Technical, Process and Logistics Factors

The limited operating range and payload (due to the heavy batteries) of EV batteries is a strong factor determining the application of freight EVs. The required range and payload is company-specific, depending on customer density, customer demand and weight or volume of goods. Freight transport in urban stop-and-go traffic with a limited kilometre range and cargo capacity is an important first market for EVs. The EVs are energy efficient and recuperate energy, when braking in stop-and-go traffic. The cases in the study confirm the technical compliance of EVs to the daily driven kilometre range on a significant amount of urban tours as can be seen in Table 2. However, for Netherlands and German examples, the limited operating range of electric trucks caused less flexibility in planning trips, or restricted ad hoc tour planning and hence caused less-efficient operations. The ability to charge in between tours is a success factor, if the range is lower than the required mileage. Companies charged or quick charged[4] whilst new freight was loaded, or installed solar panels on the roof of the EVs[5] to extend the range. While the inner city mileage of the EVs was often sufficient, the stability of the battery range was reported problematic: The kilometre range declined over time through battery ageing, when carrying heavy loads, as well as in winter due to electrical consumers

[1]colognE-mobil; DHL Germany; Meyer&Meyer Germany; United Parcel Service Germany.
[2]colognE-mobil.
[3]Effenberger Bakery.
[4]Joeys Pizza service and City Express Hamburg, Tesco and Sainsbury's London.
[5]Cargohopper, the Netherlands.

Table 2 Average mileage reported in freight transport cases

Country	Mileage in freight transport cases
UK	Used only 25 % of full battery charge per working day[a] Adequate for courier services with micro-consolidation hub[b] Localized journeys below 25 km[c]
Germany	EV range sufficient[d]; 11,000 km on average per year[e] Chose profiles with high density of stops and low parcel volume[f] Not suitable for courier services with 200 km per day[g] Low daily, reoccurring mileage[h]
Denmark	EV range described as more than suitable[i]
Netherlands	Maximal tour length of all cases in Amsterdam was 80 km

[a]UPS, parcel delivery, London
[b]Gnewt Cargo ltd., delivery services, London
[c]Melrose and Morgan, food delivery London
[d]Hermes Logistics, parcel delivery
[e]DHL, parcel delivery
[f]UPS, parcel delivery
[g]City Express Logistics, courier services
[h]Effenberger bakery, transport on-own-account
[i]Seas-NVE of Frederiksberg municipality, postal delivery

like heating, lights and ventilation.[6] Furthermore, the range listed by EV manufacturers is based on measurements according to the New European Drive Cycle (NEDC). Compared to real life energy consumption in urban last-mile delivery, these values do not give a reliable indication of the expected range. The reliability of the EVs was dependant on the model; certain prototypes and conversions were judged as reliable,[7] while others[8] were reported insufficient. Once the EVs were stable, the low maintenance needs due to less movable parts was highlighted positively.[9] Even though EVs required less maintenance and service, in many case studies throughout all countries a low quality in after-sales services was experienced. Lack of repair shops, limited know-how for repairs and low availability of spare parts lead to longer repair times and loss of money. These problems relate to the fact that the substantial truck manufacturers are not involved in the development of electric trucks strong enough yet.

[6]DHL recorded an increased energy demand in winter of 30–60 %.

[7]UPS Germany (conversion of 15 year old UPS truck); DHL (Iveco E-daily); Hermes (Mercedes Vito E-cell); Joeys Pizzy (eScooters);Nappy every after (Bradshaw EV).

[8]UPS: Modec, In the Netherlands it was felt that the vehicles were sensitive to failures, in particular converted vehicles.

[9]The costs for service and maintenance are 20–30 % lower than for conventional vehicles, (DHL Germany). Lower maintenance costs were also reported in the UK (Enterprise Mouchel, Sainsbury's, UPS).

Financial and Regulatory Factors

The cost competitiveness of electric trucks compared to conventional trucks is an important aspect that will influence large-scale implementation of EVs. Case study companies calculated the 'total costs of ownership' (TCO) as the key financial indicator for profitability of the EVs compared to conventional vehicles (CVs).[10] Due to the high investment costs, EVs are more expensive than CVs, unless they reach a daily high mileage. Countries offer different grant subsidies and exemptions to combat the cost disadvantages, as shown in Table 3.

Due to the purchase subsidies, exemption from vehicle taxes and congestion charge, most EVs operating in London were reported to be either cost neutral or offered cost advantages. With the high purchase subsidy in the Netherlands, a positive effect on the number of freight EVs would be expected, but the subsidy was not in place at the time the case studies were researched. Germany, in comparison, offers the least advantages for freight EVs and subsidies are focused on EV research projects. Apart from financial subsidies, companies deploying EVs in case studies benefited from a regulatory privilege; the right to enter inner city pedestrian zones. Unlimited entry rights were granted when the EVs were deployed in last-mile delivery as part of an urban consolidation concept.[11]

The environmentally friendly image of EVs is a soft financial factor that cannot be easily quantified. The 'green credentials' were mentioned by companies as a positive influence on deciding to use EVs. UK case examples reported benefits with taking the lead with EV delivery.[12] In Germany, positive and extensive press coverage served as a commercial measure for gaining new customers.[13] Companies in the Netherlands stated that the EV operations are not cost competitive compared to the regular vehicle operations, but believe that an EV has a strong promotional value, which may pay off by attracting new customers who appreciate sustainable transport solutions.[14]

For electric trucks to be a viable alternative, a combination of the following factors must be present: daily distances travelled are higher than the electric trucks maximum range of 100 miles (but the battery energy constraint is not binding); low speeds or traffic congestion are prevalent in the route area; customer stops are frequent/numerous (meaning the electric engine is more energy efficient), grades or other factors exist, which cause increased expenditures of energy; the purchase price is reduced by tax incentives and an increase on taxes for CVs (yearly vehicle tax, purchase tax, mineral oil tax). EVs however have a higher depreciation value.

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[10]The TCO includes costs of investment for EV and charging infrastructure, costs for energy and other costs as vehicle tax, insurance, service and maintenance, repairs and environmental charges.

[11]DPD (Nuremberg, Germany), Cargohopper (Utrecht, the Netherlands), Stadsleveransen (Gothenburgh).

[12]Gnewt Cargo Ltd, Sainsbury's, Brewers, Speedy Hire Melrose and Morgan.

[13]Effenberger bakery, City Express Logistik, Meyer and Meyer, Joeys Pizza delivery.

[14]Techniche Unie.

Table 3 Cost factors, subsidies and exemptions of electric vehicles

EV		Subsidies and exemptions			
Cost factors	Costs compared to CV	UK	Germany	Denmark	Netherlands
Investment	2–3 times higher	20 % up to £8000	In projects up to 50 %	None	50 % of difference up to € 40,000
Charging infrastructure in depot	Depends on technology	No subsidy	No subsidy	No subsidy	No subsidy
Energy	Half price	None	None	None	Free public charging[a]
Taxes	Exemption	Road fund licence, van benefit charge (5 years)	Vehicle tax (10 years)	Sales tax up to € 7500 (until 2015)	Vehicle tax
Service and maintenance	Depending on EV model	None	None	None	None
Environmental charges	Exemption	Congestion charge[b]	None	None	None
Parking	Exemption	Free or reduced	None	Free in Copenhagen	Free in Amsterdam
Driver's licence	Exemption	Class B until 7.5 t	None	Class B until 7.5 t	Class B until 7.5 t

[a]Amsterdam
[b]London

Energy Supply and Infrastructure Factors

Recharging EVs is an important issue determining the use of EVs both in terms of its charging availability and flexibility. The recharging techniques mostly discussed are slow charging, fast charging, battery swap stations and inductive charging. The most common way of charging for the case studies was to slow charge the vehicles over night at company premises. However, in-house charging infrastructure and infrastructural challenges have been faced by the freight delivery companies in Germany.[15] The in-house charging infrastructure had to be adapted several times; it was overloaded by the high capacity need of the e-trucks. Other charging related issues found were that the implementation of a smart grid and load management for large electrical fleets is not yet clarified; solutions to ensure charging in case of power outage are necessary; and charging plugs were too damageable and only specially trained staff could handle the plug, which caused problems with replacement drivers and training issues. Quick charging outside the company's

[15]DHL, UPS.

premises would be an option, if quick charging would not reduce the batteries life span. However, logistic processes and tour planning would need to be adapted (Schönewolf 2011: 7). The limited number of charging spots outside the cities and lack of battery swapping for larger vehicles was criticized in Danish cases.[16] The charging public network in London was welcomed by companies, allowing them to park and charge during lunch, extending the kilometre range.[17]

Information and Communication (ICT) Factors.

The European Commission (2007) highlights that the efficiency of urban freight distribution can be increased with the help of ICT systems, in particular through better timing of operations, higher load factors and more efficient use of vehicles. Throughout the cases of this study, the need expressed by companies for ICT solutions were ambiguous, depending on the area of business and amount of EVs used (Jacobsson 2013).[18] The introduction of an electric vehicle has resulted in some less-optimal information processes due to the fact that the long-distance transport (by regular truck) and short-distance transport (by electric truck) were no longer in one pair of hands, i.e. the short-distance transport with an electric vehicle was outsourced.[19] Mainly in larger fleets with dynamic scheduling the dispatching software should take into account the remaining (and predicted) battery level, to maximize the dynamic scheduling of EVs and capitalize on the low operational costs.[20]

Human Factors

Human factors include the behaviour and the attitude of EV users including electric truck drivers, electric truck customers and the general public. The perceived performance of EVs by users greatly determines the willingness to accept and use EVs; therefore human factors are highly relevant for EV implementation. In some cases, the drivers reported an initial rejection of the vehicles; training of drivers was important and led to a high level of acceptance. After utilizing the EVs for some time, the drivers were very positive about the EVs, especially 'the impressive acceleration', having the comfort of an 'automatic gear-box', the fail-safeness and the silent operation. It was observed that drivers identify with 'their' EV and work more than before.[21] Electric scooters proved to have strong advantages for the delivery staff.

The visibility of electrical delivery vehicles is high making them a good means of communicating the advantages of electric mobility to the public. Communicating

[16]TRE-FOR A/S and the Danish Energy Agency.

[17]Melrose and Morgan, Gnewt Cargo ltd.

[18]In Sweden, the market for urban freight transport does not express a need for ITC solutions.

[19]Delta Stadsdistributie (Netherlands).

[20]DHL and City Express Logistik (Germany).

[21]DHL, UPS, Meyer&Meyer, City Express Logistik (Germany).

EVs to passengers and customers was highlighted as a positive aspect in the UK and Germany in several cases.[22] The limited range of the vehicle was judged an advantage in two cases,[23] as drivers need to drive in a moderate and energy-efficient way; a considerate driving style increased the range by 30 %.[24] A considerate driving style includes among others gentle acceleration and using recuperation when braking.[25] The drivers' behaviour is an important factor as well as the ambient temperature and loaded weight, when discussing factors that influence the maximum range.

Conclusion

Our comparative analysis of freight EV initiatives across Germany, the Netherlands, Denmark, Sweden and the UK has revealed that enablers and barriers for start-ups and wider application of freight EVs are generally similar in these countries. The different country cases indicate many EV applications are good experiences, although whether or not an application is successful is largely case-specific and dependent on if the performance of the EV complies with the intended transport use for this vehicle. The cases suggest EVs are used for many types of transport activities in urban areas, transporting grocery products, beverages, textiles, furniture, parcels to gardening and waste. This shows potential for the wide implementation in urban transport, but the cases also indicate major conditions that are required to achieve this extensive use of EVs.

A key factor is the technical performance of the EV, although the required operating range is company-specific and satisfying in many cases there is a shared interest to increase the range to enable a higher utilization rate of the vehicle and, hence, improve its competitiveness to CVs. Increasing the range refers to improving the batteries performance, stability and reliability, particularly highlighted by case study examples in Germany and Denmark, with harsh winter conditions. The loss of payload due to the heavy weight of the batteries was a universal problem across the case study examples. Although it affects the competitiveness of the EV negatively, it is not considered critical, since adapted regulations regarding driver licence and qualifications can largely compensate its impact. One of the largest barriers experienced by all country cases was the lack of quality in after-sales services, i.e. a lack of spare parts and the limited knowledge for repairs. This suggests that the truck manufacturers are not involved strong enough in the development of electric trucks yet.

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[22]"My job did become more communicative. I talk to customers and pedestrians during the day a lot, their feedback is overwhelmingly positive. At the end of the day I feel affirmed instead of stressed: usually an express driver does receive mostly negative reactions during the day, for example because of a slow delivery, due to the traffic congestion, or when parking in the second row and hindering the traffic" (City Express Logistik).

[23]City Express Logistik (Germany), Nappy ever after (UK).

[24]DHL.

[25]Sainsbury's.

A major observation throughout the case studies is the concern that operating an electric freight vehicle is not profitable, although it could be in the near future. Companies consider their involvement in EVs as a way to explore (gain more experience in) the use of electric transport, prepare for future policy and to get a frontrunner position in the transport sector regarding sustainability. Their involvement in electric freight transport is strongly driven by companies ambitions to have sustainable operations (a green image), thus soft financial benefits have been highlighted in our case studies. Operating an EV is considered an opportunity to showcase sustainable ambitions and possibly attract new customers. The cases suggest that to use electric freight vehicles, major incentives are needed to compensate the existing disadvantages of EV use, for example subsidies to compensate the high initial investment costs and granting privileges to these vehicles (e.g. exemption of time window delivery restrictions and privileged access to city zones).

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References

AEA/Ricardo (2011) Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles—Lot 1: Strategy. AEA, Oxfordshire Available under http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf. Las accessed on Sept. 28th 2015

Binsbergen AJ, Konings R, Tavasszy L, van Duin R (2013) Mega-projects in intermodal freight transport: innovation adoption. In: Priemus H, van Wee B (eds) International handbook on mega-projects. Edward Elgar Publishing, Cheltenham, pp 488

Cars 21 (2013) Germany's Deutsche post DHL to go green with 141 electric delivery vehicles. 28/06/2013. Inside EV

Element Energy (2012) Ultra low emissions van study. Final report, Cambridge

European Commission (2007) Green paper. Towards a new culture for urban mobility. Brussels, COM

European Commission (2012) Road transport: Reducing CO2 emissions from vehicles. Available under http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm. Last accessed on Sept. 28th 2015

EV20, the Climate Group, Cenex, Energy Savings Trust (2012) Plugged-in fleets. A Guide to deploying electric vehicles in fleets. EV20, London

FREVUE (2013) MEP vote not to reduce CO_2 emission of vans. Available at http://frevue.eu/mep-vote-not-to-reduce-co2-emission-of-vans/

Jacobsson S (2013) WP 7.5 analysis of user needs for ICT solutions assisting the driver. Gothenburg, Lindholmen Science Park

Schönewolf W (2011) E-City-Logistik, Status-Seminar Elektromobilität Berlin Brandenburg, Berlin, 25 Oct 2011

University of Antwerp, University of Aegean, University of Genova, University of Delft, CNRS, LCA Europe (2012) Innovation process in surface transport (INNOSUTRA), EU FP7-project, http://www.innosutra.eu/

Yin RK (2009) Case study research: design and methods, 4th edn. Sage, Thousand Oaks

Multimodal Transportation Strategy for Southern Thailand: A Study of Water Transportation Connecting to Road Transportation of Containerized Transporters

Boonsub Panichakarn

Abstract The purpose of this study was to improve multimodal transportation strategy by evaluating and analyzing demand on roadway, railway, marine, and air transportation while investigating and collecting data on the southern supply for transportation with in depth interviewing for problems and ways to manage multimodal transportation in the South. From this research, the researcher developed a costing template for multimodal transportation between road and water transportation modes, covering all of the related activities on road transportation, port operation, and marine transportation activities. Moreover, the researcher also developed a "MULTIPLE" strategy which would apply to multimodal transport management between the roadway and marine transportation mode of containerized transporters in order to achieve the highest transportation efficiency and benefits.

Keywords Multimodal transportation · Containerized transportation · Cost management

Introduction

Currently, business competitiveness is increasing in complexity and intensity especially after the free trade area (FTA) negotiation and borderless trade integration. It is essential that a stable and sustainable business develops its potential of business competitiveness efficiently in the world market, especially regarding lower cost management and more efficiency than its local, national, and regional competitors. Logistics management is regarded as one of the key strategies to increase business competitiveness which affects economic strengths in a country.

B. Panichakarn (✉)
School of Logistics and Supply Chain, Naresuan University, Phitsanulok 65000, Thailand
e-mail: boonsub.pa@gmail.com

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From this point, we can see that to develop Thailand's competitiveness with other countries, the industrial sector should not only consider production which is emphasized in the production focused strategy but should also consider it throughout the supply chain, including the logistics system: raw materials; ready-made goods; deliverance to consumers; after-sale services; and data link between manufacturers, transporters, wholesalers, and retailers. At the same time, both government and private sectors need to have basic information in order to plan for competitiveness in overall cost, administrative efficiency, and highest customer satisfaction.

In the past, most transportation, particularly in the South of Thailand, was a roadway. The products from the factories in southern Thailand were transported to the center, Bangkok, and the eastern area for domestic consumption or export. However, increasing-fuel prices and traffic jams because of the one main roadway in the South cause high costs for transportation. As a result, Thailand is unable to compete with other countries. Most industrial factories transport their products at Penang Port.

At present, the transportation infrastructure system consists of two options: roadway, the main route being Phetkasem Road (Highway No.4) which is a single track railway together with passenger transportation with the destination of the railway network ending in Su-ngai Kolok City, Narathiwat Province and Padang Besar, Sadao City, Songkhla Province, and marine transportation. In the South, there is high potential for marine transportation because both sides of the land are sea (Thai Gulf and Andaman Sea), which is the important issue of this research: to improve the multimodal transportation management strategy in southern Thailand —a study of water transportation connecting road transportation of container transporters so that it can be a model for effective and efficient multimodal transportation to increase business competitiveness with other countries.

The conceptual framework of this research is national development strategies, specifically the strategic plan to develop Thailand's logistics system resulting from

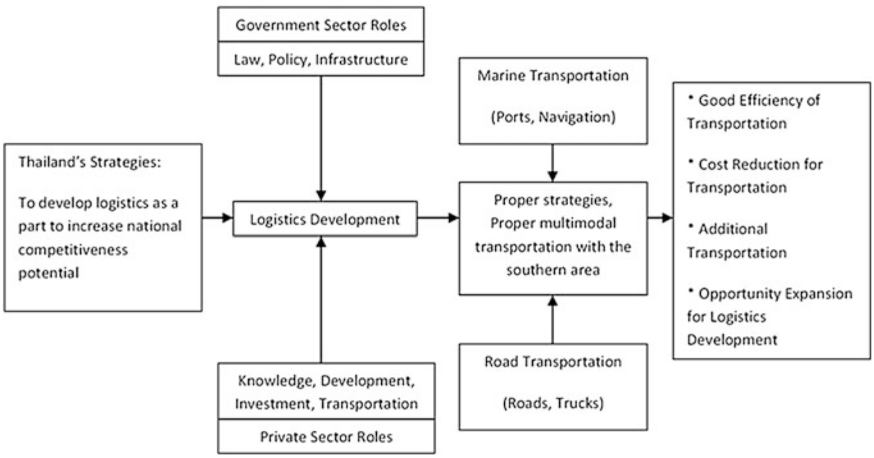


Fig. 1 The research concept

government sector and private sector roles, including multimodal transportation contributing to good efficiency of transportation, cost reduction for transportation, additional transportation, and opportunity for expansion for logistics development as shown in Fig. 1.

Objectives

1. To study transportation characteristics from product origin to consumers, i.e., product destination in the South so that any business can apply them in making a decision for administration.
2. To study the potential of existing transportation networks in order to improve multimode transportation efficiently and reduce costs in southern Thailand.
3. To study problems, barriers, and any limitations of each mode of transportation affecting an increase in efficiency or reduction in business costs in the South of Thailand.
4. To improve the multimodal transportation management strategy in the South of Thailand: a study of water transportation connecting to road transportation of container transporters.

Methodology

The methodology in this research, as shown in Fig. 2, is a demand evaluation and analysis on roadway, railway, marine, and air transportation. Moreover, data investigation and collection from original information, both of government sectors

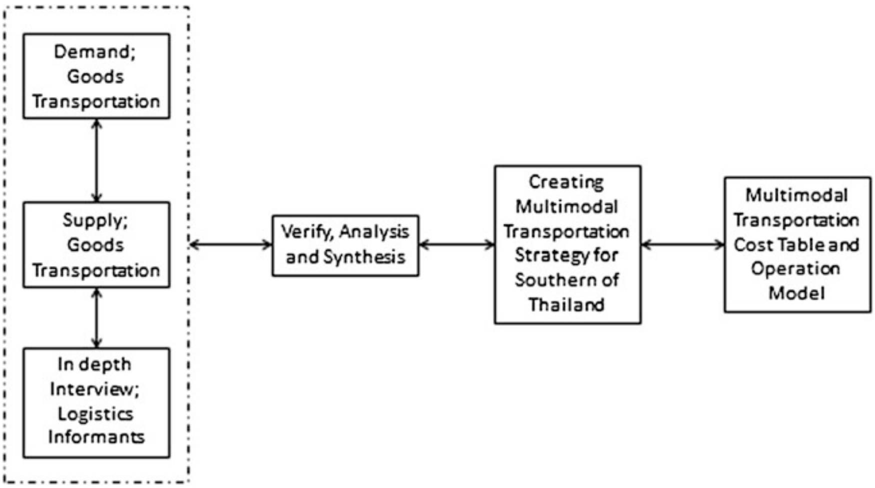


Fig. 2 Research methodology

and private sectors, on supply for transportation and for problems of transportation in the South were made, and in depth interviews for concepts to manage multimodal transportation in the South were conducted with 3 groups of 26 informants who are accepted in logistics technically and professionally: monitors and promoters, users, and facilitators.

Results

The results of the research showed that transportation volume in Thailand has not changed much in general as shown in Table 1. The highest volumes on average of road, inland waterway, coastal, and railway transportation are over 80, 9, 6 % (although it is a potential mode), and 2 %, respectively, and air transportation has low volume. From such transportation volumes, it was found that the transportation in Thailand was not balanced because of the very high proportion of road transportation which did not change. Therefore, if there is no development and no changes on transportation, this can affect the competitiveness of the country because road transportation has the highest costs over railway, coastal, and inland waterway.

There are both marine and road transportation supply in the South of Thailand; however, in the eastern area of the South there is potential for marine transportation because of its topography with the sea which is a proper natural resource for transportation services, but road transportation has a very long distance. The number of existing ports in the South is sufficient, but there is no fair administrative system, so they are not utilized enough. However, the service rates for the ports are pretty high. In the marine transportation network, the start and the destination point

Table 1 Thailand's freight transport by mode: year 2007–2012

Year	Tons	Road	Railway	Inland waterway	Coastal	Air	Total
2007	,000	428,123	11,055	47,755	30,749	110	517,792
	%	82.68	2.14	9.22	5.94	0.02	
2008	,000	424,456	13,172	47,687	35,982	106	521,403
	%	81.41	2.53	9.15	6.90	0.02	
2009	,000	423,677	11,517	41,561	35,692	104	512,551
	%	82.66	2.25	8.11	6.96	0.02	
2010	,000	420,449	11,288	48,185	36,731	121	516,774
	%	81.36	2.18	9.32	7.11	0.02	
2011	,000	406,538	10,667	46,932	41,273	131	505,541
	%	80.42	2.11	9.28	8.16	0.03	
2012	,000	425,804	11,849	47,423	34,968	130	520,174
	%	81.86	2.28	9.12	6.72	0.02	

Source Ministry of Transport (2013). http://www.otp.go.th/images/stories/PDF/2556/9_september/Transport%20and%20Traffic%20Statistics%20and%20Information.pdf

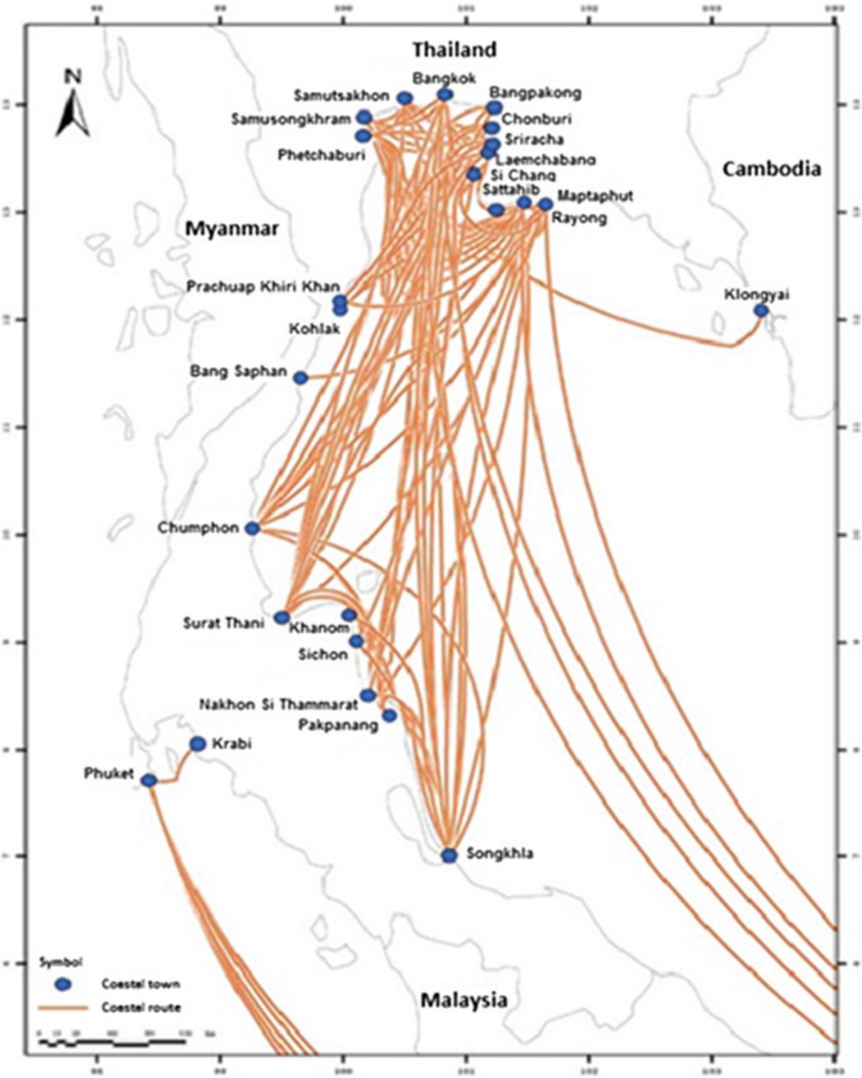


Fig. 3 Marine (Coastal) transportation network in the country. *Source* Modified from Logisticsclinic (2007). http://www.logisticsclinic.com/web/content/view/680/119/1/1/

are at the central ports, Bangkok Port, or Laem Chabang City as shown in Fig. 3. The ports in the South which support containerized transportation are Songkhla Port, NP Marine Port in Suratthani Province, and Prajuab Port. However, the number of containerized ships is very few when compared to transportation volume. The number of coastal ships for containerized products should be increased to support the high volume of transportation.

For road transportation, the vehicles serving for containers are 10 wheel trucks over which are flatbed pickup trucks or semitrailer trucks. The total truck weight and loading weight of 10 wheel 3 axle trucks are adjusted to be 25 tons.

While the weight of a 10 wheel 3 axle towing-trailer truck and semitrailer truck with double axles and double tires are adjusted to be 45 t. The road to the South under the Department of Highways in 2007 was 9921 km, but the road for transportation has to be expanded to link ports, container freight stations, factories of product distributors, and the Thailand–Malaysia border crossing in order to achieve more road transportation efficiency. Because the number of semitrailer trucks and 10 wheel trucks registered with the Department of Land Transport in 2004 was more than 200,000, which was not a small number, entrepreneurs should improve their administration to be better than at present.

The transportation problems in the South consist of (1) **road transportation problems:** no products on back haulage, long distance, and the unrest in three southern border provinces often causes unsafe operation; moreover, entrepreneurs give precedence to cost more than operation quality; (2) **marine transportation problems**: the number of ports in the South is not enough, the port facilities are insufficient with limitations in the number of ships for transportation services, and the location of ports is quite far from the industrial areas; (3) **railway transportation problems**: low capacity of service on railway transportation and lack of reliability; (4) **government sector problems**: the existing regulations do not conform with product types, policy on domestic transportation is unclear and there is a lack of serious application; and (5) **management problems**: lack of network to collect and distribute products efficiently, no application of supply chain management system, lack of integrated logistics management, and all modes of transportation emphasize labor.

Activity characteristics or multimodal transportation operations for water transportation connecting to road transportation that bring about efficiency are (1) an integrated service provider; (2) one stop service; (3) minimized trucking distance; (4) efficient product transfer duration, cost, and product safety; (5) government as a port investor for low port fee rate; (6) operation by information technology system; (7) large delivery cargoes per haulage; (8) forth and back haulage products; (9) port facilitators; (10) ensured coastal scheduling; and (11) sufficient containers.

Limitations, barriers and obstacles causing failure of multimodal transportation for water transportation connecting to road transportation operations include (1) restriction to ships registered in Thailand for domestic marine transportation, (2) high cost of investment, (3) merchant marine personnel, (4) lack of multimodal transportation and inappropriateness for time-limited transportation, (5) insufficient containers, (6) difficulty to divide the benefits of each activity involving multimodal transportation, (7) no facility on collecting transportation information by the government, and (8) the transportation business by product owners.

Conclusion

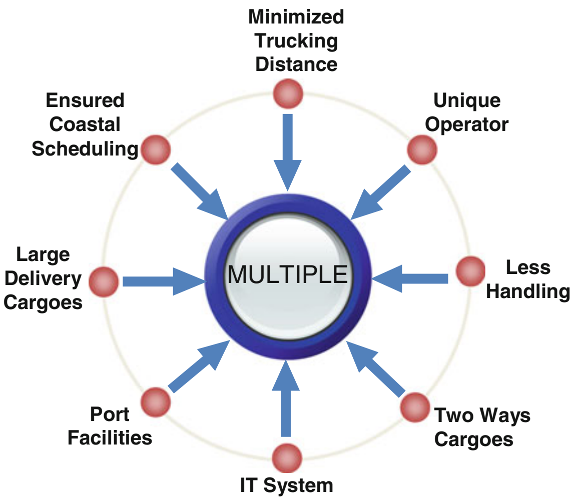
This research was able to develop a costing table covering activities of multimodal transportation for water transportation connecting to road transportation and the "MULTIPLE" strategy.

1. The cost of multimodal transportation for water transportation connecting to road transportation is quite high due to many activities on road transportation and operations at the origin and destination port. The multimodal transportation costing can be calculated as Fig. 4.
2. The "MULTIPLE" strategy is a multimodal transport management, between water transportation and road transportation modes by containerized transportation entrepreneurs in order to achieve the highest transportation efficiency and benefits. The strategy includes 8 key successes as shown in Fig. 5.

Forth Haulage			Back Haulage		
Detail	Operator	(Baht)	Detail	Operator	(Baht)
Truck freight fee at the origin			Truck freight fee at the destination		
Original Port Port Fee (Entrance) Port Fee (Exit) Lifting container (empty/laden) on truck Lifting container (empty/laden) off truck Lifting container (empty/laden) on board Lifting container (empty/laden) off board Charges for container station (empty/laden)			**Destination Port** Port Fee (Entrance) Port Fee (Exit) Lifting container (empty/laden) on truck Lifting container (empty/laden) off truck Lifting container (empty/laden) on board Lifting container (empty/heavy) off board Charges for container station (empty/laden)		
Coastal Freight Forth Haulage Freight			**Coastal Freight** Back Haulage Freight		
Destination Port Lifting container (empty/laden) on board Lifting container (empty/laden) off board Port Fee (Entrance) Port Fee (Exit) Lifting container (empty/laden) on truck Lifting container (empty/laden) off truck Charges for container station (empty/laden)			**Original Port** Lifting container (empty/laden) on board Lifting container (empty/laden) off board Port Fee (Entrance) Port Fee (Exit) Lifting container (empty/laden) on truck Lifting container (empty/laden) off truck Charges for container station (empty/laden)		
Truck freight fee at the destination			Truck freight fee at the origin		
Total			Total		
Total					

Fig. 4 The costing template for multimodal transportation

Fig. 5 Multiple model



M-Minimized Trucking Distance

Transportation by trucks from product origin at the origin port and from the destination port to a place to get the products has to have a minimized distance.

U-Unique Operator

There must be an integrated service provider with the main facilitator managing other facilitators and providing one stop service.

L-Less Handling

Containers must be moved only as needed and must cause the lowest cost for container moving per time.

T-Two Ways Cargoes

Transportation volume should be included with forth and back haulage, the volume of the back haulage should be as highest as possible.

I-IT System

Information and technology system is important for multimodal transportation because it involves a number of activities.

P-Port Facilities

Within a port, facilities should be provided and the location of the port should not be too far from product source and industrial areas.

L-Large Delivery Cargoes

The quantity of each transportation haulage must be large enough in accordance with a coastal ship's loading. It is necessary to plan for product collection to transport large quantities in each haulage.

E-Ensured Coastal Scheduling

Navigating scheduling has to be clear and ensured. It must be in accordance with the time that the user is ready to deliver and the timing of the big sized ships at Laem Chabang Port must be considered. In addition, the water level table of each day must be considered as well.

The benefits of multimodal transportation for water transportation connecting to road transportation operations are (1) **society benefits**: the reduction in air pollute on, traffic jams, and road accidents; more employment in the South; mass resolution due to running trucks; and a better environment; (2) **management benefits**: increasing provider capacity to integrate services, clearly responsible people, development in information technology, obvious product distribution, promotion on strengths of the merchant marine industry, and ability to definitely manage transportation costs; and (3) **economy benefits:** reduction of fuel import, increase of national competitiveness in the long term, reduction of transportation costs affecting national logistics costs, the optimal efficiency of natural resources (water), generation of continual industry, international support, and income distribution to the South.

References

Logisticsclinic (2007) http://www.logisticsclinic.com/web/content/view/680/119/1/1/

Office of Transport and Traffic Policy and Planning for Ministry of Transport (2013) Transport and traffic statistics and information Thailand. http://www.otp.go.th/images/stories/PDF/2556/9_september/Transport%20and%20Traffic%20Statistics%20and%20Information.pdf

Green Supply Chain Design Under Emission Trading Scheme

Fang Li and Hans-Dietrich Haasis

Abstract In response to climate regulations and customers' requirements, companies are now realizing that they will have to pay for their emissions under business as usual strategies. Emission trading scheme (ETS) was adopted and is going to take great effect in the way of cutting emissions. Hence, supply chain is faced with new challenges toward a sustainable business development. How to optimize the supply chain across all its stages to minimize their carbon footprint under ETS builds the main topic of this dissertation. The impact of ETS on sustainable development of supply chain is going to be analyzed at first and a supply chain-ETS is proposed to be implemented as a trial to test how companies along supply chain cooperate with each other based on common resource collaboration management.

Keywords Emission trading scheme · Green supply chain · Resource collaboration management

Introduction and Motivation

In response to climate change, the Kyoto protocol introduced various flexible mechanisms—emission trading scheme (ETS)—the clean development mechanism (CDM) and joint implementation (JI), through which different countries can cooperate to meet their emission reduction targets and decrease costs. Among them, EU—Emission Trading Scheme (EU ETS)—offers one of the most cost-efficient solutions for companies to realize greenhouse gas (GHG) emission reduction.

The ETS works on the 'cap and trade' principle. A 'cap,' or limit, is set on the total amount of certain GHG that can be emitted by the factories, power plants, and other installations in the system (EC 2013). The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances that

F. Li (✉) · H.-D. Haasis
Institute of Shipping Economics and Logistics, University of Bremen, Bremen, Germany
e-mail: li@isl.org

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they can trade with one another as needed. One carbon allowance gives the right to emit one tone of carbon dioxide (CO_2) or equivalent amount of GHG. They can also buy limited amounts of international credits from emission—saving projects carried out under the CDM and JI around the world to offset a proportion of their emissions.

This is a consuming world in which every unit of emissions is in some way related to one piece of consumption at least. Once a piece of consumption happens in the downstream, emissions are produced through the whole supply chain starting from materials preparation, procurement, production warehousing, and distribution to the end of consumption. Therefore, every business operator in the supply chain should take its own responsibility of emission reduction and make a joint contribution together to attain this goal as well.

Besides, a growing number of environmentally conscious consumers increase the competition among firms to provide greener products and services in order to increase their market share. In any case, companies are now realizing that they will have to pay for their emissions under business as usual strategies (Abdallah et al. 2012; Sheu and Li 2013). This trend changes the way companies manage their supply chain. They will have to find new and innovative means of optimizing the supply chain across all its stages to minimize their carbon footprint.

This paper is aiming to analyze the impact of ETS on supply chain and its role in green supply chain development. By use of ETS, this paper proposes an motivation on the whole supply chain where all members have to take their own responsibilities of reducing GHG to some extent. A certain amount of allowance cap is allocated to the supply chain as total, and companies involved will share this amount of cap together. Many studies (Wang et al. 2011; Sadegheih et al. 2010; Chaabane et al. 2012; Ramudhin et al. 2008; Pishvaee and Razmi 2012; Abdallah et al. 2012) have been done in sustainable supply chain design via such theory, aiming to allocate resources while minimizing the total cost including carbon allowance purchasing cost along the supply chain. However, the way in which companies cooperate among each other, given a total carbon cap, to attain the final goal of emissions reduction was rarely discussed so far. As profits' contradiction lies in the way still as the main obstacle for business-oriented companies in up- and downstream along supply chain, ETS implementation would finally bring another turn of challenges among their cooperation towards sustainable business development.

Research Problem

This paper proposes a supply chain ranged carbon trading scheme would be formed, where the total carbon allowance is allocated to the whole supply chain instead of the only manufacturer, and members of the supply chain have to realize the final goal of emission reduction through strategic cooperation and coordination. The total carbon allowance is allocated to each member of the supply chain according to their historical emission data, and their willingness to cut amounts of emission in the future which is jointly decided by cost-efficiency und trade-off between carbon abatement cost and carbon allowance purchasing cost. It is obvious that there are also beneficial contradictions among different supply chain members. How to allocate the carbon allowance among different members along supply chain in order to minimize the total emission as well as cost would be a problem in the aspect of operation research.

Expected Results

This paper tries to combine ETS policy with practical business development through constructing a supply chain ranged carbon trading system. Main results of this paper would include impacts of ETS on supply chain, a supply chain ranged carbon allowance allocation strategy, a decision support system for environmental governments, and managerial insights for sustainable business development.

Research Methodology

First, SWOT will be used to analyze the impact of ETS on supply chain. In this way, strength and weakness, opportunities and threat will be given in the scenario where supply chains are included into ETS. A quantitative analysis is also given to show in which extent ETS have influences on supply chain via operational cost and amount of emissions. Therefore, measures are derived for related companies, supply chain managers and environmental governments.

After the supply chain-ETS is proven to be effective, this paper is going to adopt an integer-programming model to allocate the cap along the supply chains members. An integer-programming problem is a mathematical optimization or feasibility program in which some or all of the variables are restricted to be integers. In our case, the mixed integer-programming (MIP) model captures the impact of different allowance allocation on supply chain costs and helps to define an optimal strategy, including the purchase or sale of carbon credits or green investments, for companies to meet their separate carbon cap, while minimizing opportunity cost.

Finally a numerical study will be given to verify the idea proposed in this dissertation. And useful indications are summarized to the final conclusion for further work.

References

Abdallah T, Farhat A, Diabat A, Kennedy S (2012) Green supply chains with carbon trading and environmental sourcing: formulation and life cycle assessment. Appl Math Model 36:4271–4285

Chaabane A, Ramudhin A, Paquet M (2012) Design of sustainable supply chain under the emission trading scheme. Int J Prod Econ 135:37–49

EC Climate Action (2013) The EU emissions trading system (EU ETS). Available at http://ec.europa.eu/clima/policies/ets/

Pishvaee MS, Razmi J (2012) Environmental supply chain network design using multi-objective fuzzy mathematical programming. Appl Math Model 36:3433–3446

Ramudhin A, Chaabane A, Kharoune M, Paquet M (2008) Carbon market sensitive green supply chain network design. In: IEEE international conference proceedings on industrial engineering and engineering management (IEEM), pp. 1093–1097

Sadegheih A, Li D, Sribenjachot S, Drake PR (2010) Applying mixed integer programming for green supply chain management. S Afr J Ind Eng 21(2):13–24

Sheu JB, Li F (2013) Market competition and greening transportation of airlines under the emission trading scheme: case of duopoly market. Transp Sci. doi:10.1287/trsc.2013.0473

Wang F, Lai X, Shi N (2011) A multi-objective optimization for green supply chain network design. Decis Support Syst 51:262–269

Part V
Supply Chain Management

Adapting the SCOR Model Deliver and Source Processes for the Manufacturing Firms in the Developing Countries

Fasika Bete Georgise, Klaus-Dieter Thoben and Marcus Seifert

Abstract Competition is no longer based on just bare company versus company business models, but supply chain versus supply chain. These create opportunities for the development of different supply chain models, such as the supply chain operations reference (SCOR) model. However, the existing models have not considered the early parts of the raw material suppliers' situations in the firms of developing countries (DC). In addition, the supply chain in DC has unique challenges. The successful model is delayed by these challenges. In order to incorporate the DC situation, it requires examining the firms supply chain characteristics in the DC. A questionnaires survey and semi-structured interview questions are used to collect the current practices. Based on the survey results analysis, we have identified the supply chain characteristics. These characteristics help to define the new requirements. This paper presents the proposed changes related to the deliver and source processes. Future work will consider the adaptation of the entire model.

Keywords Deliver and source processes · Developing countries · SCOR · Adaptation

F.B. Georgise (✉)
International Graduate School for Dynamics in Logistics (IGS), University of Bremen, Bremen, Germany
e-mail: fasialem@gmail.com

F.B. Georgise
School of Mechanical and Electromechanical Engineering, Hawassa University, Hawassa, Ethiopia

F.B. Georgise · K.-D. Thoben · M. Seifert
Bremer Institut für Produktion und Logistik GmbH-BIBA, Hochschulring 20, 28359 Bremen, Germany
e-mail: tho@biba.uni-bremen.de

M. Seifert
e-mail: sf@biba.uni-bremen.de

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Introduction

In today's ever increasing competition and globalized business environment, manufacturers have been exploring innovative technologies and strategies to achieve and sustain competitive advantage. One of the strategies, which has got wide acceptance and agreement among academicians and practitioners, is supply chain management (SCM). Due to this acceptability, there have been efforts to developing reference models for SCM. The supply chain operations reference (SCOR) model is one of those SCM models, which enjoys its level of industrial quasi-standard. The SCOR model endeavors to incorporate the concepts of business process reengineering, benchmarking, process measurement, best practice and enablers' information technology and apply them to SCs (SCC 2010; Lockamy and McCormack 2004; Huang et al. 2005). The manufacturing industry in developing countries (MIDC) is involved in the earlier stages of the international supply chains, often producing raw material or doing basic assembly work of products that are then further processed or packed for consumption in the developed world (Trienekens 2011). Recently, the developing countries (DC) have shown enthusiasm in SCM concepts and its models into global supply chain nature of production (Heriberto and Giachetti 2010; Irfan et al. 2008).

Companies in different industries operate with different environmental conditions and challenges, when trying to use the SCOR model in their supply chain designing and improving activities. Due to this, different academicians and practitioner are trying to adapt and apply it to many different industries, for example the service industry by Di Martinelly et al. (2009); for after sale by Legnani (2011). Legnani (2011) and Di Martinelly et al. (2009) point out that the SCOR model sometimes is too general and adaptations to different industries are necessary. From the experience of these different works, the first step in all adaptation activities is to understand the current business practices. Georgise et al. (2012) presented their findings about why and how previous researches where done by academicians and practitioners to adapt the SCOR to their local operating conditions.

This research provides a new perspective for the developed world, because companies in DC such as Ethiopia are operating in a different environment, due to existing technologies and business practices, skilled labor, and other resources. In the remaining parts, the second section introduces current literature about the supply chain challenges in the firms of DC, followed by discussion on the research methodology. The field result analysis is explained in section four. Next, the new requirement definition elaborates in section five. The proposed business processes for adapted SCOR model is discussed in section six. Finally, we conclude and share the direction of the future research.

Supply Chain Challenges in the Firms of Developing Countries

The models created and operated in developed countries situations have faced different challenges and barriers, which have not been faced in developed nations. These challenges may even cause successful and well tested strategies, and models that work in developed economies, to fail. Currently, different researchers have identified the major supply chain challenges (Hamisi 2011; Msimangira and Tesha 2009; Ohemeng 2009; Ruteri and Xu 2009; Babbar et al. 2008; Kabossa et al. 2009; Khalifa et al. 2008). Georgise et al. (2013) have reviewed the literature and systematically generalized the supply chain challenges. Figure 1 shows the systematic representation of the supply chain challenges and barriers in the MIDC. Generally, the lack and limited resources, weak and lack of ICT, cultural and organizational challenges, technical and physical infrastructure, shortage of qualified and experienced professional and outdated and/or nonintegrated production technologies, high dependency in imported inputs supply chain relationship, and other factors are influencing the success of supply chain models for companies in DC. Even though there has been some progress in the technology transfer activities in DC, advanced technologies are still in the early development stage. Legal requirements complicate the supply chain as well. In most of the cases, the supplier arrangements are usually done through a third party with little contact between the producer and customer. Therefore, the SCOR model developed for firms in a developed country

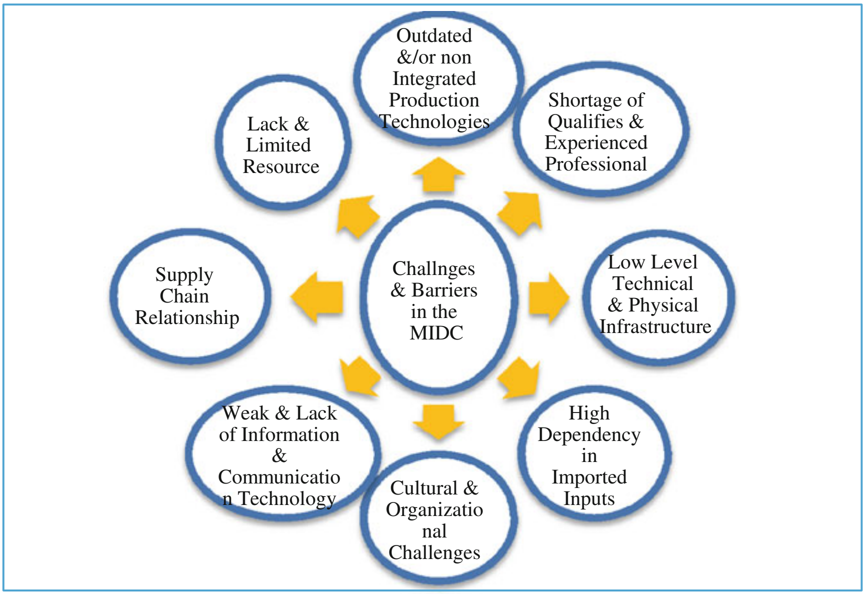

Fig. 1 Supply chain challenges in the manufacturing industry of developing countries

environment may not be suitable for the MIDC. This research paper is trying to adapt the SCOR model deliver and source processes to fit this new situation. The research addresses the following questions: how are the existing business processes affected by the challenges? and which adjustments are required to accommodate the differences? The first question is addressed by the literature review and a field study based on the questions from the model. The second one is tackled by analyzing the field result that defines the requirements for an appropriate adaptation.

Methodology

The research methodology is based on a literature review and empirical data, collected through a survey with help of a questionnaire and semi-structured interview questions. The objective of this survey is to examine the supply chain characteristics with help of the five SCOR model processes: plan, source, make, deliver, and return. The fieldwork was carried out in two stages. The first stage was based on an exploratory questionnaire. The final version of the questionnaire was sent to the 200 companies. It is essentially focused on issues related to the supply chain characteristics in Ethiopia. The second stage was carried through semi-structured interviews with senior managers of Ethiopian manufacturing firms. The aim of the second stage was to ascertain the supply chain characteristics in the Ethiopian manufacturing industry. A total of 12 top managers responsible for production operations were interviewed. The duration of the interviews varied from 90 to 120 min. The participants for both, the interviews and the questionnaires, are selected from Ethiopian manufacturing firms. The respondents are selected by top managers in command of production operations.

Field Research Results

This section summarizes the results of the questionnaire survey and semi-structured interview study. A total of 42 responses was received, 36 of which were usable, giving a response rate of 16 %. Two questionnaires mailed to the director of manufacturing were returned, as a result of having incorrect addresses. The respondents were spread over a range of industry groupings with the majority being from the beverages, chemicals and food, leather products, textile and forest industries. Consequently, an in-depth semi-structured interview has been conducted in twelve manufacturing industries in Ethiopia. The twelve organizations in this case study were selected based on their experience in export market and integration with global supply chains. The discussion of the field results are presented into two sections. The first section discusses the results of the questionnaire survey. The questions are designed to measure the use of supply chain practices with respective SCOR model source process and to rate their level of agreement to statements

Table 1 Supply chain sourcing process practices

Sourcing practice	Mean	S.D.
Long-term relationships with strategic suppliers	2.78	0.96
Imported raw materials are always available for manufacturing companies	2.34	0.79
Frequent performance feedback to suppliers	2.22	0.76
Reduction in the number of suppliers	2.18	1.00
The company use of information system in procurement process	2.13	0.81
Just-in-time delivery from suppliers	2.08	0.78
Performance indicators have been defined for your suppliers	1.97	0.81
Frequent measurement of suppliers' performance	1.97	0.85
Imported raw materials are always available locally with affordable prices	1.88	0.83

related to the above business process. The questionnaire consists of scaled response from 1 to 4 such that 1 = Never, 2 = Poorly, 3 = Well, and 4 = Extensively. Table 1 indicates supply chain source process practices. The firms often relied on long-term relationships with strategic suppliers (mean = 2.78), as well as the fact, that imported raw materials were always available for the manufacturing companies (mean = 2.34). Frequent performance feedback to suppliers (mean = 2.22) also achieved a higher value. The use of performance measurement and locally available imported raw materials were at a lower level of implementation.

This second part presents the results of the semi-structured interview. All responding companies practiced raw material sourcing from local and foreign supplies. Depending on their production operations, their dependency on local and imported raw material and procurement activities follow different purchase strategies. One of the challenging practices was the supplier selection. The supplier selection process refers to the process to select the reliable suppliers including selection criteria and negotiation. Most of the responding companies used price negotiation for local material purchase from wholesalers. The textile, leather and food industries raw material collection was done through different collectors by identifying potential suppliers. For the international purchase, companies should follow the National Bank procedure for their bidding and procurement activities. A standard procedure was used, especially for international purchase. As the companies import from different countries and also export their products to various countries and each country has a variety of standards. Procurement department officers, which were directly participating in purchasing, could not follow all rules, because the market situations were highly variable and dynamic, especially the raw material price. Most of the companies have a prepared standard contract for all suppliers.

Manufacturing industries have faced a lot of challenges in their sourcing process. The sourcing process challenges were generally categorized into two categories. One related to imported raw material and the other related to local raw material purchase. In relation to the foreign purchase, the main challenges were: lack of foreign currency, inconsistency of quality raw material during final delivery, unavailability of local suppliers for imported items and long processing, and delivery time due to lengthy bureaucratic purchase procedure. The local sourcing was also challenged by the following factors: high price fluctuation, lack of long-term relationship commitment, and loyalty from the supplier, which was manifested with the interest of the supplier to even receive small financial benefits and less in terms of raw material quality and its handling. The important challenges are associated to the seasonality and occasional sensitive availability of raw material, such as agricultural resources. The manufacturers are challenged to get reliable and consistent quality suppliers for imported raw material and therefore have a large inventory.

The Supply Chain Characteristics and Requirement

In order to better map, evaluate, analyze, control, and finally integrate the entire supply chain players into the business processes, an adapted reference model for the manufacturing industry is required. To define the needs of the industry, an extensive literature review and field study were carried out by the researchers, for adapting such a reference model. The identified gaps from the field study provided the data necessary, to determine the new model requirements. The scope of an adapted SCOR model is to integrate the entire supply chain including the DC. Table 2 shows the characteristics' of deliver and source processes in the research.

As discussed in the previous section, the firms in DC are operating in challenging environment with constraints. Due to these challenges, the building blocks of the model need to be simplified and decreased in their complexity for a smooth operation in the new situations. The results of the literature review and field studies have demonstrated the effect of the challenges in the operating behavior and capabilities. The content and its complex nature affected the models successful implementation, because of the technical difficulty understanding, collecting, managing, and exchanging information. The lack of professional expertise knowledge also limits the complexity of the supply chain model. As a consequence of financial constraints, sophisticated equipment will be unavailable. The existing physical and ICT infrastructure also challenges the implementation of the model. The observed existing practice in organizational and managerial capabilities also limits the models applicability.

Proposed Business Processes for the Adapted SCOR

The research explored the supply chain processes of the manufacturing industry in DC based on the SCOR models five processes: plan, source, make, deliver, and return. From literature review and field studies, the researchers found out, that there is quite an amount of similarities in the SCOR model business processes; however, there are still differences due to the existing environmental scenarios. Using the

Table 2 General characteristics of deliver and source processes

Identified requirement area	Characteristics of the source and deliver process	
	Local raw material	Imported raw material
Supplier relationship	Supplier are fragmented and distributed throughout the country	Very long physical distance between supplier and manufacturer
	Lack of technical and financial capacity	No direct link and relationship between manufacturer and suppliers
Material inputs	Depends on seasonal and occasional products	Highly depends on imported raw material and machinery for their production
	Supplies are not adequate to produce with full capacity	Suppliers communicated through wholesaler or agents to local manufacturers
	Raw material have perishable and decay problem	Easy to stoke but capital intensive like materials chemicals and spare parts
Selection criteria	Cost and quality	Selection guidelines focuses more in financial criteria less technical analysis
Delivery time	Lengthy collection from fragmented suppliers	Government restriction on foreign currency and bureaucratic delays in international bidding procedure
Inventory model	High inventory in peak time for seasonal and occasional raw material in order to produce though out the year	Due to lack well established physical infrastructures and ICT, high-stoke level of inventory was generally taken for granted
Procurement activities	Through price negotiation	Through International bidding using National Bank procedure
Quality check up	Factory premises	Quality check up done two times, one during sampling and other in final delivery
Information exchange	Fixed telephone, mobile and paper order	Formal communication through letter but some firms have started through fax and e-mail
Transportation	Usually done through wholesaler own trucks	More complicated because of the main suppliers are delivered products from distance through ports and locally own truck

identified general characteristics of the business process, the research proposed a business process for an adapted SCOR model, which can be used to map, evaluate and improve the entire supply chain.

Level I business processes: From the previous literature review and field results, the researchers proposed a modification of the business processes at different SCOR levels. As discussed in the previous section, the SCOR model has three levels of business processes for the modeling activities, so does the adapted

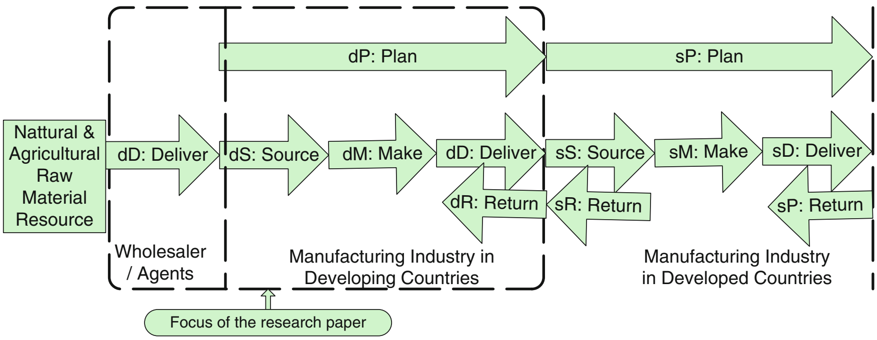

Fig. 2 Research focus and the adapted Level I business processes

SCOR model. Figure 2 illustrates the focus of this paper and representation of level I business processes for the adapted SCOR model. The research analysis focused on the initial raw material delivery process, which mainly belongs to the manufacturers source process of natural resources and agricultural products.

Level II business processes: One of the important functions of the manufacturing activities is the raw material sourcing. During the field studies and observations, the raw material sourcing processes needed special attention in the adapted model. The main local raw material sourcing was the natural and agricultural resources collected from fragmented markets by wholesalers or firm agents. The import of raw material was also practiced with different delivery strategies from the local firms. Therefore, generally, the source and deliver processes can be categorized as source and deliver of local materials and source and deliver of imported material.

Level III business processes: All level II business processes were changed appropriately in level III sub processes. All level III sub processes are done for Make-to-Stoke. The same modifications are applied to Make-to-Order product business processes.

Deliver process: The raw materials deliver processes dD1 were modified according to their subsequent level III sub processes. These processes were the more challenging ones, because of the fragmented and rural nature of suppliers for local material. The local raw materials were mostly directly delivered to the manufacturer premises. Due to the nature of the raw materials, some of the processes were removed. The sub process installation of the product is removed, because the material supplies further manufacturing operations. Additionally, the route shipments and selected carrier were also removed, because the manufacturer receives the raw material by a truck from the wholesaler on the firm premises. Figure 3 demonstrates the adapted deliver processes for sourcing local and imported raw material.

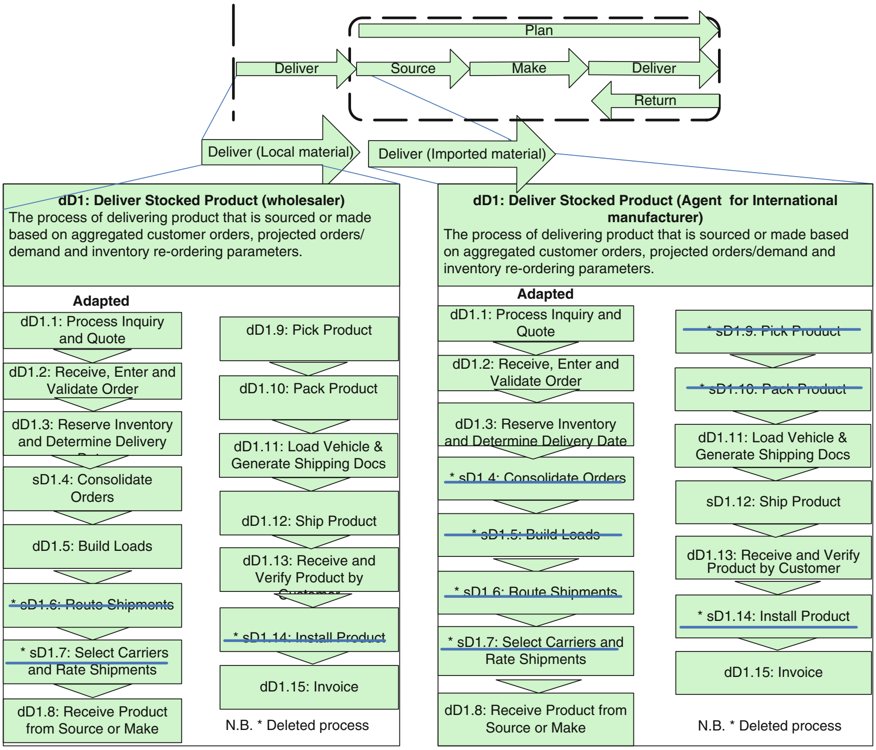

Fig. 3 dD1: adapted deliver process for local and imported material

Source process: The sourcing process in DC is facing different challenges when they are interacting with their supplier, especially in supplier availability and selection procedure. Low supplier base and supply disruptions cause the supply chain to choose alternative suppliers and new relationships must be formed frequently. Thus, to be able to use the proposed adapted model in DC, the local material source, stocked products, and the source to make product activities will require adding two additional level III elements: Identify source of supply and negotiate and set price for local purchases. Similar to this, the modification is done for international purchase also. In the current practices, the new material supplier activities were done by suppliers; the transfer product sub process was removed from the source process. Figure 4 shows the adapted source processes for local and international purchase.

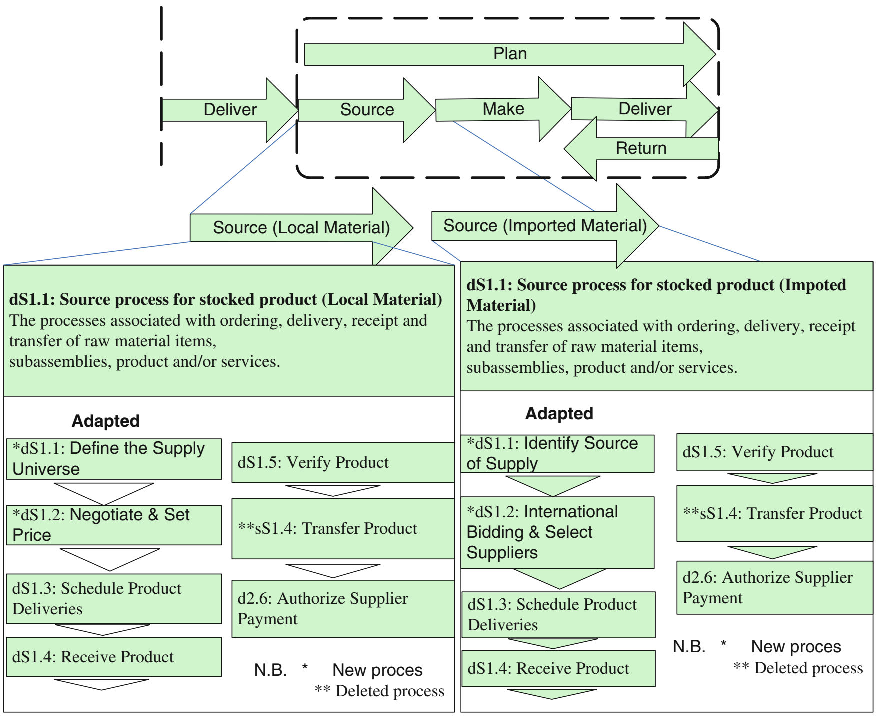

Fig. 4 dS: adapted source stocked product for local and international purchase

Conclusions

With the recent trend of the business studies that emphasis on the importance of improving the whole supply chain, including the DC, these are now being recognized. This research result discusses the characteristics of the supply chain in the DC for this effect. Then the research paper shows the practical possibility of the SCOR model adaptation to the developing countries situations. The proposed business processes are an initial step for the adapted SCOR model. It provides the first insight to the managers to model, evaluate, and improve their company's key areas of the supply chain. In short, throughout this research, we tried to propose a business process for an adapted SCOR model, to facilitate the improvement activities of firms in DC. There are several ways in which the various concepts exposed in this research can be extended in the future. For example, further development work to upgrade these proposed business processes and adapt other business processes, identifying appropriate key performance indicators and best practices, which suit DC situations.

References

Babbar S, Addae H, Gosen J, Prasad S (2008) Organizational factors affecting supply chains in developing countries. Int J Commer Manage 18(3):234–251

Di Martinelly C, Riane F, Guinet A (2009) A porter-SCOR modeling approach for the hospital supply chain. Int J Logistics Sys Manage 5(3–4):436–455. doi:10.1504/IJLSM.2009.022506

Georgise FB, Thoben K-D, Seifert Marcus (2013) A framework of the forces influencing the adaptation of the SCOR model to the situation of the manufacturing industry in developing countries, in dynamics in logistics. Springer, Berlin. doi:10.1007/978-3-642-35966-8_40

Georgise FB, Thoben K-D, Seifert M (2012) Adapting the SCOR model to suit the different scenarios: a literature review and research agenda. Int J Bus Manage 7(6):1–17. doi:10.5539/ijbm.v7n6p2

Hamisi S (2011) Challenges and opportunities of Tanzanian SMEs in adapting supply chain management. Afr J Bus Manage 5(4):1266–1276

Heriberto GR, Giachetti R (2010) Using experts to develop a supply chain maturity model in Mexico. Supply Chain Manage Int J 15(6):415–424. doi:10.1108/13598541011080400

Huang SH, Sheoran SK, Keskar H (2005) Computer-assisted supply chain configuration based on supply chain operation reference (SCOR) model. Comput Ind Eng 48:377–394. doi:10.1016/j.cie.2005.01.001

Irfan D, Xiaofei X, Sheng Chun D (2008) A SCOR reference model of the supply chain management system in an enterprise. Int Arab J Info Technol 5(3):288–295

Kabossa AB, Msimangira C, Tesha P (2009) International supply chain practices in developing countries: a study in Tanzania. In: Production and Operations Management Society (POMS) 20th Annual Conference Orlando, Florida

Khalifa N, White A, EISayed A (2008) Supply chain challenges in developing countries: cross industry case studies. Cybern Inte Sys 1–8

Legnani E (2011) Controlling and improving the provision of after-sales services. Doctoral thesis (Doctor of philosophy), Universtà Degli Studi di Bergamo, Bergamo

Lockamy III A, McCormack K (2004) Linking SCOR planning practices to supply chain performance, an explorative study. Int J Oper Prod Manage 24(12):1192–1218

Msimangira KAB, Tesha CP (2009) International supply chain practices in developing countries: a study in Tanzania. In: POMS 20th annual conference Orlando

Ohemeng FLK (2009) Constraints in the implementation of performance management systems in developing countries: the ghanaian case. Int J Cross Cult Manage 9:109–132. doi:10.1177/1470595808101158

Ruteri JM, Xu Q (2009) Supply chain management and challenges facing the food industry sector in Tanzania. Int J Bus Manage 4(12):70

SCC (2010) SCOR Model 10.0 by Supply Chain Council USA

Trienekens JH (2011) Agricultural value chains in developing countries: a framework for analysis. Int Food and Agribusiness Manage Rev 14(2):51–82

Improving the Understanding of Supply Chain Interaction Through the Application of Business Games

Jannicke Madeleine Baalsrud Hauge, Nils Meyer-Larsen and Rainer Müller

Abstract Dynamic systems such as global supply chains (SC) compel the workforce of all involved players to be faced with ever-changing working environments. This complexity makes it difficult to predict the impact of decisions taken, thus future SC managers need to be trained in taking decisions under uncertainty and to reflect the impact on the whole SC. This type of practical decision making is necessary to take shape within the business and engineering schools since it prepares future practitioners for the requirements they will face. Game-based learning (GBL) is well suited to GBL process. This paper compares two different game-based learning setups with students. The first explains a pure game-based course, whereas the other discusses how a new game is introduced in an undergraduate course on container security. Our comparison helps others to avoid pitfalls in the introduction of GBL in logistics education.

Keywords Supply chain management · Decision making · Gamebased learning · Serious gaming · Case studies

Introduction

The goal of supply chains (SC) is the optimisation of logistical and production processes (Pfohl 2002; Jüttner 2005) Contemporary SCs are becoming longer, leaner and more brittle (Christopher and Peck 2004), involving more co-operation and collaboration and thus transforming into global SCs (Barrat 2004; Braziotis and Tannock 2011). An important side effect in the operation of global networks is that they are more vulnerable and inflexible due to the large number of different entities involved. Their complex interrelations also increase the number of risks occurring,

J.M. Baalsrud Hauge (✉)
Bremer Institut für Produktion und Logistik, Bremen, Germany
e-mail: baa@biba.uni-bremen.de

N. Meyer-Larsen · R. Müller
Institut für Seeverkehrswirtschaft und Logistik, Bremerhaven, Germany

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which might lead not only to higher costs but also to reducing the reliability of on-time deliveries, or in the worst case, no delivery at all (Sørensen 2005; Peck 2003; Jüttner 2005; Pfohl 2002).

SCs are complex and the information and data exchange take place at different levels. van Oosterhout et al. (2007) introduces three different levels in order to explain the complexity that modern SCs are subject to. The **bottom level** comprises the physical flow of material. At this level, different tracking and tracing technologies can be used in order to collect data from different stakeholders. Examples of the technology in use at this level are the use of electronic seals, RFID technology, sensor networks, etc., in order to collect the relevant data. Regarding the resilience, at this bottom level, this would be more in line with the information technology (IT) terminology, in which resilience describes the system's ability to cope with errors during execution—i.e. the robustness of the system (Christopher and Peck 2004, p. 2)

At the **transaction level**, we are more concerned with using technologies ensuring a seamless and secure information flow throughout the SC. This requires not only the use of a common information system (IS) and methods, but also the willingness to co-operate and share information (Pfohl et al. 2010; Christopher and Peck 2004). At the second layer in van Oosterhout et al. (2007) model, we look at the information flow. The typical problems dealt with at this level are the problems with data exchange. There are several examples of solutions that increase the SC's visibility, but most of them are solutions only involving a few stakeholders, and the integration is a challenge.

At the **governance** layer, the focus is more on the question of monitoring and assessing information and material flow. At this level, methods for identifying, assessing, managing and, monitoring risks are needed. However, the stakeholders (suppliers, authorities, logistic and infrastructure service providers, manufacturers, customers, etc.) often have different risk perceptions and tolerances, which can influence the risk treatment strategy. Furthermore, there is also clearly an asymmetric information flow between participants in the SC leading to different possibilities of identifying and monitoring risks.

This article will present and discuss how games can be used for competences development regarding security issues as well as for risk management and decision making. It discusses how the courses evolve and the lessons learned.

Problem Statement

Dynamic systems such as SCs compel their workforce to be faced with ever-changing working environments (Baalsrud Hauge et al. 2006). Successful co-operation does not only rely on a seamless information flow between all partners, but also on the ability of the participating organizations to learn and to act in a dynamic environment. The complexity in SCs makes it difficult to predict the impact of decisions made. Thus, future SC managers need to be trained in taking decisions under uncertainty and to reflect on how these decisions impact the whole SC (Manuj and Sahin 2011). Typical risks for SCs are related to collaboration, connectivity, information sharing, and communication, etc. (Peck 2005; Sheffi 2005; Waters 2007; Pfohl et al. 2008). Educational institutions need to aim at preparing their students as best as possible for these dynamic working environments and to give them the opportunity to acquire risk management skills during their studies.

Within business schools, the criticism between transferring knowledge based upon research rather than practice, with an emphasis on conflicting benefits for relevant stakeholders, and ineffectively linking research results and actual (or future) practice have been documented (Starkey and Tempest 2005). Game-based learning (GBL) (Prensky 2003; Gee 2003) has been introduced in several engineering and business schools. GBL has the advantages of simulating realistic contexts, it is experiential—allowing the students to learn through experience, to experiment with different decisions and to learn from the resulting feedback. GBL is an established teaching method (Faria et al. 2009) used at several business and engineering schools. Serious games can be defined as entertaining games with nonentertainment goals, used to educate, train and inform (Bellotti et al. 2010; Raybourn 2007; Michael and Chen 2006; Shute and Ke 2012; Arnab et al. 2014). In the field of business and engineering education, serious games are mostly conducted used in a workshop setting (Angehrn and Maxwell 2009).

Research Methodology

The first step was to identify the needs and requirements regarding the relevant competences in the field of supply chain security and supply chain risk management (SCRM).

Based upon the identified educational needs, a curriculum was designed and the learning goals were established. In the first case study, this was connected with the development of a game, which has been continuously improved. The game and its curriculum were used in an SCRM course over a period of 5 years. An evaluation method was developed to assess how well the game met the learning goals. The evaluation results showed that in the first versions of the game the students' achievements were lower than expected. Hence, an iterative improvement process was used for the game, as well as the blended learning concept so that it achieved the learning goals at a satisfactory level.

In the second case study, a different approach was taken, making the students themselves develop serious games on the topic of supply chain security. The aim was to achieve a more interactive educational process and to attain more concrete results with an advanced practical relevance in contrast to the mainly theoretical considerations during a conventional ex-cathedra lecture course.

Case Study Beware

This section will describe the evolvement of the course and the corresponding game for a GBL course for master students.

Beware is a web-based multi-player online game implemented in a workshop setting with three groups spatial separated. The *Beware* game is an extension of a game engine, which is developed and used at BIBA (Baalsrud Hauge et al. 2008). In order to be used in the current setting, several changes were necessary. The game objective is to handle risks occurring while developing and producing products in a distributed working environment with a minimum of 98 % quality rate in shortest possible time and to lowest possible cost, i.e. comprising both elements of concurrent engineering and supply chain management. The game is facilitated, and the facilitator can monitor the game play via the monitoring interface (Baalsrud Hauge et al. 2008). It uses a blended learning concept and is used to let students apply SCRM methods and strategies. At the beginning, each student is assigned to a role with a more or less co-operative character. During game play, the players have to complete their tasks, mostly by either taking actions or completing documents, while continuously monitoring the performance indicators as well as to identify upcoming risks and manage these risks according the risk management procedures. Based on the performance, different events will occur. The information is distributed among the players, so that they have to communicate. Currently, *Beware* is designed with two different levels. In the first level, the players develop a simple product and experience risks within their organization, whereas at the second level, the players are faced with the design, development and manufacturing of an extended product within an inter-organizational co-operation.

The game enables students to identify how different types of risks impact differently on the success of a co-operation, both depending on the type of co-operation and also depending on previous performance and also how the impact of risks increases and affects the partners' success over time, if no actions are taken to reduce and control the risks. In order to succeed, the students have to apply risk management methods and thus increase their awareness of risks in production networks as well as the complexity of decision making in dynamic environments.

The game is used at the **University of Bremen** as part of a 3 ECTS lab course on "Decision making in distributed production environment". The course is open for master of industrial engineering, production, and system engineering. The knowledge of risk management in general and SCRM varies. Thus each attendee has to make a pre-test before starting. This is necessary in order to define the complexity level of the risk management parts. The playing time is about 5 h at each level with an additional 60 min for the debriefing phase. The game concept and the curriculum used for this course are concurrently developed, so that the learning outcome to be achieved within the game corresponds to the learning objective of the syllabus. The gaming scenario is process based and event triggered.

Based on the test results and previous experience with the development of educational games (Baalsrud Hauge et al. 2013; Hunecker 2009) a user-centred

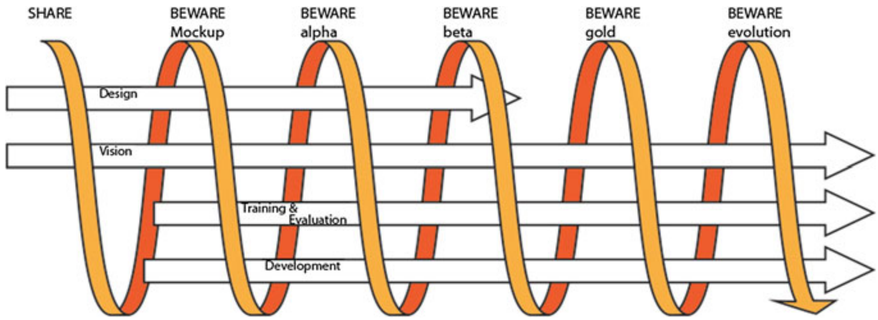

Fig. 1 Beware development process

development approach was taken, using principles from the Agile Programming Community after (Beck et al. 2006) and the spiral development approach (see Boehm 1988). The methodology is illustrated in Fig. 1.

This approach ensures fast feedback from the potential users regarding usability and also user acceptance (Bødker 1996; Bellotti et al. 2013). The user is the teacher, who has made the curriculum and the game concept, but has no skills in programming, as well as the students. Currently no adjustments are needed.

Case Study Security Game

This section of our paper describes a GBL approach which was taken in the winter semester 2013/2014 within the lecture "Security in intermodal container transport", being part of the Bachelor course of Transport Engineering/Logistics (Studiengang Transportwesen/Logistik TWL) at Hochschule Bremerhaven (University of Applied Sciences). It explains why based on our previous experience we think a GBL approach will improve the learning outcome and also explains how this will be evaluated. The course is still under development, and thus we have no preliminary results so far.

This course is designed to meet the fast changing requirements of logistics. Its curriculum follows the fast changes in technology, information processing and organization in all fields of logistics and consists of 6 semesters presence. The first two semesters focus on the basics of logistics, the following three semesters are designed to provide the students with professional skills and the last semester can be used to serve a placement in an industrial environment in order to experience up to date methods and techniques. Optionally the last semester may be used to solve a practice project at the university. This practical part of the studies is an integrated, in its contents defined and monitored part of the education. Generally, the modules amount to 4 h per week per semester (HWS). There are 35 modules which are generally credited with 5 credit points (ECTS) (Hochschule Bremerhaven 2014).

The course was given several consecutive semesters with different students. The topics to be taught to the students are e.g. derived from the Container Supply Chain Compendium (Integrity 2008; Hintsa 2012) developed within the EU project Integrity (2014) and further developed and extended by risk considerations in the CASSANDRA project (2014).

In the first semesters, the course was organized as ex-cathedra teaching combined with several units of students' work during quiet time and subsequent discussion of the results. The content focused on basic knowledge on the topic e.g. referring to the background of supply chain security, existing laws and initiatives, and organizational and technical approaches to enhance supply chain security. In the following semesters, the curriculum was enriched by a special phase of the course, where the students were developing certain security-relevant scenarios in container transport, e.g. a terrorist attack or cargo theft. The students had to analyse the respective scenario in depth and reflect on possible actions or countermeasures and the resulting consequences, leading to an advanced interactivity of the educational process and to more concrete results with an advanced practical relevance in contrast to the mainly theoretical considerations before. Some examples of scenarios together with relevant questions to be examined by the students are shown in Table 1.

In order to further develop the curriculum and create an even more interactive learning environment, it was decided to develop this course phase into a serious gaming phase. Unfortunately serious games addressing the topic of security in intermodal container transport are to our knowledge not available at the moment. Consequently, the decision to include serious games was to perform an experiment, i.e. to ask the students to develop respective games addressing these topics themselves. The students were introduced into this task by providing theoretical

Table 1 Examples for scenarios to be examined during the lectures

Scenario	Relevant questions
Thief wants to steel goods from a container	Which container to choose? How to proceed to achieve the goal?
Container laden on a truck is breached	What happens in case it is equipped with a Container Security Device (CSD)? Whom to notify?
All partners in a chain except the haulier are Advanced Economic Operator (AEO) certified	Can usage of a CSD compensate the lacking AEO status?
Container laden on a sea vessel to the U.S. is breached	What happens if the incident is remarked in the U.S. port only?
Container is breached by opening the front wall	Can a CSD detect this incident?
Terrorists plan to place a bomb in a container	Which container to choose? How to obtain the necessary information?
A bomb is found in a container laden on a vessel	Is the vessel allowed to call a port? How to proceed?

background on supply chain security and respective approaches and projects during the first lecture phase. They were made familiar with the expectation that the game should create a safe learning environment in which the gamers can apply different strategies and discover the impact of their decisions on the system. Of course the fact was taken into account that the developed games will most likely not be very complex due to the lack of experience and theoretical background on game development by the students and the limited time and effort they can invest in this task.

Main goal of the game is to design the mechanism between the risks and the different risk mitigation measures. In detail, the game shall describe the different risks in the field of supply chain security like risk of theft, smuggle or terrorist attack. In order to mitigate these different risks, several risk mitigation measures are in place, for example, using monitoring devices for containers or screening of personnel. Consequently, for the design of the game the students have to take into account which risk mitigation measure is able to cope with which risk. Another aspect is that the complex structure of SC includes different supply chain actors. In detail, each actor has a different role, which has to face different risks, and is able to use different risk mitigation measures. Because of this, the different specialities of each actor have to be taken into account for the game design process. In addition, beside typical supply chain actors like shippers and freight forwarders, also the methods of the different criminals (for example, thieves and terrorists) have to be modelled for the game design. In detail, these different criminals have different goals and methods for attacks of the supply chain. In particular, thieves have different modi operandi to steal contents of the container, the container itself or the truck with the container.

First discussions with the students made clear that they will most probably choose the form of a board game or a card game as a platform to develop their games.

The game is designed by the students. The objective is, according to the theory of constructivism, to actively involve them in the learning process. In our case, the students build small groups of two to four persons and choose a topic from their related theoretical knowledge on supply chain security they have gained during the earlier lessons. Each group of students will develop a small game in which the player can learn about specific aspects of supply chain security, e.g. how to react to certain criminal actions or how to identify criminal interventions. By having this concrete task, the students will reflect in more detail on what is important and what is not, as well as deepen the knowledge in a specific area. This anticipation is supported by discussions with the students during the current development phase of the games, as it was clearly stated by the students that the educational outcome of this process was already considered more successful than during a conventional lecture course.

Based on this preliminary result, we expect that the creation of the game, its definition and the consideration of the theoretical mechanisms on which the game is based and the reflection on how these mechanisms are functioning in the real world might even have an enhanced impact on the understanding of the topic of security in intermodal container transport than just playing the game. The game creation process targets watching, thinking, and doing, which leads to concrete outcomes and as such conforms to the Kolb's cycle. We anticipate that this process will support the students' ability to analyse a situation and decide on an adequate reaction, thereby considering several alternatives, to reflect their actions and to evaluate the outcomes. Quantitative results from the development and deployment of the games are not yet available. However, dependent on the outcome, we will decide if some of the developed games will be included in further education curricula and/or developed further. We believe that the description of our approach could be useful for other educators as well.

Conclusions

For subjects conveying skills to be used in complex dynamic systems with rapidly technology development, it is a challenge to keep curricula up to date. Thus, it is necessary to look at possibilities to handle this flexible and the type of skilled to be conveyed requires active participation of the students. GBL has proven to be effective and was thus considered as teaching method in both cases. However, the course development was different. In the first case study, the course was developed as a game-based course right from the beginning, but the game used needed to be adapted and extended in order to reach the learning goals. This required development of new functionalities and the adaption took place over years. Currently, the course delivers according to the expectations. In the second case study, the course was developed as a normal teacher centric course and was slowly adopted towards using games for increasing the user involvement, and currently, the students are developing small games to a security related topic in order to deepen the understanding of the theoretical gained knowledge.

Moving from theory to practice signifies an important step in one's mind-set, and this was indicated in our results. As mentioned above, the players needed time to prepare for this step, and consideration for decisions needed effort. Our paper provides avenues for enhanced teaching in SCM, but it also shows the drawback of using games build for only one purpose. The development time is high and the integration difficult. The experience so far has shown that a well-designed game will not only help the learners to transfer their theoretical knowledge to practical skills, but also to transform gained experience into knowledge so that they can assess previously acquired knowledge and generate new understanding. It is also interesting to notice, that some students did find it so engaging that they asked to play the game for a second time. This shows how important *virtual practice* is as part of a theoretical course. The observation fits well into Kolb's learning model.

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References

Angehrn AA, Maxwell K (2009) EagleRacing: addressing corporate collaboration challenges through an online simulation game. Innovate J Online Educ 5(6):4

Arnab S, Lim T, Carvalho MB, Bellotti F, de Freitas S, Louchart S, Suttie N, Berta R, De Gloria A (2014) Mapping learning and game mechanics for serious games analysis. Br J Educ Technol (BJET). doi:10.1111/bjet.12113

Baalsrud Hauge J, Duin H, Oliveira M, Thoben K-D (2006) User requirements analysis for educational games in manufacturing. Proceedings of the ICE conference, pp 47–49

Baalsrud Hauge J, Duin H, Thoben K-D (2008) Increasing the resiliency of global SN by using games. In: Pawar KS, Lalwani CS, Banomyong R Conference Proceedings ISL 2008, Centre for Concurrent Enterprise, Nottingham University Business School, Nottingham 2008, S. 125–132

Baalsrud Hauge J, Boyle E, Mayer I, Nadolski R, Riedel JCHK, Moreno-Ger P, Bellotti F, Lim T, Ritchie J (2013) Study design and data gathering guide for serious games' evaluation. Psychology, pedagogy, and assessment in serious games. IGI Global 2014:394–419. doi:10.4018/978-1-4666-4773-2.ch018

Barrat M (2004) Understanding the meaning of collaboration in the supply chain. Supply Chain Manage: Int J 9(1):30–42

Beck K et al (2006) Manifesto for agile software development. http://www.agilemanifesto.org. Accessed 12 Jan 2006

Bellotti F, Berta R, De Gloria A (2010) Designing effective serious games: opportunities and challenges for research. Special issue: creative learning with serious games. Int J Emerg Technol Learn (IJET) 5:22–35

Bellotti F, Kapralos B, Lee K, Moreno-Ger P (2013) User assessment in serious games and technology-enhanced learning. Hindawi Adv Hum-Comput Interact

Bödker S (1996) Creating condition for participation: Conflict and ressources in systems development. Hum-Comput Interact 11(3):215–236

Boehm B (1988) A spiral model of software development and enhancement. Computer 21 (5):61–72

Braziotis C, Tannock J (2011) Building the extended enterprise: key collaboration factors. Int J Logistics Manage 22(3):349–372

CASSANDRA (2014) www.cassandra-poject.eu. Accessed 27 Jan 2014

Christopher M, Peck H (2004) Building the resilient supply chain. Int J Logistics Manage 15 (2):1–13

Faria AJ, Hutchinson D, Wellington WJ, Gold S (2009) Developments in business gaming: a review of the past 40 years. Simul Gaming 40(4):464–487

Hintsa (2012) CASSANDRA COMPENDIUM, www.cassandra-project.eu/userdata/file/Publicdeliverables/Cassandra. Accessed 27 Jan 2014

Gee JP (2003) What video games have to teach us about learning and literacy. Palgrave Macmillan, New York

Hochschule Bremerhaven (2014) www.hs-bremerhaven.de/en/. Accessed 27 Jan 2014

Hunecker F (2009) A generic process simulation-model for educational simulations and serious games. On the Horiz 17(4):313–322

Integrity (2008) Global container supply chain compendium, integrity-supplychain.eu/index.php?module=Downloads&func=prep_hand_out&lid=82. Accessed 27 Jan 2014

Integrity (2014) www.integrity-supplychain.eu. Accessed 27 Jan 2014

Jüttner U (2005) Supply chain risk management. Int J Logistics Manage 16(1):120–141

Manuj I, Sahin F (2011) A model of supply chain and supply chain decision-making complexity. Int J Phys Distrib Logistics Manage 41(5):511–549

Michael D, Chen S (2006) Serious games: games that educate, train and inform. Thomson Course Technology, Boston

Peck H (2005) Drivers of SC vulnerability: an integrated framework. Int J Phys Distrib Logistics Manage 35(4):210–232

Peck H (2003) Creating resilient SCs: a practical guide, Centre for Logistics and SC Management. Cranfield School of Management, England

Pfohl H-C, Gallus P, Köhler H (2008) Supply Chain Risikomanagement—Vision oder pragmatisches Konzept? Ergebnisse des BVL-Arbeitskreises “Sicherheit und Risikomanagement in der Supply Chain”. In: Pfohl H-C, Wimmer T (eds) Wissenschaft und Praxis im Dialog. Robuste und sichere Logistiksysteme. 4. Wissenschaftssymposium Logistik. München. Hamburg, pp 446–470

Pfohl H-C, Köhler H, Thomas D (2010) State of the art in supply chain risk management research. Empirical and conceptual findings and a roadmap for the implementation in practice. Logistics Res 2(1): 33–44

Pfohl H-C (2002) Risiken und Chancen: Strategische Analyse der Supply Chain. In: Pfohl H-C (ed) Risiko- und Chancenmanagement in der Supply Chain: proaktiv - ganzheitlich - nachhaltig. Erich Schmidt Verlag, Berlin, pp 1–58

Prensky M (2003) Digital game-based learning. ACM Comput Entertain 1(1)

Raybourn EM (2007) Interact Comput 19:206–214

Sheffi Y (2005) Building a resilient supply chain. Harvard Bus Rev Supply Chain Strategy 1 (5):1–4

Shute VJ, Ke F (2012) Games, learning, and assessment. In: Ifenthaler D, Eseryel D, Ge X (eds) Assessment in game-based learning: foundations, innovations and perspectives. Springer, New York, pp 43–58

Sørensen L.B. (2005) How risk and uncertainty is used in SC management: a literature study, Copenhagen

Starkey K, Tempest S (2005) The future of the business school: knowledge challenges and opportunities. Hum Relat 58(1):61–82

van Oosterhout MPA, Veenstra AW, Meijer MAG, Popal N, van der Berg J (2007) Visibility platforms for enhancing supply chain security: a case study in the port of rotterdam. Paper presented at the the international symposium on maritime safety. Security and Enviromental Protection, Athens, Greece

Waters D (2007) Supply chain risk management: vulnerability and resilience in logistics. Kogan Page, London

Responsible Innovation in Supply Chains: Insights from a Car Development Perspective

Nils Thomas and Helen Rogers

Abstract Innovation within companies is a collaborative process. Supply chain management (SCM) concepts such as 'Early Supplier Involvement' and 'Open Innovation' encourage the involvement of stakeholders, such as suppliers, customers, universities and the government. Customer participation for example helps to reduce the uncertainty of acceptance of an innovation in advance. Following market launch, the number of stakeholders increases further. With investors, customers and competitors globally dispersed, the stakeholder network of a new innovation could become complex and unmanageable. This not only makes risk identification arising from innovations very complex but also the accompanying assignment of responsibility. Research on Responsible Innovation (RI) brings along various challenges that arise from the rights, duties and behavior of stakeholders. This paper aims to identify the most important stakeholders for Responsible Innovations and determine their influence on the innovation lifecycle using the car development process as an example.

Keywords Responsible innovation · Car development · Stakeholder analysis

Introduction

Product innovations can generate considerable benefits for individuals and companies, as well as for society and the environment. They shape the future and among other things can improve health, living standards, and lifestyle (Owen et al. 2009, 2012). Long-term company success and competitive advantage is in many

N. Thomas
Friedrich Alexander University, Erlangen, Germany
e-mail: nils.thomas@studium.uni-erlangen.de

H. Rogers (✉)
Technische Hochschule Nürnberg, Nuremberg, Germany
e-mail: helen.rogers@th-nuernberg.de

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ways rooted in innovation. However, innovations can also have negative impacts, such as damage to the environment or public health (Haubner 2001; Hellström 2003; Krewitt et al. 2010). Innovations can also endanger established industries and make manual labor redundant (Ford 2003). Essentially, innovations need to provide benefits in order to become successful products, but these benefits can come with risks (Hellström 2003). Understanding the impact innovations can have on an industry, society, and environment are the focus of this paper.

Existing RI Research and Research Questions

Hellström (2003), Ishizu et al. (2007) and Owen et al. (2012) used practical examples to determine the importance and benefits of RI as a tool for innovation management. They showed where risks occur, how they influence the supply chain and how science, environment, and society interplay within innovation processes. For example, air and water quality innovations show how effective government regulation of innovations can improve health in a society (Owen et al. 2009). In order to estimate what a broader view of the stakeholder network can contribute to RI, a detailed stakeholder analysis of the car development process from its beginnings to today was conducted.

This paper addresses three questions about the stakeholder network of an innovation. One major challenge of the research on RI is the definition of 'responsible' (Owen et al. 2012). Stakeholders already have a number of different responsibilities. Scientists must ensure that their actions are morally acceptable and do not originate from plagiarism (Mahlouji and Anaraki 2009; Owen et al. 2012). Companies need to ensure that products generate a demand and that customers are willing to pay a certain price (Hellström 2003).

Q1: Which aspects of stakeholder analysis are important to consider when a definition of the term 'responsible' in RI is developed?

The next aspect analyzed in this paper is the importance of the pioneers at the early stages for RI. In R&D stages, scenario planning, risk identification, and standard setting are possible ways to ensure that a product will be responsible in the future (Lettice et al. 2013). A major benefit of considering RI at the early stages is that new technologies or products are modifiable and can still be retrenched. The major disadvantage is the high uncertainty about customer acceptance and market diffusion of a product (Owen et al. 2009). Ubois (2010) brought together the terms 'to be responsible' and 'to cause'. If both are used as synonyms, then one might immediately think of the pioneers who made an invention to be the most responsible stakeholders in the entire lifecycle of an innovation. But in order to decide on their responsibility, the extent and influence of these pioneers and their possibility to imagine how an invention will develop needs to be analyzed in more detail. Therefore, the second question is:

Q2: How much influence and foresight do pioneers and the early stages provide for RI in the full innovation life cycle?

There are three stakeholder groups that are likely to be the most important ones for an innovation following the pioneers; namely the companies, its customers and the government. Companies produce and sell products that result from innovations and therefore make these innovations public. However, no innovation will become successful without customer acceptance and market diffusion. Therefore, customers represent the second group of these stakeholders (Dannenberg and Burgard 2007). Government represents the third group. It has the power to regulate innovations, markets, and influence the customer's behavior (Arnold et al. 2010). In turn, some facts make the influence of companies, customers, and the government questionable. According to the basic idea of RI, customers as part of the society need to be protected (Owen et al. 2012). The government can only slowly react with regulation on the development of innovations (Owen et al. 2009). Companies are not able to make innovations public and successful without customer acceptance (Dannenberg and Burgard 2007). This paper aims to shed light on the real responsibilities of these stakeholder groups. Therefore, the third research question is:

Q3: What roles do customers, car manufacturers, and governments play for RI in practice and how do these stakeholder groups influence each other?

Methodology

The analysis of the car development process was chosen for a number of reasons. First, the 130-year history allows an overview of developments and a detailed analysis of stakeholders influence in innovation processes. Second, in the last 10 years, car manufacturers conducted extensive research on technologies, which enable a change from environmentally harmful engines to emission-free alternatives (Dannenberg and Burgard 2007). Third, the German car industry alone employs hundred of thousands of people, collaborates with thousands of suppliers, and sells millions of cars to customers (Volkswagen 2013). This is why individual stakeholder groups have had strong influences on the car development process allowing for analysis (Arnold et al. 2010; Dannenberg and Burgard 2007; Haubner 2001). Finally, the car industry generated the highest numbers of German patent applications in 2012 making it suitable for innovation management studies.

The car development process is arranged in four phases. In 1886, Carl Benz presented the first car to the public. Research was conducted mainly by Daimler and Benz in the R&D phase to make the car available to customers and to increase its usability (Lüdkte 2012). In the Ascent phase, the global car industry emerged and manufacturing processes were improved (Haubner 2001). Then in the Maturity phase, the car was launched to the broader public and customers required individualization, once again influencing manufacturing processes (Stieniczka 2001). In the Decline phase, alternatives to replace the combustion engine in the future are being developed (Dannenberg and Burgard 2007).

Methods of Stakeholder Analysis

The approach to stakeholder analysis adopted here was as follows. First, stakeholders were identified, categorized, and grouped. Interdependences between these stakeholder groups were then examined (Bourne and Walker 2006; Reed et al. 2009). Finally, experts of innovation management departments in the car industry were interviewed to evaluate the findings and further applicability potential.

Stakeholder Identification: The number of stakeholders in an innovation process can increase up to an unlimited dimension. Hence boundaries for the identification of stakeholders must be defined. In general, various criteria can be used for boundaries such as age groups or geographical areas (Reed et al. 2009). However, since a global network of companies and individuals participates in the car development process, geographical criteria are not adequate. According to a general definition, each individual or organization which affects or is affected by the process can be taken into consideration (Freeman et al. 2010). The only limitation is the extent of influence on the car development process. If a stakeholder is poorly affected by the car in the process and this has no significant impact on its development, the stakeholder is not considered for the purposes of this research. In this way, the number of relevant stakeholders can be limited and excluded from the analysis.

Stakeholder Categorization: The first way to categorize car development process stakeholders is to assign primary and secondary stakeholders. Primary stakeholders are essential to the innovation process and its progress is dependent on their participation and support. Especially customers, suppliers, employees, and investors can belong to this group. These stakeholders can have a high impact due to their rights and influence (Clarkson 1995; Wadenpohl 2010). Secondary stakeholders (e.g., the media) also have an impact on innovation but this is based (e.g.,) on reputation. They are not engaged in transactions or bound by a contract. Therefore, the survival of the innovation process is possibly not directly dependent on these stakeholders but rather the speed of progress can be. The second way to analyze the stakeholders is based on the 'Stakeholder Circle' (Bourne and Walker 2005). As shown in Fig. 1, this tool helps visualize stakeholder characteristics within the car development process. Here, three characteristics of stakeholder groups are considered; power, degree of influence, and proximity to the car development process. The black center of the circle represents the car development process surrounded by several rings representing stakeholder distance. The number of individual stakeholders that form a group is shown roughly by color gradings. The degree of influence is represented by the width of the group and the power by the radial depth of a group in the circle. Any stakeholder group that ranges from the center to the

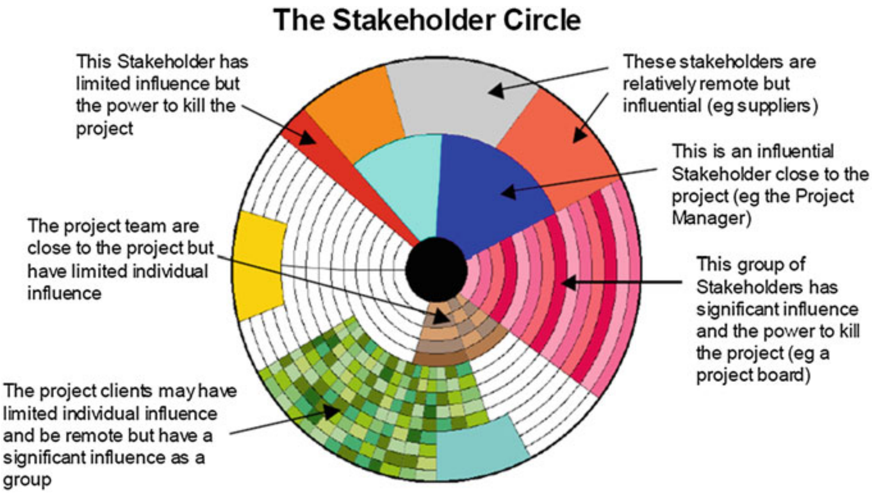

Fig. 1 The stakeholder circle (Bourne and Walker 2005)

outline has enough power to stop the entire innovation process (Weaver and Bourne 2002). The proximity of stakeholders is represented by their location in the circle.

The 'Power and Interest Grid' is another stakeholder analysis tool. It identifies four categories of stakeholders based on their relationship to business strategy (Eden and Ackermann 2004; Reed et al. 2009). We modify this to provide detailed information about car development process stakeholders. The modified Grid considers the interest of stakeholders in the success of this process and their power to influence achievement. Accordingly, the description of the stakeholder categories also needs to be adapted. Victims have a low interest in the success of the car development process but little power to influence it. So for RI, these stakeholders might need protection. Players and obstructionists both have high power to influence the innovation process. Players are likely to support the process and aim to benefit from it, while obstructionists can impede/stop it.

Accordingly, responsibility can be assigned to groups of stakeholders. Enthusiasts are interested in the success of the innovation process but lack power. However, their interest can be increased if they are mobilized in large groups. Furthermore, they can have a strong influence on other stakeholders.

Findings

Figure 2 summarizes when these stakeholder groups become important to the car development process and if they changed from primary to secondary stakeholders or vice versa.

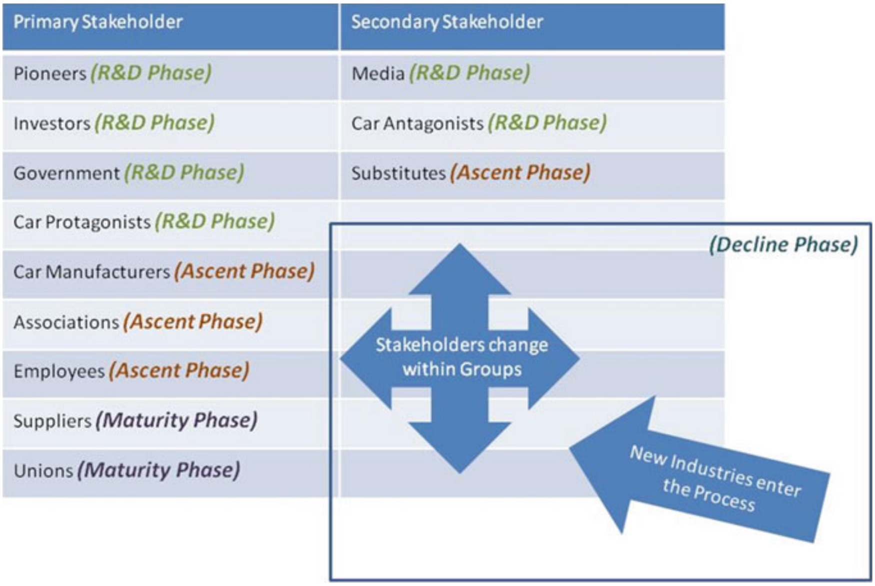

Fig. 2 Appearance, differentiation, and dynamic of the stakeholder network

As indicated, the number of groups that become important for the process in one phase constantly decreases from six groups in the R&D phase to four groups in the Ascent phase to two groups in the Maturity phase to zero groups in the Decline phase. Even when new industries participate in the process the individual stakeholders can be assigned to the existing groups. Consequently, the RI risks and benefits of an innovation can be identified at the early development process stages, as many of the important stakeholders are already known. Furthermore, none of the stakeholder groups changes from the left column to the right column or vice versa. Once a stakeholder group is engaged into transactions or bound by a contract to the innovation, it is unlikely that it will ever become a group that only affects reputation. The pioneers and the government participate in the car development process right from the start. Customers and car manufacturers appear for the first time in the Ascent phase. However, once these stakeholder groups participate in the process they also become and remain important stakeholders. In the next step, the power, influence, and proximity of these stakeholder groups is determined by analyzing their development in the "Stakeholder Circle." Owing to space limitations, only two groups will be discussed here—customers and car manufacturers.

The development of customers is illustrated in Fig. 3. In the R&D phase the customers, which are still part of the public, are not identified yet and customer acceptance is uncertain. In the Ascent phase, there is a small amount of car protagonists to which the customers belong to. They make up the minority of the public but have medium influence on the car development process because they join forces in associations such as the ADAC (Haubner 2001).

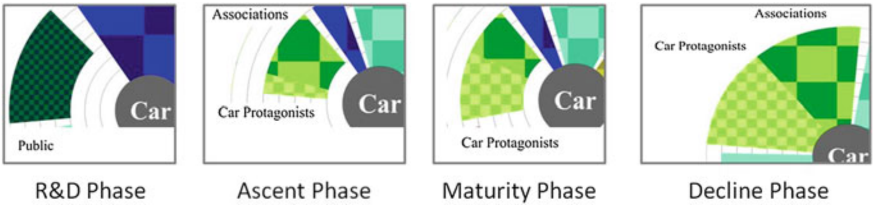

Fig. 3 Development of customers in the stakeholder circle

In the maturity phase, the number of car protagonists significantly increases. It was the first time that customers strongly influenced the car development process when they claimed for cheaper compact cars and individualization. These requirements led to a significant change in the product design and to the reorganization of the entire industry (Haipeter 2001). In the decline phase, the customers have the highest influence. They can choose from a number of different technologies which can then become most important in the future (Arnold et al. 2010). For this reason, the customers are the only group of stakeholders which have the power to stop the car development process after the R&D phase. The development of car manufacturers in the "Stakeholder Circle" is illustrated in Fig. 4.

In the R&D phase, pioneers invent and mainly improve the car in order to reach customer acceptance and market diffusion. At this early stage, the car is mainly equipped for motor sports (Haubner 2001). The car manufacturers become important in the ascent phase where the manufacturing processes need to be improved in order to generate a significantly increasing sales volume. They strongly influenced the product design to enable fast manufacturing, high performance, and reliability (Ford 2003). In the maturity phase, car manufacturers reorganize themselves and source out activities to suppliers. In this way, they lose influence on the car development process but remain successful in the increasingly competitive market. In the decline phase, car manufacturers and suppliers closely collaborate and share an almost equal amount of influence on the car development process. As the government provides financial support and fuelling infrastructure and due to the high uncertainty about customer acceptance, car manufacturers and suppliers together only have medium influence on the car development process.

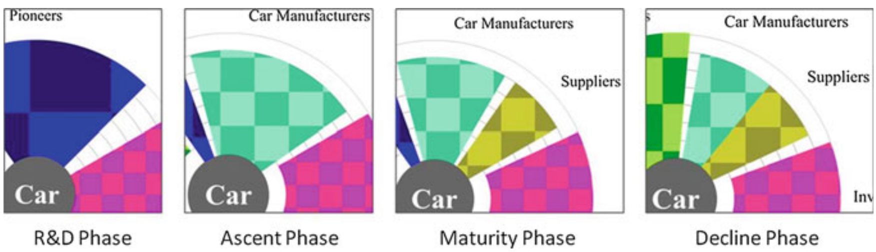

Fig. 4 Development of car manufacturers in the stakeholder circle

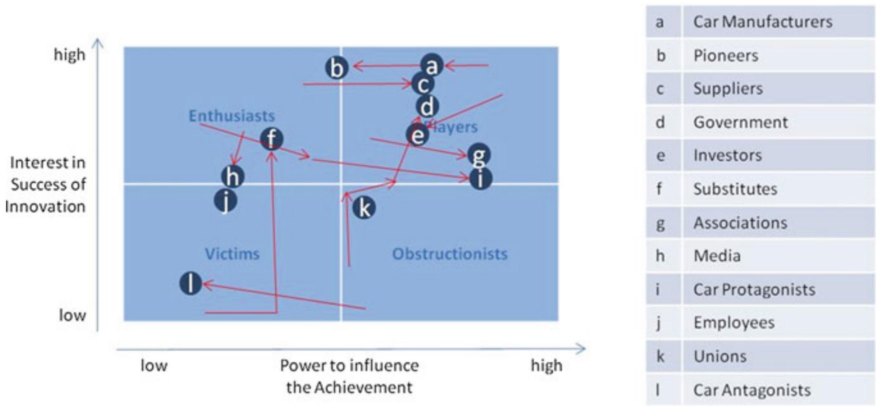

Fig. 5 Movement of stakeholders in the “power and interest grid”

The analysis of stakeholders with the help of the “Power and Interest Grid” resulted in three important findings. First, the locations of those stakeholders who directly research and work on the innovation are relatively stable (a, b, c in Fig. 5). Furthermore, it can be stated that many other stakeholders frequently change their location. This means on the one hand that they easily change their attitude toward the car. Reasons for this can be, for instance, new benefits or risks, which they identify as a consequence of the development (Dannenberg and Burgard 2007). Second, this figure shows that the power of stakeholders to influence the achievement of the car development process can change over time. Reasons for this can be, for example, the participation of new industries or political changes (Arnold et al. 2010). Third, the power to influence the car development process and the interest in its success positively relate to each other. There has never been a stakeholder in the upper left or lower right corner of the grid.

Conclusions

This research focuses on three research questions which are answered based on the findings of the stakeholder analysis.

Q1: Which aspects of the stakeholder analysis are important to consider when a definition of the term “responsible” in RI is developed?

Answer: The interests and influences of stakeholders frequently change. To address stakeholder demands, “responsibility” in RI needs a dynamic definition which is recurrently and continuously fixed, controlled, revised, and adapted to environmental changes. The groups of stakeholders, to which responsibility for an innovation can be assigned, do not change over time.

Q2: How much influence and foresight do pioneers and the early stages provide for RI in the full innovation life cycle?

Answer: The early stages provide essential information about the most important stakeholder groups of an innovation. Pioneers are able to retrench the entire innovation process, but customer acceptance and market diffusion cannot be predicted in the R&D Phase.

Q3: What roles do customers, car manufacturers, and governments play for RI in practice and how do these stakeholder groups influence each other?

Answer: The government can strongly influence customers and car manufacturers with incentives and regulations. However, their influence is limited to a geographical area. The influence of car manufacturers is strongly dependent on the customer demand and on the conditions of the market. Globalization and increasing competition have reduced their influence. The uncertainty about customer acceptance strongly affects the innovation process at the early stages. Once the customers are identified, their influence is constantly high. Customers, car manufacturers, and the government are all essential for RI in practice because they share high influence and responsibility in innovation processes. None of these stakeholder groups can be solely made responsible.

Based on our findings a research agenda is proposed. First, the car is special in its political relevance, environmental impact, and social embeddedness. Hence, experiences from stakeholder analysis of other innovation life cycles need to be collected. The same stakeholder groups can have completely different relations to other innovations that could provide new insights in their responsibilities. Other stakeholder groups can have a so far unknown influence on the development of responsible innovations. This information is essential for the definition of "responsible" in RI. Large-scale longitudinal data collection is now required to elaborate upon these findings and gain deeper insights into the meaning of responsible innovation and what it means for future supply chains.

References

Arnold H, Kuhnert F, Kurtz R, Bauer W (2010) Elektromobilität - Herausforderungen für Industrie und öffentliche Hand. Available from: http://www.iao.fraunhofer.de/images/downloads/elektromobilitaet.pdf. Accessed 22 Aug 2012

Bourne L, Walker DHT (2005) Visualising and mapping stakeholder influence. Manag Decis 43 (5):649–660

Bourne L, Walker DHT (2006) Using a visualising tool to study stakeholder influence - two australian examples. Proj Manag J 37(1):5–21

Clarkson MBE (1995) A stakeholder framework for analyzing and evaluating corporate social performance. Acad Manag Rev 20(1):92–117

Dannenberg J, Burgard J (2007) Innovationsmanagement in der Automobilindustrie. Available from: http://www.oliverwyman.de/deu-insights/Car_Innovation_2015_deutsch.pdf. Accessed 22 Aug 2013

Eden C, Ackermann F (2004) Making strategy, 5th edn. SAGE Publications Ltd, London
Ford H. (2003) My Life and Work. 1 ed. Fairfield: 1st World Library
Freeman RE, Harrison JS, Wicks AC (2010) Stakeholder theory: the state of the art, 1st edn. Cambridge University Press, Cambridge
Haipeter T (2001) Vom Fordismus zum Postfordismus? Über den Wandel des Produktionssystems bei Volkswagen seit den siebziger Jahren. In: Boch R (ed) Geschichte und Zukunft der deutschen Automobilindustrie, 1st edn. Steiner Verlag, Stuttgart, pp 216–246
Haubner B (2001) Automobilismus im Kaiserreich - Auftakt zur Massenmotorisierung oder Freizeitvergnügen für Wohlhabene. In: Boch R (ed) Geschichte und Zukunft der deutschen Automobilindustrie, 1st edn. Steiner Verlag, Stuttgart, pp 23–40
Hellström T (2003) Systemic innovation and risk: technology assessment and the challenge of responsible innovation. Technol Soc 25(3):369–384
Ishizu S, Sekiya M, Ishibashi K-I, Negami Y, Ata M (2007) Toward the responsible innovation with nanotechnology in Japan: our scope. J Nanopart Res 10(2):229–254
Krewitt W, Pregger T, Simon S, Naegler T (2010) A sustainable world energy outlook. Available from: http://www.greenpeace.org/international/Global/international/publications/climate/2010/fullreport.pdf. Accessed 24 Aug 2013
Lettice F, Pawar K, Rogers H (2013) Responsible innovation: what challenges does it pose for the new product development process? 19th international ICE & IEEE-ITMC international technology management conference. The Hague, Netherlands, 24–26 June
Lüdkte K (2012) Deutsche Erfindungen verändern die Welt. Available from: http://heureka-stories.de/Erfindungen/. Accessed 24 Aug 2013
Mahlouji H, Anaraki N (2009) Corporate social responsibility towards social responsible innovation: a dynamic capability approach. Int Rev Bus Res Pap 5(6):185–194
Owen R, Baxter D, Maynard T, Depledge M (2009) Beyond regulation: risk pricing and responsible innovation. Environ Sci Technol 43(18):6902–6906
Owen R, Macnaghten P, Stilgoe J (2012) Responsible research and innovation: From science in society to science for society, with society. Sci Publ Policy 39(6):751–760
Reed MS, Graves A, Dandy N, Posthumus H, Hubacek K, Morris J, Prell C, Quinn CH, Stringer LC (2009) Who's in and why? A typology of stakeholder analysis methods for natural resource management. J Environ Manage 90(5):1933–1949
Stieniczka N (2001) Vom fahrbaren Untersatz zur Chromkarosse mit "innerer Sicherheit" - der Wandel der Nutzeranforderungen an das Automobil in den 50er und 60er Jahren. In: Boch R (ed) Geschichte und Zukunft der deutschen Automobilindustrie. Steiner Verlag, Stuttgart, pp 177–200
Ubois J (2010) Responsible innovation/sustainable innovation. Annual meeting of the American anthropological association
Volkswagen AG (2013) Geschäftsbericht 2012. Wolfsburg
Weaver P, Bourne L (2002) Concepts for a 'Stakeholder Circle' Management Tool. PMI Melbourne chapter conference
Wadenpohl F (2010) Stakeholder Management bei grossen Verkehrsinfrastrukturprojekten, 1 edn. vdf Hochschulverlag AG, Zürich

Current Issues in Teaching Logistics Management

Helen Rogers and Christos Braziotis

Abstract By surveying university educators across the world who teach logistics [and supply chain management (SCM)], this paper sought to gauge key opinions and issues both now and in the future regarding how the subject is taught. Specifically, we identify both the most effective teaching methods currently used and those that logistics academics would like to use to impart knowledge to students. Responses were collected and analyzed from 17 countries via an anonymous questionnaire. Of the current teaching methods, case studies and in-class discussion emerged as the most used. In terms of future teaching methods that academics would like to use, simulations featured prominently as did the increased use of virtual-based teaching. The paper closes with a future research agenda including garnering opinion from other stakeholders such as industry executives and students as well as focusing on the likely implications of the increasing use of virtual classrooms.

Keywords Logistics teaching · Virtual classroom · Teaching methods

Introduction

What constitutes a logistics course?: In comparison to other disciplines in higher and further education, logistics remains relatively new, needing to overcome several barriers in developing the relevant academic programs (Lancioni et al. 2001). Currently, there is no consensus in terms of what constitutes course content; for

H. Rogers (✉)
Technische Hochschule Nürnberg Georg Simon Ohm, Bahnhofstraße 87, 90402 Nuremberg, Germany
e-mail: helen.rogers@th-nuernberg.de

C. Braziotis
Nottingham University Business School, Jubilee Campus, University of Nottingham, Nottingham, UK
e-mail: Christos.Braziotis@nottingham.ac.uk

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instance, Johnson and Pyke (2000) indicated there is considerable breadth of material employed in teaching logistics modules. Van Hoek (2001) suggested the need for logistics educators to be up to date with current practices and challenges to logistics due to evolutions in the market and business requirements. Acknowledging the pressure that this placed on academic staff, the same author suggested that "… they need to develop a 'continuous updating' approach to the content of courses, which might mean employing more didactic skills than those used in the traditional (monologues) lectures" (Van Hoek 2001, p. 518). Logistics and supply chain management (SCM) as a whole remains a dynamic domain of management and engineering, not least owing to the dynamic nature of industry. This in turn filters through to questions regarding what is relevant at a university teaching level, meaning that the syllabus is constantly in a state of flux (Gravier and Farris 2008). Understanding logistics education remains a topic of interest, with previous research focusing primarily on the analysis of existing logistics curricula (e.g., Gravier and Farris 2008; Wu 2007).

To extend our understanding of how logistics is taught and identify future trends, we set the following research question: "What is the 'as-is situation' of logistics teaching in higher education?" Therefore, the purpose of this research directed at all levels of logistics teaching in higher education is to:

- Take stock of what is currently covered in logistics courses across the world;
- Gauge the effectiveness of current teaching methods;
- Determine which teaching methods are highly rated by students;
- Establish what is on the "wish list" of teaching methods and determine any impediments to implementing these;
- Gain insights into how logistics teaching is likely to change in future.

This is one of the first papers that attempts to collectively capture the detailed aspects of teaching logistics: the means of teaching (currently and in the future), as well as of the breadth of means used in the assessment of such modules—considering the views of the educators and their perception on what students value. Subsequently, the paper seeks to capture what are considered to be the core topics of logistics. Based on our literature review and discussions with colleagues, it is anticipated that such information is of high interest to academics involved in teaching in the domain of logistics and SCM.

Methodology

The questionnaire was developed by two experienced academics who teach logistics at university level and a pilot tested by further three experienced academics who teach logistics in three countries (UK, Germany, and India). The survey instrument consisted of 14 questions: most of them "tick box" questions covering demographic questions (gender, experience), followed by specific logistics teaching questions. Where practical, the questions allowed the respondent to select "other" and type in an alternative response in case one of the options provided did not cover his/her views. In other words, a combination of open-ended (e.g., in the case of the means of teaching logistics) and closed questions (e.g. demographics) was employed, paying particular attention to the wording to avoid, among other issues, leading or loaded questions (e.g., Forza 2002). The questionnaire was developed in a way that it took the respondent approximately 5 min to complete, with the option to leave individual comments. The questionnaire could be completed anonymously or by leaving contact details (if a summary of the results was requested). The online link to answer the questionnaire was available for a short period of time only (10 days) in late 2013. An e-mail providing the link to the survey was sent to 600 academics in the International Symposium on Logistics (ISL21.org) community worldwide.

Survey Results

In total, 50 usable responses were received (response rate of 8 %). The respondents held a variety of academic roles, ranging from PhD students to professors, the latter constituting the majority (Fig. 1).

In terms of gender profile, there were 10 female and 40 male respondents. Overall, the respondents were employed in several countries, with the majority (60 %) being employed by European academic institutions (as shown in Fig. 2).

A good level of experience was also represented by the sample size, with 58 % of the respondents having more than 10 years of teaching experience (Fig. 3). This

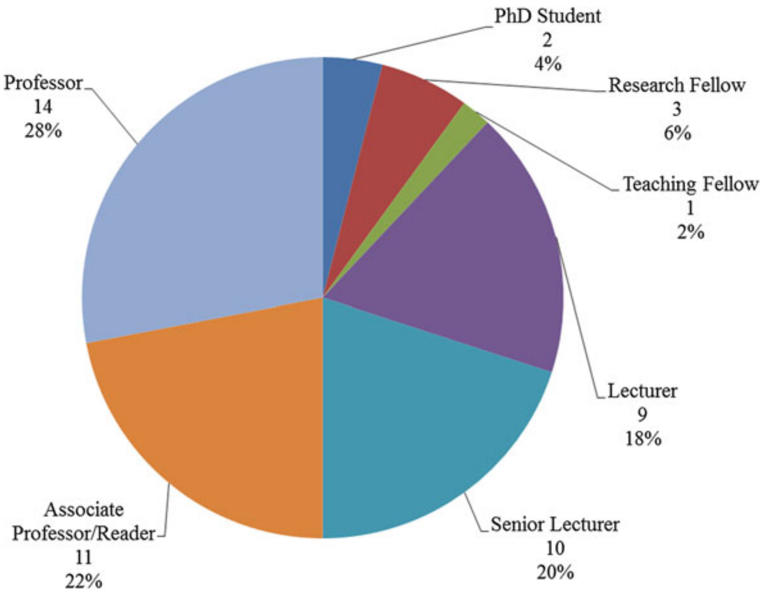


Fig. 1 Respondents by academic role

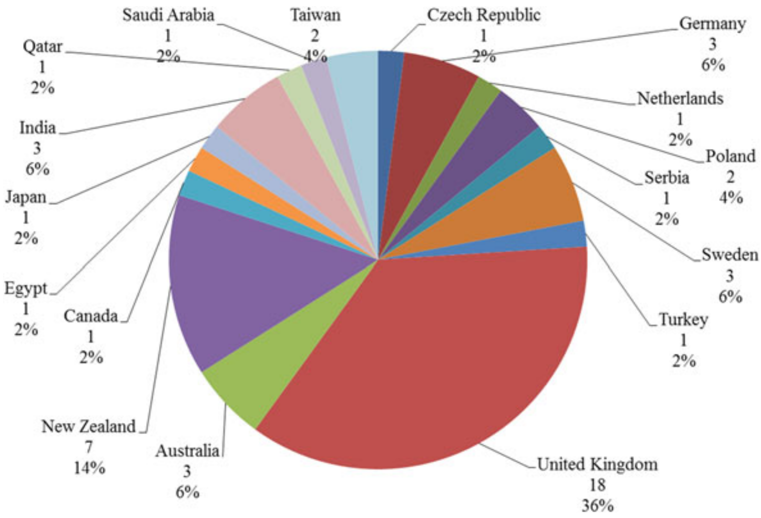
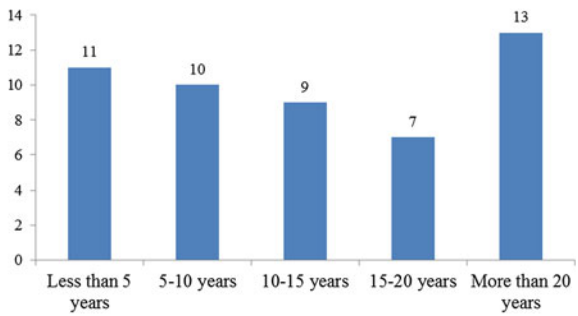


Fig. 2 Respondents by country of employment

may be attributed to the number of professors and associate professors/readers participating in the survey, representing a total of 50 % of the sample. Based on the survey, the majority of the teaching in logistics and SCM takes place on the postgraduate level, followed by the undergraduate level, the executive level, and finally company/exec training (Fig. 4). Interestingly, academic educators with less than 5 years of experience are involved in postgraduate teaching (9), executive teaching (1), and company training (2). However, as perhaps anticipated, the majority of the contribution for these three types of teaching comes from senior lecturers, associate professors/readers, and professors.

Several interesting findings emerged from the comparison of the current means used in teaching logistics courses against future wishes (Fig. 5). Most of the current methods experienced a dip in preference from what is currently used to what respondents would like to use in the future; this included the use of case studies (from 44 currently using it to 24 wanting to use it in the future), company meetings/observations (from 13 to 11), videos (from 35 to 20), company visits

Fig. 3 Respondents by experience



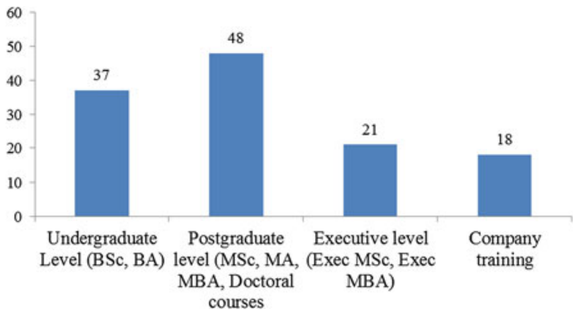


Fig. 4 Level of teaching carried out

(from 26 to 25), presentation/textbook slides (from 34 to 20), class discussions/question in lectures to reinforce previous learning/topic (from 42 to 23), individual coursework/student projects (from 36 to 20), group coursework/student projects (from 36 to 23), guest speakers from industry (from 34 to 28), YouTube video clips (from 27 to 19). At the same time, more respondents indicated they wanted to employ more business games/simulations (from 26 to 33), competitions (e.g. 'Logistics Masters') (from 1 to 14), guest speakers from academia (from 13 to 15), Massive Open Online Courses (MOOCs) (from 2 to 8), live video linkups (from 2 to 7), and visual factory tours (from 2 to 14). The employment of master classes remained unchanged (at 8). As part of other current methods, some respondents made reference to MS Excel tutorials, outbound training programs for experiential learning, analogies (bullwhip/traffic congestion), case company problems, internships/placements for research students, research informed material, as well as own presentation slides. As part of the means they would like to use, one participant noted research-informed materials, while three indicated they do not wish to change their approach, and one indicated this was dependent on the learning objective. The research indicated an interesting shift in the teaching means preference. For instance, while the current means for undergraduate level teaching are case studies (33) and in-class discussions (31), the means academic educators would like to use are mainly business games/simulations (22). A similar picture emerged with postgraduate level teaching. The current means here are case studies (43), followed by in-class discussion (41), videos (35), individual (35), and group (35) coursework, and guest speakers from industry (34). However, the means academic educators would like to use are mainly business games/simulations (31), followed by company visits (25), and guest speakers from industry (27).

The main aspects preventing academics from using the methods they would like to teach are time constraints (mainly associated with the preparation of the relevant material, and second with the duration of the teaching sessions), followed by the associated cost (Fig. 6). The issue of availability of and access to industrial speakers and of suitable cases was also raised, as well as of the multiple location teaching, availability of online resources and the level and number of students. Interestingly, three respondents indicated "none" as a barrier, indicating no need to amend the

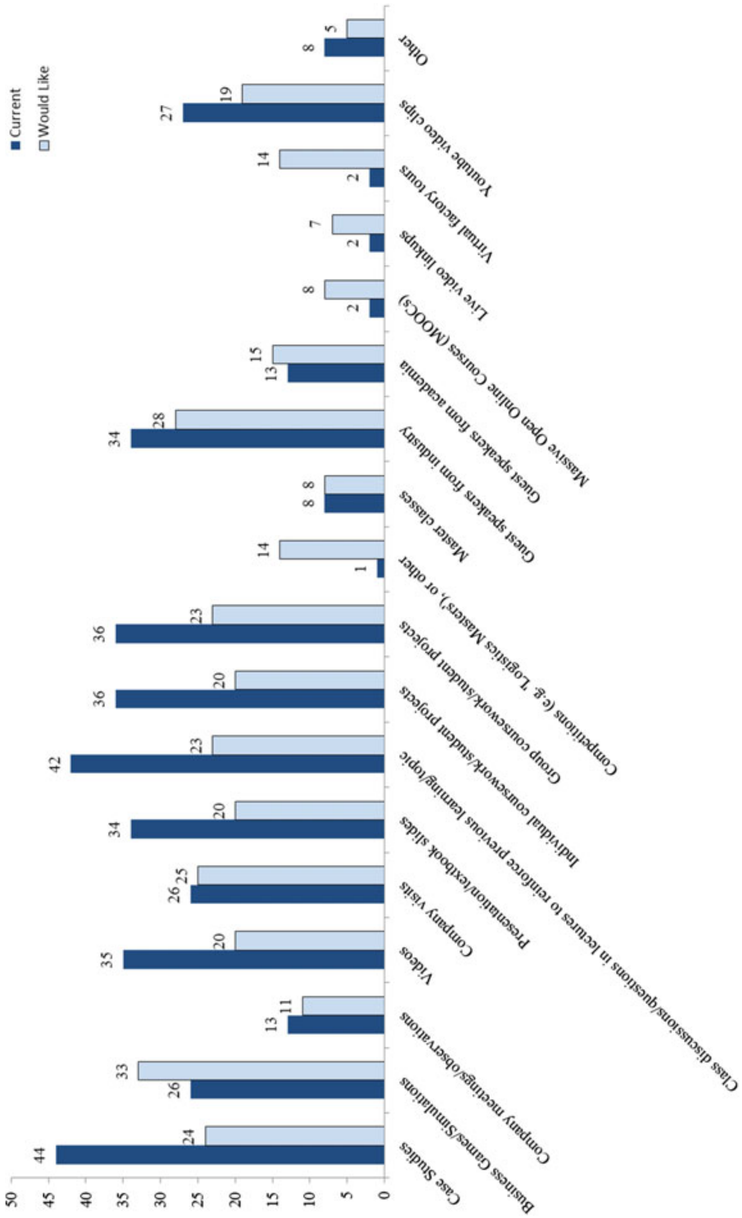


Fig. 5 Current versus "would like" teaching

Fig. 6 Main barriers

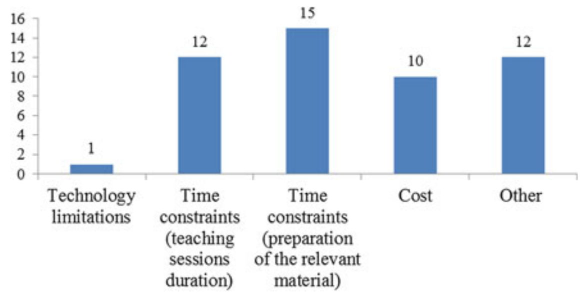
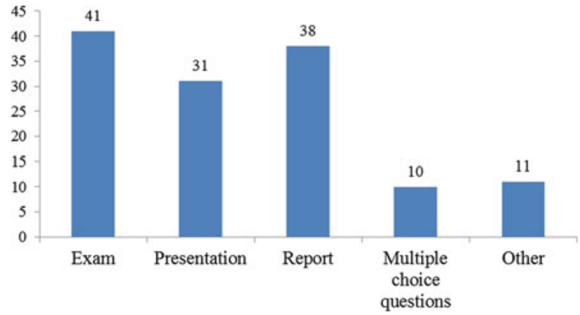


Fig. 7 Course assessment methods



relevant teaching methods. To add to our picture of how logistics is taught, a question in the survey instrument asked the respondents to indicate the assessment methods employed. The majority indicated the exam as the main assessment instrument, closely followed by the report assessment and then presentation (Fig. 7). In fact, the exam was preferred by those academics with either 10 years of experience and less (20), or more than 20 years (12). The least preferred way appears to be multiple choice questions, while few respondents indicated case study analysis and MS Excel-based or class participation as assessment instruments. As perhaps expected, presentations and reports as a means of assessment were employed to a higher degree in postgraduate rather than undergraduate level teaching. Interestingly, multiple choice questions were used across all levels, from undergraduate level to company training.

Case studies emerged as the primary and secondary choice of teaching means that students find particularly useful, or for which the academic educator gets the best feedback (Fig. 8). Company visits were the third choice, while videos and presentation/textbook slides followed.

In this sample, logistics was taught in a more qualitative way (34 respondents, i.e., 68 %), with only 5 (10 %) teaching it in a more quantitative way, and 11 (22 %) with an even balance (the latter practiced predominantly by academics with more than 20 years of experience). As discussed above, logistics curricula have been the topic of research in the past. Here “inventory management” and “distribution and networks” emerged as the most likely core logistics topics (Fig. 9), followed by

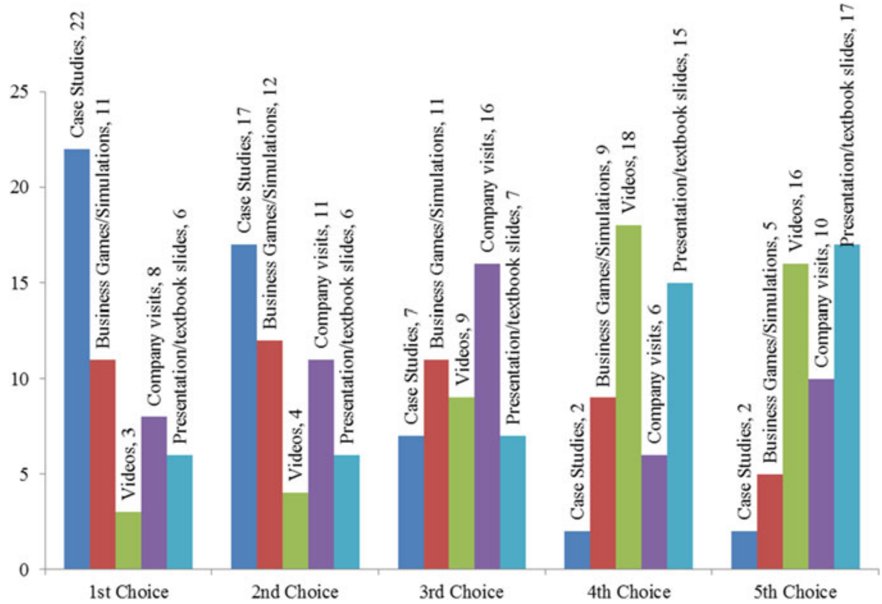


Fig. 8 Students preference

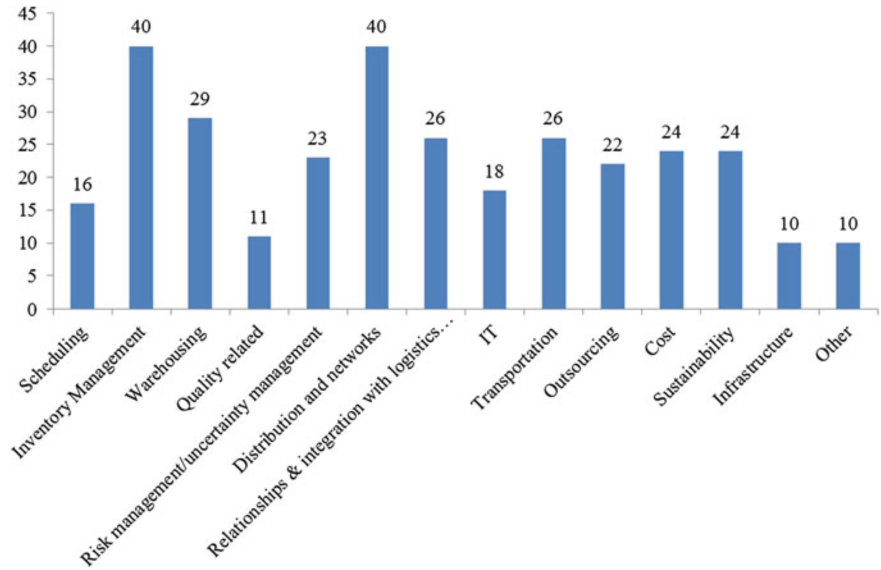


Fig. 9 Core topics

"warehousing," "transportation," and "relationships and integration with logistics service providers." Less likely core topics were "infrastructure" and "quality" issues, while respondents added "humanitarian logistics," "procurement," and "purchasing and supply/operations management," with one indicating all the topics were appropriate to ensure customer needs were well-served. Figure 9 illustrates the complexity of a modern logistics course, in terms of the range of topics covered. This places demands on teaching staff, as some topics require a specialized background and are technical in nature. It raises questions of appropriately and adequately staffing academic departments to cover logistics curricula.

Discussion

Although timescales were short, the interest in this research was notable, as evidenced by the 50 responses during a 10-day period. Logistics is taught across all levels of higher education and company training. However, there are significant barriers to overcome to increase the teaching effectiveness—most of which are time and cost-related. Our survey has indicated the complexity and difficulty in effectively teaching logistics and the multiple aspects it encapsulates. Furthermore, it has indicated some interesting areas that require further research. For instance, there was evidence to suggest that while there are different approaches used in teaching logistics, some of the commonly used methods (e.g., case studies, in-class discussions, individual and group coursework) do not appear to be the most dominant means in the future. In contrast, business games/simulation and competitions appear to be the preferred means of teaching in the future. The underlying reasons and the implications of such a shift will need to be explored in the next phase of this research. This becomes essential when one considers the contradictory evidence provided in terms of the perception of academic educators on what students prefer as a means of teaching; namely primarily case studies and secondarily business games/simulation needs. To a great extent, these have to be considered in light of the core topics for logistics as identified by the research, namely primarily inventory management and distribution and networks, as well as the implication of the evidence that logistics is currently taught mostly from a qualitative rather than a quantitative perspective. In this respect, this initial phase of our research provided some exploratory evidence on the way logistics is taught.

A New Research Agenda

In line with our initial findings, we propose the following research agenda:

1. A comprehensive and ongoing literature review of teaching developments in logistics and SCM.

2. A follow-up, large-scale, and more rigorous online questionnaire to allow for more reliable and insightful data analysis/interpretation.
3. Garner opinion from logistics managers on what they want to see taught on logistics courses to best equip logistics graduates for industry.
4. Gain insights directly from students on what they would expect and wish to see on a logistics course syllabus. Whilst those at undergraduate level may not necessarily have fixed expectations, postgraduate and executive course students could provide some interesting insights drawn from their career experience.
5. Evaluate whether logistics course titles aptly reflect the course contents.
6. Further investigate the influence of internationalization on core logistics topics. Whilst one could argue this is captured within the core topics of logistics it warrants more explanation, e.g., is there a need for specialized subtopics on international/global logistics management?
7. Evaluate implications of the increasing use of virtual and online teaching.

Conclusions

This paper has provided initial insights into the way logistics and SCM is currently taught based on a straw poll small sample of logistics educators. The results indicate that logistics is indeed a dynamic and evolving discipline, with a relatively high degree of complexity, making it a challenging domain to teach. The positive response to the survey (carried out over a 10 day period) indicates that there is interest from academics to collaborate and improve the teaching techniques along with the course syllabuses of the discipline. The next step in our research will involve designing and implementing a full-scale and rigorous questionnaire based on the findings of this initial survey. The full-scale survey will also avoid the limitations associated with the small sample size represented in this paper owing to the short duration and the fact that many academics were away from work due to the Christmas holidays.

References

Forza C (2002) Survey research in operations management: a process-based perspective. Int J Oper Prod Manag 22(2):152–194

Gravier MJ, Farris MT (2008) An analysis of logistics pedagogical literature: past and future trends in curriculum, content, and pedagogy. Int J Logist Manag 19(2):233–253

Johnson ME, Pyke DF (2000) A framework for teaching supply chain management. Prod Oper Manag 9(1):2–18

Lancioni R, Forman H, Smith MF (2001) Logistics and supply chain education: roadblocks and challenges. Int J Phys Distrib Logist Manag 31(10):733–745

Van Hoek RI (2001) Logistics education: Achieving market and research driven skill development. Int J Phys Distrib Logist Manag 31(7/8):505–519

Wu Y-CJ (2007) Contemporary logistics education: an international perspective. Int J Phys Distrib Logist Manag 37(7):504–528

A Concept for an Integrated Transport Management System in Distributed Production Networks

Daniel Dreßler, Ulrike Beißert, Torben Beyhoff and Thomas Wirtz

Abstract Usually, production and supply networks are characterized by insufficient transports, where resources are not fully utilized, delivery time performance and service level can be improved. Existing IT-systems do not support a holistic planning of transports considering all participants and their available resources. However, especially in supply chains, an integrated planning of transport resources is essential. Participants, e.g., transport service providers require the same resources like cranes at loading points. In this paper, a concept for an integrated transport management system is introduced supporting the long- and short-term demand-capacity planning as well as the execution phase.

Keywords Transport management system · Capacity planning · Disruption management · Supply chain management

Introduction

Transports in production and supply networks are often characterized by inefficiencies in utilization of resources and poor performance levels. Furthermore, they are prone to disruptions. The lack of information and missing holistic planning process can be identified causing these problems. A multitude of process participants are involved in transport execution. For example, different transport

D. Dreßler (✉) · U. Beißert
Fraunhofer IML, Joseph-von-Fraunhofer Str. 2-4, 44227 Dortmund, Germany
e-mail: daniel.dressler@iml.fraunhofer.de

U. Beißert
e-mail: ulrike.beissert@iml.fraunhofer.de

T. Beyhoff · T. Wirtz
ThyssenKrupp Steel Europe AG, Kaiser-Wilhelm-Str. 100, 47166 Duisburg, Germany
e-mail: torben.beyhoff@thyssenkrupp.com

T. Wirtz
e-mail: thomas.wirtz@thyssenkrupp.com

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service providers on external and internal relations supply the customers and production plants within the network with goods. Thereby, different modes of transport like truck or railway have to be considered as well as the limited capacities of service providers' resources. Looking at the plant, the loading and unloading devices are scarce resources that are requested by every transport process. Thus, the arrival of transport resources has to be coordinated to avoid waiting times at the (un–) loading points. Currently, each participant organizes his own transport processes without informing other participants. This results in a general process nontransparency and the overbooking of resources is common as well as an inefficient utilization of transport capacity. Besides the missing holistic planning process, the lack of information leads to a disruption management that is executed locally. Within this context, local disruption management means that decision makers are focused on identifying measures to resolve the disruption very fast and/or to the lowest price. The effects on the whole network are often not considered or even transparent investigated to identify appropriate measures.

In practice, in production and supply networks various IT-systems already exist, to plan production supply and transports. Systems like ERP and Production Planning and Control (PPC) systems are well established to support production planning. During production planning, the transport processes are not focused and therefore considered as certain time buffers between production processes. Usually, within these systems transport capacities are considered as unlimited resources. On the transport planning side, mainly transport management systems (TMS) are used. In general, these systems focus on, e.g., itinerary planning, loading consolidation, and order procurement. All these systems are not able to perform a planning that can be applied for the introduced problems.

Therefore, a system is necessary which allows an integrated transport planning considering different transport modes as well as lead times. Furthermore, the system should distinguish between different data aggregation. Based on the production schedule a forecast of internal and external transport demand in a long term planning horizon is required. Thus, capacities can be reserved in advance and possible bottlenecks can be identified early. When all transport demand for a certain period is known, a detailed planning for a short-term planning horizon considering the current utilization of loading capacities and external transports is necessary. This enables an efficient transport planning and avoids waiting times and capacity overloads. Additionally, in case of unexpected events, like truck breakdown, a decision support should be given to evaluate measures considering effects on the whole network.

Therefore, in cooperation with the steel producer ThyssenKrupp Steel Europe AG (TKSE), the concept of an integrated transport planning and control system is developed. This system should support the planning of transport and loading capacities for semi-finished and finished steel products in a production network. Furthermore, the system should support the operational transport execution, especially an evaluation of measures when disruptions occur. Within this paper, a conceptual approach of an integrated transport management system is introduced.

Review Transport Management and Planning Systems

To support planning of processes and resources in production and transport networks a multitude of different IT-systems and tools exist (Schuh and Stich 2012).

TMS support the process around planning and executing the transport.

PPC systems as part of ERP systems plan and schedule the companies' production and financial resources and create a master schedule for production (Schmidt 2008; Wannenwetsch 2006).

In the following, it is determined whether the current understanding of TMS meets the requirements of the problem statement. Besides, it should be evaluated if systems exist that allow planning of transports and their required capacities in distributed production and supply networks.

The VDI guideline 3591 focuses on internal transports and defines a TMS as a "computer-based aid for planning and control of internal transports within a company, external transports of a freight carrier or individual traffic flows" (VDI 3591). The tasks and aims of TMS are specified as: optimization of transports, creation of system transparency, and reduction of costs. Furthermore, this guideline divides the functions of a TMS in registration of transport orders, central administration of transport orders, and resource assignment. The transport orders are entered either manually or transmitted from planning systems. The registration of transport demand, derivation of transport orders, and balancing available capacities is not considered with this guideline (VDI 3591).

Burgwinkel (1998) developed a TMS for planning, control, and surveillance of the material flow in coal mines. He suggests that a TMS should provide performance indicators to support the planning of succeeding processes like utilization and number of transports. However, capacities of transports or a forecast of demanded resources are also not considered within these suggestions.

Buchholz et al. (1998) define system requirements especially for freight companies. The main tasks are route planning, vehicle scheduling, and operational management of transports. This definition focuses on single freight carriers. Therefore, only capacities of the company are considered in their planning concept while all other network capacities are not integrated in planning.

The study "IT in der Logistik 2013/2014" presents an overview of current providers of IT-systems used in logistics (Ten Hompel 2013). A high variety of TMS is available at the market. In Logistik Heute (2005) systems have already been evaluated amongst others by their main functions, e.g., disposition (scheduling), itinerary planning, order management, transport modes. Most systems have equal basic functions but differ in field of application and interfaces to other systems. Exemplarily, the software SyncroTESS by INFORM is introduced. SyncroTESS provides, e.g., real-time scheduling of orders for internal, intraplant, and regional transports. The orders are assigned to the transport vehicles considering of priorities, shortest routes, workload, and others. Combined with the function SyncroSupply, as well by INFORM, time windows at loading points for vehicles can be considered (Inform 2013). Like many TMS, SyncroTESS supports the operative process of the transport execution, provides functions to optimize the utilization of vehicles as well as transportation times and costs through scheduling and route planning. Other tools also provide rescheduling methods to include additional orders. According to the given definitions, the main functions of existing systems are concentrated on single freight carriers or certain fields of application. The integration of different service providers and network-wide planning of capacities is not considered.

Since planning of capacities is the main function of PPC it should be determined whether transport capacities can be planned in these systems and meet the missing requirements from the TMS. Especially in steel production, where high workload of the machinery is necessary, PPC and APS systems are important (Deuse and Deckert 2006). PPC systems are part of ERP systems. The purpose of the system is to schedule orders with a start and end date on the machines along the production process and guarantee a punctual production and high utilization of the machinery (Schuh and Stich 2012; Schmidt 2008; Wannenwetsch 2006). A high variety of PPC systems is available on the market. They are mostly customized for an industrial sector or a company. An overview is given in Kurbel (2005). One widely used solution is mySAP ERP as part of the mySAP business suite. In the "Value Generation" section, e.g., production orders are created and dependencies defined. For transportation planning, the tasks are, e.g., route planning, transport carrier selection, and freight calculation (Kurbel 2005).

In conclusion, ERP/PPC systems are systems to plan orders in a supply chain but they focus mainly on production. Relevant aspects to plan and handle transports in the supply chain are not considered. Especially, internal capacity restrictions, capacities of external partners and transport service providers are not included in the planning phase (Hellingrath et al. 2004). Although PPC systems include transport times in planning, transport capacities remain unconsidered, respectively are not integrated. The resulting master production schedule is based on the assumption that sufficient transport capacities are available to fulfill all necessary product movements in time.

According to the problem statement, a system is demanded that allows the forecast of transport demand, integrated capacity planning, and disruption management. Neither current available PPC systems nor TMS allow the consideration of transport capacities on a network level or disruption management. Within this paper, an integrated TMS is introduced consisting of three components to plan roughly capacity demand, to schedule transport orders, and at least to investigate disruptions during the execution.

Integrated Transport Management System

The integrated transport management system is developed in cooperation with TKSE. The general task of the system is planning and scheduling the transport demand based on available resources. Figure 1 shows a general overview of the concept.

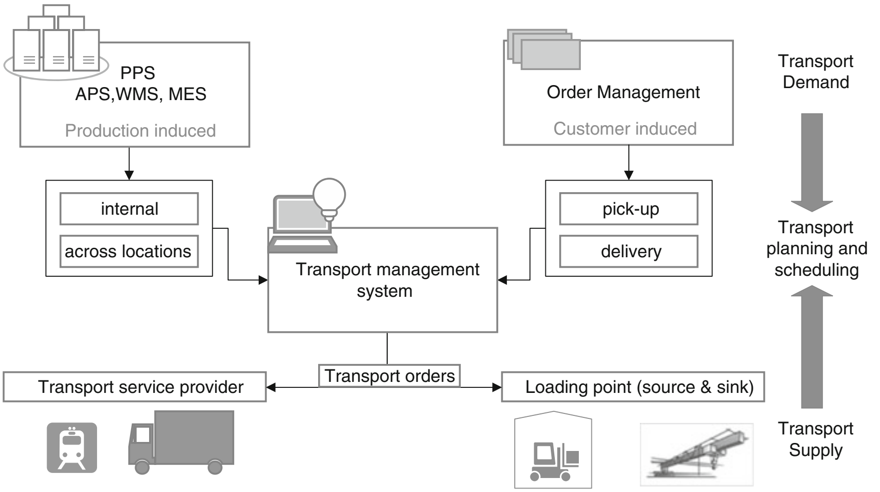

Fig. 1 Balance between transport demand and supply

The transport demand has to be divided into production- and customer-induced demand. Production-induced demand causes a material transport between two production plants which results in internal or interplant transports. Internal transports refer to transports between two plants at the same site. Contrary to that, interplant transports are transports between two sites. Customer-induced demand results in material transports between plants and customers. Thus, customer demand results in external transports that can be further divided into delivery transports executed by the producer and pick-up transports organized by the customer himself.

Different IT-systems are involved in the planning process. The production-induced demand can be derived from the PPC system or similar production planning systems. On the other hand, the customer demand is derived from the order management systems. Different kinds of resources are involved to execute the transport: transport resources like trucks, trains, and its wagons from different transport service providers and loading devices like cranes at the loading and unloading points. Depending on the available capacity of the resources and the demand, the integrated transport management system generates transport orders and assigns the orders to the resources.

Production planning is often based on a continuous planning approach which means the planning is renewed periodically, e.g., every day (Schuh and Stich 2012; Klein and Scholl 2004). Depending on the considered time horizon for planning, the deviation of the demand between planning and execution can be vast. For example, customer-induced transport demand often occurs unscheduled and on short notice. Thus, considering long planning horizon, the transport demand can only be forecasted until the material becomes physical available and can be scheduled as a real transport order. The estimation of transport demand has to be performed in the same interval like production planning.

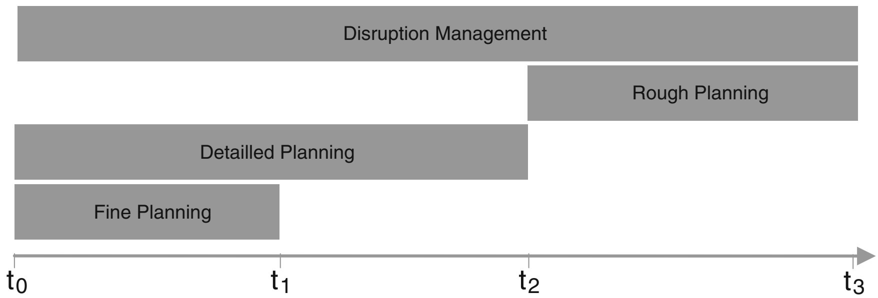

Fig. 2 Planning phases of the integrated TMS

The integrated transport management system is designed to allow the forecasting of future transport demand and estimate necessary transport capacities. Furthermore, the system should allow the generation of precise transport plans for the actual execution date. At least the system should provide assistance whenever disruptions during the execution occur. Therefore, the system consists of different planning phases: (1) rough planning, (2) detail and fine planning, and (3) disruption management (cf. Fig. 2). Based on the present initial planning point t_0, the necessary transport capacities from t_2 until t_3 is only planned roughly based on demand forecast. The transport demand becomes reliable transport orders, e.g., when the material has been produced or customer orders certain material. Transport orders for one planning period (e.g. a shift) are considered within the detail planning (t_0–t_2). Depending on the modes of transport, the planning processes require different lead times. For e.g., truck transports can be scheduled within a shorter lead time than train transports. Thus, the fine planning is introduced. Furthermore, when disruptions occur during the planning and execution process, the disruption management is needed to investigate proper measures to adapt the plan or system considering the effects on the whole network. The phases are described in detail below.

Rough Planning

Within rough planning the future transport demand for time period t_2–t_3 is forecasted and the resulting demand for transport capacity is roughly calculated. The production-induced transport demand is defined based on the master schedule of production planning. The customer-induced transport demand is determined by existing customer orders and prognosis based on historical data. The result of the rough planning is an approximation of demand for transport capacity for the time period t_2–t_3. This information is communicated to the process participants. Based on this information, the participants can plan their own processes and capacity availability. Thus, bottlenecks and high utilization can be identified in advance and countered proactively.

In a first step, the transport horizon for the production-induced transport demand is identified. The transport horizon is the time frame between the earliest possible pick-up time (EPPT) and the latest possible delivery time (LPDT) of an order. This information is derived from the starting and ending time of the production order given by the production master plan.

Afterward, an exact transport date is planned. The scarce resources have to be considered to guarantee that capacities are not overloaded. Initially, the mode of the transport has to be defined, e.g., by truck, train or ship, considering the infrastructural conditions of the loading (source) and unloading point (sink). Whenever different modes are possible, usually the economical solution is preferred. Within the supply chain of a steel mill, the goods are very heavy; so, for e.g., for land transport from economical point of view, the train is being preferred toward trucks.

Next step is the investigation of the resource availability per shift at the scheduled transport date. Transport demand with high priority is first investigated and its required resources are blocked. In this phase, the overbooking of transport resources is allowed within a certain limit that is defined by the planners. The loading resources have to be considered separately because they are used for different transport modes and types of transport. Thus, the capacity offer from the loading device is segmented (cf. Fig. 3). When the preferred transport resource is not available on the estimated date another transport date within the transport horizon has to be evaluated. If the transport cannot be planned within the desired transport horizon another transport mode has to be selected and the scheduling procedure starts from the beginning. When no transport date can be found within the transport horizon under the current capacities, the capacity limits have to be increased and the situation has to be evaluated in detail.

Besides production-induced transport demand, also the customer-induced transport demand has to be planned. Due to customer-induced transport demand is usually announced after production-induced transport demand it is necessary to reserve certain capacities to avoid bottlenecks and late delivery of products. However, the demand is only relevant for loading points. The capacities for customer-induced transport demand are blocked based on available orders or historical data.

The rough planning is performed continuously. Thereby, changes of the transport demand and therefore resource requirement are updated as well.

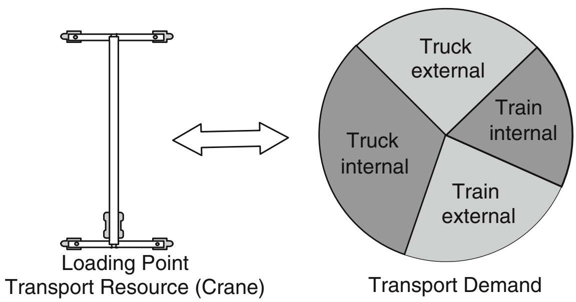

Fig. 3 Segmented transport demand at a loading point

Detail Planning

Within the detail planning phase, the production- and customer-induced transport orders are scheduled and assigned to the different transport service providers. The planning horizon is individually specified, e.g., a shift or a day. The specification depends on the lead times for different transport modes. Longer lead times are, e.g., required by train transports while truck transports are planned within shorter lead times. Therefore, the phase of the fine planning is introduced. Using the former generated transport schedule, orders which occur on shorter notice are then integrated.

The bases for detail planning are reliable information regarding produced and available material that is ready for transport. This information is delivered by APS, Warehouse Management Systems (WMS) or Manufacturing Execution Systems (MES) (cf. Fig. 1). Furthermore, order management systems deliver customer-induced orders.

In the beginning of the planning procedure, deviations between the transport demand from the rough planning and transport orders of detailed planning have to be identified. Thus, each transport order is compared with its former known transport demand. When orders differ to the declared demand or orders are newly created, the available capacities from the transport service providers have to be checked again and resource demand has to be blocked. This procedure follows the procedure during rough planning. Afterward, transport demand requiring resources with long lead times like transports by train are identified and scheduled. The resulting transport orders are assigned to the transport service providers and time windows at loading points are blocked. Transport demand for service providers with short lead times are not scheduled during this phase, they remain planned on the capacity level. On the other side certain customer orders that are already known are scheduled as well. Finally, the segments of capacity offers at the loading points are adapted (cf. Fig. 3). For, e.g., if less capacity is needed for internal trains than previously reserved, the free capacity is assigned to truck transport segments.

The bases for fine planning are reliable information regarding produced and available material and blocked time windows for external transport vehicles at the loading points. This can be derived, for e.g., from a time slot management system. The fine planning procedure is similar to the detailed planning. First, the transport demand is scheduled considering, e.g., blocked time windows by train and customer vehicles at the loading points. Afterward, the resulting transport orders are assigned to the transport service providers and time windows at loading points are blocked. In result, transport service providers receive a plan with detailed information when to be at a loading point. In the same manner, loading points receive detailed information regarding arrival times of internal and external trucks, and the loading end dates for the transport orders.

Disruption Management

The master production planning in complex networks with distributed locations is an incident-sensitive planning environment. Unexpected events like production changes and disruptions occur during the planning as well as in the execution phase. The task of the disruption management is to identify and register disruptions like changes in transport demand and offer and technical failures of transport devices. Their effect on the current plan has to be evaluated before the plan is rescheduled considering planning criteria.

When disruptions affect a transport demand in the rough planning phase, the disruption is considered in the next planning run. Mostly, the effects of rescheduling measures would not be directly noticeable for the participants, e.g., when one order is substituted by another with similar basic conditions. However, during the phase of the detail or fine planning, when orders are already scheduled, the effect of the disruption on the current transport plan has to be evaluated. Due to limited resources, a disruption can affect the whole transport plan. Therefore, a systematic concept is needed to evaluate the disruption and the effect of counter measures on the current plan.

When no integrated planning exists and a disruption event occurs, very often in networks the implementation of a local countermeasure without considering the effects on the whole network can be observed. To avoid negative effects, the component disruption management of the integrated TLS is introduced. The component consists of three parts: analysis, planning, and evaluation (cf. Fig. 4).

The disruption database is used for the registration of disruptions and countermeasures. Based on given and historical disruption data, e.g., duration, place, and applied countermeasure, an experiment plan is created to evaluate the countermeasures considering variable durations for disruption. The variable durations are derived from the historical data. Using simulation, different alternative schedules are generated and evaluated. Thereby, plan and output stability are crucial evaluation criteria to allow identification of plans with minimum adaptations to avoid strong turbulences during execution. Based on transparent information and a broad investigation, planners are able to objectively identify appropriate countermeasure considering the effects on the whole network. In result, a new transport plan is generated and provided to the network participants. The concept has been described and applied in detail in Dreßler and Beißert (2013).

Fig. 4 Components of the disruption management

Conclusions and Outlook

Current IT-systems in production, transport, and resource planning are insufficient when transport capacities in a network have to be planed and scheduled. Especially, the integration of external transport service providers is performed inadequately. While PPC systems only consider transports as time buffer, common TMS focus on transport execution or single freight carriers. A network-wide capacity planning is not addressed. With the integrated TMS a concept is introduced to plan and forecast transport demand considering transport resources in a network. The separation in rough planning, detail planning, and disruption management allows support during different phases of planning. Thus, the integrated TLS can be used for long- and short-term planning and even to support the transport execution. Bottlenecks at scarce resources are early recognized.

In future, the concept is planned to be implemented and tested at TKSE. To demonstrate the potential of this integrated planning approach various studies are envisaged like case studies to analyze the cost-benefits. Therefore, as well simulation models can be used. On the other side, the disruption management component needs to be extended since current concept only considers disruptions that are directly influenceable by countermeasures but not those disruptions where only the effects can be diminished.

References

Buchholz J, Clausen U, Vastag A (1998) Handbuch der Verkehrslogistik. Logistik in Industrie, Handel und Dienstleistungen. Springer, Berlin

Burgwinkel P (1998) Das Transportleitsystem TLS. Ein zentrales Planungs-, Steuerungs- und Überwachungssystem zur Verbesserung der Materiallogistik von Steinkohlenbergwerken. Habilitation thesis. Techn. Hochsch. Aachen. Aachener Beiträge zur Angewandten Rechnertechnik des Instituts für Bergwerks- und Hüttenmaschinenkunde, vol. 31. Wissenschaftsverl. Mainz, Aachen

Deuse J, Deckert C (2006) Lean steel production. Stahl und Eisen 126:84–86

Dreßler D, Beißert U (2013) Integrated disruption management approach in complex transport networks considering variable durations of disruptions. In: Dangelmaier W, Laroque C, Klaas A (eds) Simulation in Produktion und Logistik. Entscheidungsunterstützung von der Planung bis zur Steuerung, pp 157–166

Hellingrath B, Laakmann F, Nayabi K (2004) Auswahl und Einführung von SCM-Softwaresystemen. In: Beckmann H (ed) Supply chain management. Strategien und Entwicklungstendenzen in Spitzenunternehmen. Springer, Berlin, pp 99–122

Heute Logistik (2005) Die Qual der Wahl. Logistik Heute 5:36–37

Inform (2013) Optimieren mit einem Transportleitsystem (Staplerleitsystem). http://www.inform-software.de/produkte/syncrotess/transportleitsystem-staplerleitsystem/. Accessed 24 July 2013

Klein R, Scholl A (2004) Planung und Entscheidung. Konzepte, Modelle und Methoden einer modernen betriebswirtschaftlichen Entscheidungsanalyse. Vahlens Handbücher der Wirtschafts- und Sozialwissenschaften. Vahlen, München

Kurbel K (2005) Produktionsplanung und -steuerung im Enterprise resource planning und supply chain management, 6th edn. Oldenbourg, München

Schmidt M (2008) Produktionsplanung und -steuerung. In: Arnold D, Isermann H, Kuhn A, Tempelmeier H, Furmans K (eds) Handbuch Logistik, 3rd edn. Springer, Berlin, pp 323–343

Schuh G, Stich V (2012) Grundlagen der PPS, 4th edn. Springer, Berlin

Ten Hompel M (ed) (2013) IT in der Logistik 2013/2014. Marktübersicht & Funktionsumfang: Enterprise-resource. Planning, warehouse-management, transport-management & supply-chain-management-systeme. Fraunhofer Verlag, Stuttgart

Wannenwetsch H (2006) Integrierte Materialwirtschaft und Logistik, 3rd edn. Springer, Berlin

A Matchmaking Assignment Model for Supply Chain Partnership

Jafar Rezaei

Abstract Partner selection is one of the first steps in establishing partnerships. Traditional supply chain partner selection models assume that a buyer searches for one or more suppliers from a set of suppliers. Once the best supplier is found and selected, a partnership is formed. However, in reality, the relationship itself is bilateral, and the existence of other buyers and suppliers needs to be taken into account. In this paper, an interactive partner selection approach is proposed, where not only the buyers evaluate suppliers, but also the suppliers have the opportunity to evaluate buyers. Considering a marketplace where there are several buyers and suppliers, an integrative model is proposed in the form of an assignment model to optimally match all the buyers and suppliers. The proposed model is illustrated using a numerical example.

Keywords Supply chain partnership · Partner selection · Supplier selection · Buyer–supplier relationship · Assignment model

Introduction

Supply chain partnership is a central concept in supply chain management (SCM). Supply chain is defined as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer" (Mentzer et al. 2001). Managing such supply chains efficiently, helps these entities (partners), and the entire chain to become excellent competitors—through exploiting the competitive advantages of their partners—in today's highly competitive world. Although a supply chain should be viewed and managed as a single entity (Stevens 1989),

J. Rezaei (✉)
Faculty of Technology, Policy and Management, Delft University of Technology,
2628 BX Delft, The Netherlands
e-mail: j.rezaei@tudelft.nl

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it is the individual companies which make the decisions. Nevertheless, it should be emphasized that in a supply chain the decisions should be made jointly by all the involved partners (Petersen et al. 2005). One of the main decisions companies should make, in the context of SCM, is partner selection. In fact, selecting a partner means entering one or more supply chains and involving the selected partner in the company's current supply chain(s). Companies have to form strategic partnerships with key suppliers. However, many buyers do not have a proper understanding of this selection, as most of them fail to understand that "the relationship is bilateral" (Spekman 1988) meaning that both partners should be part of shaping the nature and future direction of their relationship (Nowak et al. 1997). The traditional adversarial model is a one-way evaluation process, where only the buyer evaluates the suppliers generally based on price criterion. The traditional adversarial model is intrinsically being replaced by a collaborative mode, where trust and commitment play the key role (Kwon and Suh 2005). Partnership is defined as "a tailored business relationship based on mutual trust, openness, shared risk and shared rewards that results in business performance greater than it would be achieved by the two firms working together in the absence of the partnership" (Lambert et al. 1996). Attaining the mutual objectives of a partnership necessitates building the partnership together from the very beginning, implying that both partners should see selection as a mutually strategic activity rather than solely the choice of a buyer or supplier alone.

In the literature identifying evaluation/selection criteria and a set of potential suppliers is generally considered to be a supplier selection problem. A decision-making method is then applied to identify the best supplier(s) among the set of potential suppliers. Several quantitative and qualitative criteria have been identified as the main selection criteria, the most important of which being price, quality, and delivery. To see different selection criteria, we refer to (Dickson 1966; Humphreys et al. 2003; Verma and Pullman 1998; Weber et al. 1991; Wilson 1994) among others. There are many applications of decision-making methods to supplier selection; multicriteria decision-making (MCDM) such as: Analytic Hierarchy Process (AHP) (Nydick and Ronald 1992; Tam and Tummala 2001) Analytical Network Process (ANP) (Sarkis and Talluri 2002), Data Envelopment Analysis (DEA) (Liu et al. 2000), and also hybrid approaches such as: AHP and linear programming (Ghodsypour and O'Brien 1998), and multi-objective decision-making methods (Demirtas and Üstün 2008; Rezaei and Davoodi 2011, 2012; Ustun 2008; Weber and Current 1993). To see more applications, we refer to (Ho et al. 2010).

Reviewing the literature reveals that the buyer is considered to be an active partner in supplier selection, evaluating suppliers and selecting the best one, according to particular criteria and their relative importance. The supplier, however, is considered to be a passive partner with no role in this process. The buyer selects, the supplier is selected, and we expect a partnership to be formed. In our opinion, however, this is not what happens in the real world, that both partners are actually (or should be) active in the selection process, and that therefore a proper methodology should be devised to incorporate this into the models. The literature is almost exclusively about finding an attractive supplier. However, the fact that the relationship is bilateral indicates that both parties should be mutually attractive to each other. Some scholars have acknowledged the importance of mutual attraction in buyer–supplier relationships (see for example Ellegaard et al. 2003; Hald et al. 2009; Mukherji and Francis 2008; Rezaei and Ortt 2012, 2013; Tang et al. 2001; Yilmaz et al. 2005). As has been highlighted by Rezaei (2012, p. 195) "considering the potential of the buyer and supplier simultaneously and combining the two may result in more effective buyer-supplier strategies". In addition, when parties are more similar and are equally important to each other, the chance of the relationship succeeding increases (Lambert 2008). The importance of attractiveness, mutuality, and symmetry in buyer–supplier relationship has been recognized, although their importance in one of the first and perhaps most important stages of building a relationship has been neglected. In this paper, we propose a general framework for an interactive partner selection (a matchmaking assignment model), where both partners are involved in evaluation and selection.

The rest of this paper is organized as follows: In the next section, we propose a mathematical model for an integrative and interactive partner selection. In section "Numerical Example", a numerical example is presented to illustrate the model. Finally, the conclusion, managerial implications, and recommendations for future research are presented in section "Conclusion and Future Research."

Mathematical Modeling

We assume that there is a central buyer–supplier partnership agency with the objective of optimizing the mutual advantages gained by partners through partnership and with knowledge of all the characteristics of the buyers and suppliers within a specific industry. The marketplace is composed of a set of buyers $B = \{1, 2, \ldots, m\}$ and a set of suppliers $S = \{1, 2, \ldots, n\}$. Without losing generality, it is assumed that both the total number of suppliers and buyers are equal, that $|B| = |S|$. It is also assumed that each buyer is searching for a single supplier and vice versa. Each buyer has a set of selection criteria C_{bi} for choosing a supplier. Given that suppliers are given different scores for various criteria and each buyer assigns a different weight to each criterion, the overall score of the suppliers from the perspective of the buyer i is calculated as follows:

$$\begin{aligned} & s_{ij} = \sum_{c \in C_{bi}} w_{ci} \gamma_{cj}, \quad \forall i \in B, \forall j \in S \\ & w_{ci} \geq 0 \quad \forall c \in C_{bi}, \sum_{c \in C_{bi}} w_{ci} = 1 \end{aligned} \tag{1}$$

where S_{ij} is the overall score (or the perceived attractiveness) buyer i gives to supplier j, w_{ci} is the weight the buyer assigns to criterion $c \in C_{bi}$, and γ_{cj} is the score of the supplier j with respect to criterion $c \in C_{bi}$.

Each supplier is also able to evaluate different buyers. That is, the supplier j uses a set of selection criteria C_{sj} to calculate the overall score of the buyers as follows:

$$\begin{aligned} b_{ji} &= \sum_{c \in C_{sj}} w_{cj}\eta_{ci}, \quad \forall j \in S, \forall i \in B \\ w_{cj} &\geq 0 \quad \forall c \in C_{sj}, \sum_{c \in C_{sj}} w_{cj} = 1 \end{aligned} \tag{2}$$

where b_{ji} is the overall score (or the perceived attractiveness) supplier j gives to buyer i, w_{cj} is the weight the supplier assigns to criterion $c \in C_{sj}$, and η_c is the score of the buyer with respect to criterion $c \in C_{sj}$.

As mentioned before, the literature generally stops with Eq. (1), as a buyer can make its decision based on the results obtained by Eq. (1). As discussed above, however, collaboration is a mutual relationship. As such, the best partner for buyer i is not necessarily the supplier with the maximum value for S_{ij}. Although this supplier is the most favorable (most attractive), the buyer should also consider its own attractiveness as perceived by the supplier. The same logic applies to the supplier side. In what follows, an interactive mutual selection procedure is suggested. In this procedure, the marketplace is considered as well as both the buyers' and suppliers' sides in an integrative system. As such, the goal is not (and in section "Conclusion and Future Research" we will show that it cannot be) optimizing the objective of individual buyers and suppliers, or pairs of buyers and suppliers. It is rather optimizing the entire system including all buyers and suppliers.

Considering all of the overall scores buyers give to suppliers S_{ij}, and all the overall scores suppliers give to buyers b_{ji}, the following joint matrix $A_{b,s}$ is made.

$$A_{b,s} = \begin{array}{c} \text{Buyers} \\ b_1 \\ b_2 \\ \vdots \\ b_m \end{array} \overset{\displaystyle \text{Suppliers}}{\begin{array}{c} \begin{matrix} s_1 & s_2 & \cdots & s_n \end{matrix} \\ \begin{pmatrix} s_{11}, b_{11} & s_{12}, b_{21} & \cdots & s_{1n}, b_{n1} \\ s_{21}, b_{12} & s_{22}, b_{22} & \cdots & s_{2n}, b_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ s_{m1}, b_{1m} & s_{m2}, b_{2m} & \cdots & s_{mn}, b_{nm} \end{pmatrix} \end{array}} \tag{3}$$

Each element of matrix $A_{b,s}$, is a pair of s_{ij}, b_{ji} which shows the overall scores buyer i and supplier j give to each other respectively. When s_{ij} and b_{ji} for buyer i and supplier j are close together, the buyer and supplier evaluate each other equally. That is, they are equally attractive to each other and the chance of having a symmetric mutual relationship is higher than in a situation where partners perceive each other's attractiveness differently. We calculate the absolute difference between s_{ij} and b_{ji} for buyer i and supplier j as $\left|s_{ij} - b_{ji}\right|$, and consider it a penalty. As the inequality itself is important and not its direction, we consider the absolute value. As it is possible that different pairs of s_{ij} and b_{ji} result in the same value of $\left|s_{ij} - b_{ji}\right|$, we cannot only look at the buyer–supplier couples with the minimum $\left|s_{ij} - b_{ji}\right|$ in order to minimize the total inequality (penalty) of the system. The magnitude of the evaluations needs to be incorporated such that the pairs with greater values get fewer penalties. To this end, we calculate $\frac{\left|s_{ij}-b_{ji}\right|}{s_{ij}+b_{ji}}$. This formula, however, fails to make a distinction between the pairs with similar elements. To solve this issue, we add a constant k to this formula $f = \frac{\left|s_{ij}-b_{ji}\right|+k}{s_{ij}+b_{ji}}$. Now we have $\lim_{s_{ij}-b_{ji}\to 0} f = \lim_{s_{ij}-b_{ji}\to 0} \frac{\left|s_{ij}-b_{ji}\right|+k}{s_{ij}+b_{ji}} = \frac{k}{2s_{ij}} = \frac{k}{2b_{ji}}$, which shows how the formula makes a meaningful distinction between different pairs with similar elements. We now calculate the following matrix.

$$A_{\frac{|s-b|+k}{s+b}} = \begin{pmatrix} \frac{|s_{11}-b_{11}|+k}{s_{11}+b_{11}} & \frac{|s_{12}-b_{21}|+k}{s_{12}+b_{21}} & \cdots & \frac{|s_{1n}-b_{n1}|+k}{s_{1n}+b_{n1}} \\ \frac{|s_{21}-b_{12}|+k}{s_{21}+b_{12}} & \frac{|s_{22}-b_{22}|+k}{s_{22}+b_{22}} & \cdots & \frac{|s_{2n}-b_{n2}|+k}{s_{2n}+b_{n2}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{|s_{m1}-b_{1m}|+k}{s_{m1}+b_{1m}} & \frac{|s_{m2}-b_{2m}|+k}{s_{m2}+b_{2m}} & \cdots & \frac{|s_{mn}-b_{nm}|+k}{s_{mn}+b_{nm}} \end{pmatrix} \tag{4}$$

The goal is to assign the suppliers to buyers such that the sum of the items of the matrix $A_{\frac{|s-b|+k}{s+b}}$ is minimized. Doing so, the buyers and suppliers are assigned to their best partners considering the entire system. To this end, the following problem is formulated.

$$\begin{aligned} \min & \sum_i \sum_j \frac{\left|s_{ij}-b_{ji}\right|+k}{s_{ij}+b_{ji}} x_{b,s} \\ \text{s.t.} & \sum_b x_{b,s} = 1, \quad \forall s \in S, \\ & \sum_s x_{b,s} = 1, \quad \forall b \in B, \\ & x_{b,s} = \left\{ \begin{array}{ll} 1, & \text{if supplier } s \in S \text{ assigned to buyer } b \in B, \\ 0, & \text{otherwise} \end{array} \right\} \end{aligned} \tag{5}$$

Model (5) is a form of classical linear assignment problem. To see more about the assignment problems, applications, and algorithms we refer to (Burkard and Cela 1999; Munkres 1957; Pentico 2007; Rtello and Paolo 1987) among others.

Numerical Example

In an industry, there are four key buyers, $B = \{1, 2, 3, 4\}$, and four key suppliers, $S = \{1, 2, 3, 4\}$. The suppliers all produce a product that all the four buyers need. There is a central agency that collects several characteristics of these buyers and suppliers (Table 1). The scores reported in Table 1 are in the form of a seven-point scale (1: poor; 7: excellent).

Table 2 shows the relevant importance of the criteria based on the perspective of different buyers and suppliers. Finding the weights is not the aim of this paper. They can be obtained using MCDM methods, see for instance (De Boer et al. 1998, 2001; Ho et al. 2010; Mikhailov 2002; Weber et al. 1991). As can be seen from Table 2, different buyers and suppliers give different weights to different criteria.

Using Eqs. (1)–(3), we have the joint matrix $A_{b,s}$ (the mutual attractiveness matrix) (Table 3).

Table 1 Characteristics of suppliers and buyers

	Suppliers			
Criteria	1	2	3	4
Quality	7	4	3	6
Delivery	7	5	6	3
Cost	5	3	1	6
Financial position	5	6	4	7
	Buyers			
Criteria	1	2	3	4
Market coverage	3	7	5	6
Demand volume	7	6	3	5
Willingness to share demand information	4	1	6	2

Table 2 Weight of the criteria based on the perspective of different buyers and suppliers

	Weights based on the buyer's perspective			
Criteria	1	2	3	4
Quality	0.4	0.1	0.4	0.2
Delivery	0.1	0.3	0.5	0.2
Cost	0.2	0.4	0.1	0.3
Financial position	0.3	0.2	0.0	0.3
	Weights based on the supplier's perspective			
Criteria	1	2	3	4
Market coverage	0.4	0.2	0.4	0.5
Demand volume	0.5	0.6	0.4	0.4
Willingness to share demand information	0.1	0.2	0.2	0.1

Table 3 Joint matrix $A_{b,s}$ for the buyers and suppliers

Buyers	Suppliers			
	1	2	3	4
1	6.0, 5.1	4.5, 5.9	3.2, 4.1	6.0, 5.1
2	5.8, 5.6	4.3, 5.2	3.3, 4.0	5.3, 4.6
3	6.8, 4.8	4.4, 5.4	4.3, 4.4	4.5, 4.8
4	5.8, 4.7	4.5, 6.0	3.3, 4.3	5.7, 5.2

Table 4 The assignment matrix

Buyers	Suppliers			
	1	2	3	4
1	0.171	0.231	0.260	0.171
2	0.105	0.200	0.233	0.172
3	0.259	0.204	0.126	0.140
4	0.200	0.238	0.263	0.138

Using Eq. (4), we get the resulting assignment matrix (Table 4).

Solving model (5) for the assignment matrix, the following optimal buyer-supplier matches are found: buyer 1 ⇔ supplier 2; buyer 2 ⇔ supplier 1; buyer 3 ⇔ supplier 3; buyer 4 ⇔ supplier 4, with min $\sum_i \sum_j \frac{|s_{ij} - b_{ji}| + k}{s_{ij} + b_{ji}} x_{b,s} = 0.600$.

Conclusion and Future Research

Building a long-term relationship between buyer and supplier is a function of two main factors: mutual dependence and trust (Ganesan 1994). To guarantee a long-term relationship, supply chain partners should evaluate one another to see how they fit together. This approach calls for scholars to develop collaborative evaluation/selection procedures to assist supply chain partners to make more sustainable partnerships. The literature contains many applications of decision-making methods for partner selection, characterized however by two major issues:

1. A one-way approach toward partner selection is dominant. That is, only buyers are assumed to have the selection role, and suppliers are assumed to be simply just selected. That is why the selection process is usually named as “supplier selection”.
2. The selection process is assumed to be conducted by individual buyers independent of the other buyers from the same industry.

Today’s buyer–supplier relationship is, however, mostly more than a simple transaction. Buyers and suppliers are more dependent on each other. In addition, the competition to attract partners is very tough. In sum, a firm not only searches for an attractive partner, but also needs to be attractive enough for that partner to create a real enduring partnership. In this paper, we propose an interactive approach to partner selection that solves these two major issues. This interactive approach involves both buyer and supplier in the evaluation and selection procedure. This new approach also considers the entire system, that is, it considers other buyers and suppliers operating in the same industry and competing for partnership. The proposed approach finds the best buyer–supplier matches, and simultaneously optimizes the partnership in the entire marketplace. We think that the new approach facilitates building more sustainable partnerships.

We suggest some future research to further extend the interactive partner selection approach proposed in this paper. First, empirical studies are suggested to validate the proposed approach and method. We think that the interactive partner selection can also be combined with some other partner-related activities. As an excellent example, we think investigating the relationship between interactive partner selection and partner segmentation (Day et al. 2010; Kraljic 1983; Rezaei and Ortt 2012) can provide new interesting insights. Rezaei and Ortt (2012) concluded that: "The suitable approach to dealing with a supplier with low capabilities and high willingness is different for a buyer with high capabilities and high willingness compared with a buyer with low capabilities and low willingness. Indeed, considering the potential of the buyer and supplier simultaneously and combining the two potentials may result in more effective buyer–supplier strategies." Therefore, we think that interactive partner selection may lead to a better partner segmentation, and in turn to a better buyer–supplier relationship management. Another suggestion is to apply different MCDM methods to find the final overall scores buyers and suppliers give to each other, and to study the suitability of different methods for different situations. The implementation of a central agency, as part of the proposed approach in this paper, leads to organizational and legal issues, which need to be investigated.

References

Burkard R.E., Cela E. (1999) Linear assignment problems and extensions. In: Handbook of combinatorial optimization, vol 4(1), pp 221–300

Day M, Magnan GM, Moeller MM (2010) Evaluating the bases of supplier segmentation: a review and taxonomy. Ind Mark Manage 39(4):625–639

De Boer L, Van der Wegen L, Telgen J (1998) Outranking methods in support of supplier selection. Eur J Purchasing Supply Manage 4:109–118

De Boer L, Labro E, Morlacchi P (2001) A review of methods supporting supplier selection. Eur J Purchasing Supply Manage 7(2):75–89

Demirtas EA, Üstün Ö (2008) An integrated multiobjective decision making process for supplier selection and order allocation. Omega 36(1):76–90

Dickson GW (1966) An analysis of vendor selection systems and decisions'. J Purchasing 2(1):5–17

Ellegaard C, Johansen J, Drejer A (2003) Managing industrial buyer-supplier relations—the case for attractiveness. Integr Manuf Syst 14(4):346–356

Ganesan S (1994) Determinants of long-term orientation in buyer-seller relationships. J Mark 58 (2):1–19

Ghodsypour SH, O'Brien C (1998) A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. Int J Prod Econ 56–57:199–212
Hald KS, Cordón C, Vollmann TE (2009) Towards an understanding of attraction in buyer–supplier relationships. Ind Mark Manage 38(8):960–970
Ho W, Xu X, Dey PK (2010) Multi-criteria decision making approaches for supplier evaluation and selection: a literature review. Eur J Oper Res 202(1):16–24
Humphreys P, Wong Y, Chan F (2003) Integrating environmental criteria into the supplier selection process. J Mater Process Technol 138(1):349–356
Kraljic P (1983) Purchasing must become supply management. Harvard Bus Rev 61(5):109–117
Kwon I-WG, Suh T (2005) Trust, commitment and relationships in supply chain management: a path analysis. Supply Chain Manage Int J 10(1):26–33
Lambert DM (2008) Supply chain management: processes, partnerships, performance. Supply Chain Management Institute, Sarasota
Lambert DM, Emmelhainz MA, Gardner JT (1996) Developing and implementing supply chain partnerships. Int J Logistics Manage 7(2):1–18
Liu J, Ding F-Y, Lall V (2000) Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. Supply Chain Manage Int J 5(3):143–150
Mentzer JT, DeWitt W, Keebler JS, Min S, Nix NW, Smith CD, Zacharia ZG (2001) Defining supply chain management. J Bus Logistics 22(2):1–25
Mikhailov L (2002) Fuzzy analytical approach to partnership selection in formation of virtual enterprises. Omega 30(5):393–401
Mukherji A, Francis JD (2008) Mutual adaptation in buyer–supplier relationships. J Bus Res 61 (2):154–161
Munkres J (1957) Algorithms for the assignment and transportation problems. J Soc Ind Appl Math 5(1):32–38
Nowak LI, Boughton PD, Pereira AJ (1997) Relationships between businesses and marketing research firms: impact of partnering on performance. Ind Mark Manage 26(6):487–495
Nydick RLH, Ronald P (1992) Using the analytic hierarchy process to structure the supplier selection procedure. Int J Purchasing Mater Manage 28(2):31–36
Pentico DW (2007) Assignment problems: a golden anniversary survey. Eur J Oper Res 176 (2):774–793
Petersen KJ, Handfield RB, Ragatz GL (2005) Supplier integration into new product development: coordinating product, process and supply chain design. J Oper Manage 23(3):371–388
Rezaei J (2012) SMEs and supply chain management: a functional perspective. PhD dissertation, Delft University of Technology, The Netherlands. ISBN: 978-90-90-27097-5
Rezaei J, Davoodi M (2011) Multi-objective models for lot-sizing with supplier selection. Int J Prod Econ 130(1):77–86
Rezaei J, Davoodi M (2012) A joint pricing, lot-sizing, and supplier selection model. Int J Prod Res 50(16):4524–4542
Rezaei J, Ortt R (2012) A multi-variable approach to supplier segmentation. Int J Prod Res 50 (16):4593–4611
Rezaei J, Ortt R (2013) Supplier segmentation using fuzzy logic. Ind Mark Manage 42(4):507–517
Rtello SM, Paolo T (1987) Linear assignment problems. Surv Comb Optim 31:259
Sarkis J, Talluri S (2002) A Model for strategic supplier selection. J Supply Chain Manage 38 (1):18–28
Spekman RE (1988) Strategic supplier selection: understanding long-term buyer relationships. Bus Horiz 31(4):75–81
Stevens GC (1989) Integrating the supply chain. Int J Phys Distrib Logistics Manage 19(8):3–8
Tam MCY, Tummala VMR (2001) An application of the AHP in vendor selection of a telecommunications system. Omega 29(2):171–182
Tang J-TE, Shee DY, Tang T-I (2001) A conceptual model for interactive buyer–supplier relationship in electronic commerce. Int J Inf Manage 21(1):49–68
Ustun O (2008) An integrated multi-objective decision-making process for multi-period lot-sizing with supplier selection. Omega 36(4):509–521

Verma R, Pullman ME (1998) An analysis of the supplier selection process. Omega 26(6):739–750
Weber CA, Current JR (1993) A multiobjective approach to vendor selection. Eur J Oper Res 68 (2):173–184
Weber CA, Current JR, Benton WC (1991) Vendor selection criteria and methods. Eur J Oper Res 50(1):2–18
Wilson EJ (1994) The relative importance of supplier selection criteria: a review and update. J Supply Chain Manage 30(3):34–41
Yilmaz C, Sezen B, Ozdemir O (2005) Joint and interactive effects of trust and (inter) dependence on relational behaviors in long-term channel dyads. Ind Mark Manage 34(3):235–248

Toward Dynamic Expiration Dates: An Architectural Study

Åse Jevinger and Paul Davidsson

Abstract The durability of perishable food varies due to different storage and handling conditions during the supply chain as well as final consumer activities. If the durability of the individual products can be estimated, dynamic expiry dates may be developed and used to prevent food waste, ensure quality, and improve supply chain activities etc. Depending on the system architecture used for such a service, different qualities can be obtained in terms of usability, accuracy, security etc. This paper presents a novel approach for how to identify and select the most suitable system architectures of a dynamic expiry date service. The approach is illustrated by focusing on one of the potential user groups, the supply chain managers. The approach consists of three steps: (i) identify the potential architectures, (ii) filter out the least relevant candidates by applying a specified set of principles, and (iii) perform an analytic hierarchy process (AHP) based on a set of quality attributes.

Keywords Dynamic expiry date · Perishables · Architecture · AHP · Supply chain management

Introduction

Studies show that temperatures during supply chain activities often differ from the ones recommended by the producer, which might result in shorter durability of perishables, such as dairy products, fresh meat, and fish (Likar and Jevšnik 2006).

Å. Jevinger (✉) · P. Davidsson
Malmö University, Malmö, Sweden
e-mail: ase.jevinger@mah.se

P. Davidsson
e-mail: paul.davidsson@mah.se

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Thereby the specified expiry dates[1] are no longer valid. On the other hand, food that has been well treated can often be safely consumed after the expiry date has passed. It has been estimated that one third of all food produced globally for human consumption is lost or wasted (Gustavsson et al. 2011). Jedermann et al. (2009) state that among environmental parameters during transport, temperature has the most significant influence on the quality of food products. Studies furthermore show significant temperature variations inside a vehicle as well as during storage (Moureh and Flick 2004).

To prevent people from discarding food still suitable for human consumption, as well as to ensure the quality of the expiry dates, information about the actual conditions during the supply chain activities are needed. By using local sensors to measure the environmental conditions, such as the temperature, the quality of each individual product can be estimated. These sensors must be present throughout the transport chain, and the closer to the products they are placed, the more accurate estimations can be made. Based on the estimated quality, the expiry dates can be updated continuously enabling actors within supply chain management as well as the final consumers, to make more informed decisions about how to handle the food and when to discard it. Furthermore, a dynamic expiry date service might be colligated with other services such as tracking and tracing, product information (for instance origin and handling instructions), carbon dioxide labeling, and dynamic pricing based on currently estimated expiry date (Bartels et al. 2010).

The aim of the paper is to present and apply a novel approach for how to select the most suitable system architecture for a service providing dynamic expiry dates of perishable food. The approach consists of three steps:

1. Identify all potential system architecture candidates based on a new system architecture representation model.
2. Filter out the least relevant candidates by applying a specified set of principles.
3. Perform an AHP based on a set of quality attributes to determine which architecture is the most suitable.

The approach is used to analyze all architectures satisfying the requirements of one particular user group, the supply chain managers, in order to select the most suitable architecture. The architectures differ in the intelligence required at product-level, vehicle/terminal level, mobile terminal level, and central level.

[1]The producer generally guarantees good quality as long as the best-before date has not passed (if certain conditions have been respected). The producer generally guarantees food safety as long as the use-by/expiry date has not passed (if certain conditions have been respected). Shelf life is the length of time for which an item remains usable, fit for consumption, or saleable.

Related Work

Concepts implying a higher level of intelligence related to the product itself, in comparison to only possessing an associated ID, are often referred to "smart" or "intelligent," such as "Intelligent Goods," "Smart Goods," or "Intelligent Products" (Meyer et al. 2009). Depending on the level of intelligence, these concepts can be applied for monitoring the local conditions during transportation (López et al. 2011), and maybe for calculating a dynamic expiry date. The intelligence related to a product may or may not be located on the product itself (Meyer et al. 2009). However, for the dynamic expiry date service, local intelligence, for instance implemented on the product, a pallet or in the vehicle, able to perform condition monitoring is required.

Within the area of communicative packaging, potential means to monitor the condition of packaged contents by enhancing the intelligence of the package itself have been investigated. The solutions consist of a combination of packaging technologies and communicative signals (e.g., changing colors, diagrams, displays) (Dobon et al. 2011). Communicative packaging is seen as a specific type of smart packaging, which uses different technologies to add extra features to packaging (e.g. information about expiry date, identification about the type/origin of the product and protection against counterfeiting). A life-cycle assessment study on the use of a flexible best-before-date communicative device (FBBD, with a temperature logger and a display) on packaging consumer units, shows that the use of FBBD devices decreases environmental burdens associated to the production, packaging, and delivery to the point of sale, thanks to reduction in food losses (Dobon et al. 2011). Other case studies show potential benefits of radio-frequency identification (RFID)-based cold-chain monitoring in increased sales due to reduced out-of-stock, reduction in inventory due to lower safety stock, improvement of visibility and transparency in the supply chain etc. (Jol et al. 2006). Benefits from using time temperature indicators (TTIs) have also been investigated (Sahin et al. 2007; Bhushan and Gummaraju 2002). An alternative to enhancing the package of a product itself is to place the local intelligence, including temperature sensors, on a higher level, for instance on containers or in vehicles (Ruiz-Garcia et al. 2007). A discussion about different degrees of decision freedom that may be dedicated to products as well as commonly used applications on different hardware layers can be found in Jedermann and Lang (2008). Placing intelligence on different levels in the transport system results in different processing, information, and communication requirements as well as enables different service qualities and functionalities. Depending on the purpose of local condition monitoring and expiry date estimations, different solutions based on different system architectures might thereby be preferred—in particular by different target user groups. To the best of our knowledge, no previous study has identified these system architectures and investigated the differences between them, with respect to the issues above.

Methodology and Service Description

In order to be able to compare different system architectures of the dynamic expiry date service, they must first be identified and characterized. We identify the potential architectures by first specifying all activities (A) that must be performed, as well as the different locations (L) where each of these activities could be performed. By combining the activities with the locations we get the set of all potential architectures (i.e., the Cartesian product $L^{|A|}$). This set is then reduced by filtering out impossible and obviously impractical architectures. From the remaining set of architectures, the most suitable ones, with respect to the functional and quality requirements of each target user group, shall be found. Ideally, every identified architecture should be evaluated and compared. However, due to the amount of work this process would require, the least suitable ones are filtered out in two steps. First, all solutions possible for each user group are identified based on some prerequisites regarding how the expiry date should be presented. In this paper, we only focus on the architectures satisfying the requirements of the supply chain managers. Second, heuristics derived from general requirements on the architecture are applied to identify the most promising candidates. Finally, an AHP is performed on the resulting set of architectures, prioritizing the most suitable ones according to a set of quality-based criteria. AHP is a method for analyzing complex decision problems with multiple criteria (Saaty 1980).

Input to the dynamic expiry date service is Goods-ID (the unique ID of a product, e.g. SGTIN) and output is the expiry date. In this study, we assume that the calculation of expiry date is based on sensor data related to the condition of the product, including both current and historical data, for instance temperature values. Thus, a local sensor is needed to sense and record the local conditions according to some time interval, and the stored sensor data must be possible to read. Theoretically, the service could have been based on measuring the current bacteria level only, without regard to any historical data. However, given the current status of sensor technology, direct and possibly automated measurement of the current bacteria level in a product is not a viable approach. The Goods-ID is assumed to be stored at product level, making all products electronically identifiable.

The System Architecture Representation Model

The expiry date service requires the execution of four main activities: (a_1) the local conditions of the product have to be measured, (a_2) the recorded sensor data must be stored, (a_3) the expiry date must be calculated based on the stored sensor data, and (a_4) the result must be presented to the user of the service. These activities ($A = \{a_1, a_2, a_3, a_4\}$) can be located: at product level (P), on a fixed local device (N), on a mobile local device (M), in a remote device (R) or in the cloud (C), i.e. L = {P, N, M, R, C}. Below, a more detailed explanation of the different locations

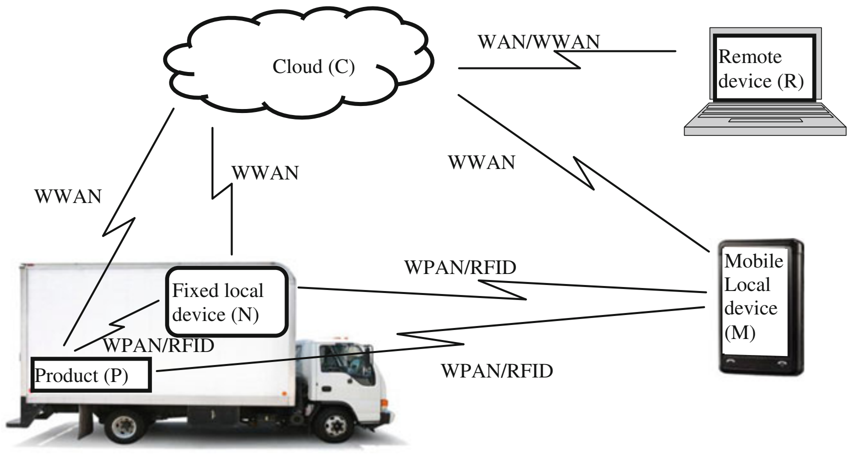

Fig. 1 Possible communication links between different parts of the service system, *(W)WAN* (wireless) wide area network, *WPAN* wireless personal area network

is given, whereas Fig. 1 illustrates the corresponding possible communication links. In this study, we assume that both R and M are connected with the cloud (when there is coverage) and that N is available whenever needed in accordance with the requirements of the architecture.

P: Entity at product level, e.g., attached to the primary package, secondary package or a pallet. This entity follows the product throughout the transport.

N: Fixed local device near the products, located for instance inside a vehicle, a terminal, or a refrigerator. The N used by the service on behalf of a product may change during transport, when the product is moved.

M: Mobile local device near the products, for instance a mobile phone provided with an app or an RFID reader. Consumers and local supply chain personnel (e.g. drivers and terminal workers) may employ such a device. M communicates with N and P directly, via RFID or WPAN (Wireless Personal Area Network). For instance, M may read the Goods-ID from the product and then retrieve the corresponding expiry date from C.

R: Remote device, for instance, a stationary computer running an ERP system. R is unable to communicate directly with N and P but communicates through the cloud instead.

C: Cloud-based entity, for instance a network server, accessible from any device with Internet access.

The set of potential architectures, $L^{|A|}$, consists of 625 elements of which some correspond to architectures that are impossible or obviously impractical. Measuring the local conditions in C or R is impossible, and to do it on M is impractical since M may be moved around. Also, to store the sensor data on M or N is impractical since the service should not be dependent on M being present (receiving sensor data via

WPAN/RFID) and since storing sensor data on N would require a data transfer whenever N changes and that might not be possible (or desirable for security reasons). Finally, to present the expiration date in C is not meaningful. To sum up, the activities may be executed in the following locations in the system:

1. Measurement of local conditions: P or N
2. Sensor data storage: P, C or R
3. Calculation of estimated expiry date: P, N, M, R or C
4. Presentation of expiry date: P, N, M, or R

The calculated expiry dates are assumed to be stored either where they are calculated or where they are to be presented in the system. The calculation of the expiry date is based on current and historical sensor data and this sensor data might, on the other hand, be stored somewhere apart from where it is collected or used. The reason for storing this data in a third place might be to avoid overloading the product level or to allow for the fixed local device to be changed during transport. Depending on where the sensor data is stored, a higher level of intelligence might be required by the involved entities, as well as additional communication.

The filtration above results in 120 different alternative architectures ($2 \times 5 \times 4 \times 3 = 120$). We have investigated each one of them with respect to individual characteristics, usefulness for different target user groups, communication paths and required capabilities (according to Jevinger et al. (2011)). Additionally, the set of architectures has been further extended to also incorporate different alternatives for long distance communication between P and C/R (resulting in 186 architectures), since this in some cases introduces additional entities and capability requirements. Long distance communication between P and C/R can be performed using a direct link, or by transmission via N or M. In this paper, we assume that P does not communicate directly with C/R, but only through N/M. The reason for this assumption is that the most reasonable solution considering today's technology, is to use short distance wireless communication to N/M and let N/M be responsible for the long distance communication.

The architectures can be grouped based on where measurement, storage, and calculation are located. All architectures with the same locations of these activities only differ in where the expiry date is presented, and they may therefore be combined to provide several means of accessing the expiry date. For instance, a solution showing the expiry date in both the R and M might be required (e.g. to satisfy requirements from drivers and terminal workers as well as centralized supply chain managers), based on architectures with the same locations of the other service activities (measurement, storage and calculation). In this study, we show an approach for how to prioritize and select the most suitable solutions for one of the target user groups; however, this approach can be used to prioritize the solutions for other user groups as well. If a combination is required as described, the topmost architectures with the same locations of measurement, storage, and calculation should be selected from the resulting prioritized lists of architectures.

Heuristics

Different user groups require different alternatives for how the expiry date should be accessed. This paper focuses on supply chain managers and we assume they will read the date in a remote device (R). Ideally, all architectures fulfilling this requirement should be evaluated with respect to the functional and quality preferences of the supply chain managers. This would mean evaluating 48 architectures. For other user groups identified, the set of architectures to evaluate result in 138 architectures, and performing an AHP on all of these would require a huge amount of work. Moreover, many of the architectures that are possible from a theoretical perspective reflect solutions that do not seem reasonable from a practical perspective, such as calculating the expiry date in M and showing the result on P. Therefore, we have developed two principles for filtering out the least promising architectures, from the perspective of the supply chain managers. The list of principles may have to be extended for other user groups, though the principles below should be applied for those as well.

Principle 1: If sensor data is stored on C/R and the expiry date is presented on R, the calculation should be co-located with the storage or the presentation. The purpose of this principle is to prioritize the simplest solutions that do not involve sending information back and forth, in particular from the central level, to the local level, and back again. For instance, architectures storing sensor data in R, using P/N for calculation, and showing the resulting expiry date in R, are removed. This principle filters out the following architectures (Measurement-Storage-Calculation-Presentation): P-C-P-R, N-C-P-R, P-C-N-R, N-C-N-R, P-C-M-R, N-C-M-R, P-R-M-R, N-R-M-R, P-R-C-R, N-R-C-R, P-R-N-R, N-R-N-R, P-R-P-R, N-R-P-R.

Principle 2: Architectures showing the expiry date on R shall not use M for calculation. The supply chain managers should not be dependent on M for receiving the expiry date since M is mobile and is therefore not guaranteed to always be present. This principle filters out the following architectures: P-P-M-R, N-P-M-R.

As a result, 14 candidates have not been rejected by the principles and are thus subjects for AHP analysis. The choice of where to measure the local conditions (P or N) depends on the temperature variations between N and the product, but also on how sensitive the product is to measurement errors. Based on the properties and shelf life model of a specific product, architecture candidates measuring the conditions on N may in some cases be filtered out. In this paper, we assume relatively insensitive products in order not to narrow the analysis more than necessary.

AHP Analysis

AHP is an approach for selecting the best from a number of alternatives, which are evaluated with respect to several criteria. Pairwise comparisons are used to develop overall priorities reflecting the importance of each criterion, relative to the goal of the selection problem. The performance of each alternative on each criterion must also be determined, and together with the priorities of the criteria, a ranking of the alternatives can be produced. AHP has previously been successfully used for evaluating architecture candidates (Svahnberg et al. 2003). As a first step, the set of criteria must be selected. We have identified the quality attributes listed in Table 1, as relevant for the dynamic shelf expiration date service.

The second step of AHP involves prioritizing the criteria according the importance of each criterion, in relation to the goal of the selection problem. Each criterion is pairwise compared to all other criteria with respect to how desired they are to the service system. These comparisons are based on interviews with three actors within the food supply chain. We only use consistent priorities, and after the

Table 1 Criteria for AHP analysis

Criteria	Meaning
Response time	How long it takes to process a request (O'Brien et al. 2007). We define it as the time it takes from asking for the expiry date, until it is available for the user. Situations where the expiry date cannot be provided at all are covered by availability
Security	We consider integrity and confidentiality as the most relevant aspects of security. Integrity guarantees that information is not corrupted and confidentiality ensures that access to the information/service is granted only to authorized subjects (O'Brien et al. 2007). In our context, integrity corresponds to how difficult it is to manipulate the system into producing no or erroneous expiry dates, and confidentiality to how difficult it is for unauthorized users to access the expiry date
Availability	The proportion of time a system or component is operational and accessible (O'Brien et al. 2007). In our context, it is measured as the proportion of the time the service is operational during its lifetime. We do not address physical damage of equipment
Modifiability	The ability to make changes to a system quickly and cost-effectively (Clements et al. 2001). In our context, it is a measure of how easy and cost-effectively the software (date estimation algorithms, software functionality etc.) and the hardware components (tags, readers, displays etc.) of the service can be exchanged
Scalability	The ability of the system to function well when the system is changed in size or in volume in order to meet users' needs (O'Brien et al. 2007). In our context, it concerns how well the service system is able to handle a growing number of products or longer transport distances
Accuracy	The precision of computations and control (Larsson 2004). In our context, it concerns how well the estimated expiry date approximates the actual expiry date, including the reliability of the sensor data

Table 2 Priorities derived from interviews and comparisons between the architecture candidates with respect to the criteria as well as the final results of the AHP analysis

	Response time	Security	Availability	Modifiability	Scalability	Accuracy	AHP results
Priorities	*0.1467*	*0.1333*	*0.1533*	*0.1200*	*0.1133*	*0.1667*	
P-P-P-R	0.0719	0.0727	0.0727	0.1017	0.0455	0.1172	0.0819
N-P-P-R	0.0240	0.0242	0.0242	0.0508	0.0455	0.0391	0.0339
P-P-N-R	0.0719	0.0727	0.0727	0.0508	0.0227	0.1172	0.0715
N-P-N-R	0.0240	0.0242	0.0242	0.0339	0.0227	0.0391	0.0283
P-P-C-R	0.0360	0.0364	0.0364	0.1017	0.0455	0.1172	0.0631
P-C-C-R	0.0360	0.0727	0.0364	0.1017	0.0909	0.0781	0.0673
N-P-C-R	0.0288	0.0182	0.0182	0.0508	0.0455	0.0391	0.0326
N-C-C-R	0.1439	0.0727	0.1455	0.0508	0.1364	0.0469	0.0990
P-C-R-R	0.0360	0.0727	0.0364	0.1017	0.0909	0.0781	0.0673
N-C-R-R	0.1439	0.0727	0.1455	0.0508	0.1364	0.0469	0.0990
P-P-R-R	0.0719	0.0727	0.0727	0.1017	0.0455	0.1172	0.0819
N-P-R-R	0.0240	0.0242	0.0242	0.0508	0.0455	0.0391	0.0339
P-R-R-R	0.0719	0.1455	0.0727	0.1017	0.0909	0.0781	0.0919
N-R-R-R	0.2158	0.2182	0.2182	0.0508	0.1364	0.0469	0.1483

pairwise comparisons, the priorities are normalized to sum up to one. The resulting priorities from the interviews are listed in the first row of Table 2.

In the third step of AHP, the architecture candidates are compared with all other candidates, with respect to the criteria. These comparisons are based on pairwise subjective assessments and as before, we use consistent priorities, normalized to sum up to one. The resulting sets are shown in Table 2.

In the fourth step, the relative importance of each criterion is combined with how well each architecture candidate satisfy the criteria, by multiplying the normalized priorities related to the architecture candidates with the normalized priorities of the criteria. The resulting products are thereafter summed for each architecture candidate and the values of these sums reflect the suitability of each candidate, in relation to the other candidates. The final values for each architecture candidate are presented in the last column of Table 2.

Table 2 shows that, with this approach, architecture N-R-R-R receives the highest priority for the supply chain managers, with respect to quality and functionality requirements. Architectures N-C-R-R and N-C-C-R are similar and regarded as second best. Taking into consideration the costs of each solution as well naturally would change the order of priorities. For instance, architecture P-R-R-R most probably entails a higher cost than architecture N-P-R-R, since architecture P-R-R-R requires sensor capability on P whereas architecture N-P-R-R may be implemented using a simple read/write passive RFID tag on P. Implementing a high level of intelligence in product-level devices is usually relatively costly since the number of products is high in relation to the other potential locations, for instance vehicles. Thereby, the approach presented in this paper shall primarily be used for prioritizing the architectures from a functional and quality perspective, and based on these results, in combination with the costs of each architecture candidate, the most suitable solution can be selected.

Conclusions and Future Work

We have shown a novel approach for how to identify the most suitable system architectures of an expiry date service. The approach is illustrated by focusing on one user group, the supply chain managers. Apart from the analytical desktop work, the selection process also incorporates interviews with three actors within the food supply chain, affecting how different qualities should be valued.

In order to be able to list all architectures we have developed a representation model, which is used to characterize the architectures based on where the different activities involved in the service are located. The primary advantages with this approach are that all possibilities can be identified and evaluated. Thereafter, we have used user group requirements and heuristics to filter out architecture candidates that reflect the general requirements on the final solution. The candidates have been evaluated in an AHP based on a number of quality criteria, and the results are presented as a list of priorities of the candidates.

In this study, we have assumed N is available whenever needed. In reality, this might not always be the case. Architectures in which N is only available during certain parts of the transport, sensor data might only be possible to transmit at arrival to the terminals, produce other values of the quality criteria. A more concrete situation would reveal the alternative locations of N and taking these locations into consideration as well would expand the set of architecture alternatives. This paper is focused on the fundamental solutions and if other varieties need to be evaluated, the approach presented in this paper may be used for these as well.

Once the solutions satisfying the functional and quality requirements have been identified, they should be analyzed with respect to their costs, in order to determine the ideal solution. We plan to consider the costs in a second paper, by performing a cost–benefit analysis on the set of architecture candidates resulting from this paper. The environmental impacts of each architecture will also be considered in the AHP criteria. Furthermore, the second paper will describe a pilot study implementing a number of architecture candidates, and the measured values from this study will be used in an additional AHP.

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References

Bartels PV, Tromp SO, Rijgersberg H, Kreft F (2010) Improvement of sustainability in the perishable food supply chain by using communicative packaging devices. In: Towards effective food chains: models and applications. Academic Publishers, Wageningen

Bhushan N, Gummaraju K (2002) A petri net based simulation approach for evaluating benefits of time temperature indicator and wireless technologies in perishable goods retail management. In: FOODSIM'2002 the second international conference on simulation and modeling in the food and bio-industry

Clements P, Kazman R, Klein M (2001) Evaluating software architectures. Addison-Wesley, Reading

Dobon A, Cordero P, Kreft F, Østergaard SR, Robertsson M, Smolander M, Hortal M (2011) The sustainability of communicative packaging concepts in the food supply chain. A case study: part 1. Life cycle assessment. Int J Life Cycle Assess 16:168–177

Gustavsson J, Cederberg C, Sonesson U, van Otterdijk R, Meybeck A (2011) Global food losses and food waste. Food and Agriculture Organization of the United Nations, Rome

Jedermann R, Lang W (2008) The benefits of embedded intelligence -tasks and applications for ubiquitous computing in logistics. The internet of things. Springer, Berlin, pp 105–122

Jedermann R, Ruiz-Garcia L, Lang W (2009) Spatial temperature profiling by semi-passive RFID loggers for perishable food transportation. Comput Electron Agric 65:145–154

Jevinger Å, Davidsson P, Persson JA (2011) A framework for agent-based modeling of intelligent goods. Agents in principle, agents in practice. Springer, Berlin, Heidelberg, pp 97–112

Jol S, Kassianenko A, Wszol K, Oggel J (2006) Issues in time and temperature abuse of refrigerated foods. Food Saf 11(6):30–32

Larsson M (2004) Predicting quality attributes in component-based software systems. Dissertation, Mälardalen University, Västerås

Likar K, Jevšnik M (2006) Cold chain maintaining in food trade. Food Control 17:108–113

López TS, Ranasinghe DC, Patkai B, McFarlane D (2011) Taxonomy, technology and applications of smart objects. Inf Syst Front 13:281–300

Meyer GG, Främling K, Holmström J (2009) Intelligent products—a survey. Comput Ind 60:137–148

Moureh J, Flick D (2004) Airflow pattern and temperature distribution in a typical refrigerated truck configuration loaded with pallets. Int J Refrig 27:464–474

O'Brien L, Merson P, Bass L (2007) Quality attributes for service-oriented architectures. In: International workshop on systems development in SOA environments, IEEE Computer Society

Ruiz-Garcia L, Barreiro P, Rodríguez-Bermejo J, Robla J (2007) Review monitoring the intermodal, refrigerated transport of fruit using sensor networks. Span J Agric Res 5:142–156

Saaty TL (1980) The analytic hierarchy process. McGraw Hill, New York

Sahin E, Babaï MZ, Dallery Y, Vaillant R (2007) Ensuring supply chain safety through time temperature integrators. Int J Logist Manag 18:102–124

Svahnberg M, Wohlin C, Lundberg L, Mattsson M (2003) A quality-driven decision-support method for identifying software architecture candidates. Int J Softw Eng Knowl Eng 13:547–573

Innovation in Transport Logistics—Best Practices from the EU Project LOGINN

David Ciprés, Lorena Polo and Alberto Capella

Abstract Innovation has historically played a vital role in increasing efficiency. However, while other industry sectors have experienced rapid growth of productivity, the transport logistics industry has seen relatively small improvement in terms of efficiency. The European LOGINN project undertakes several activities aiming at fostering collaboration among the involved stakeholders of the logistics domain regarding the promotion of innovative transport logistics solutions. The LOGINN approach for supporting logistics innovation achievement involves three interlinked and mutually reinforcing dimensions: innovative business models within the supply chain, innovative logistics best practices, and innovative technologies. In this work, we describe a methodology for innovative best practices identification and we present a selection of best practices identified from the LOGINN project in the areas of e-freight, co-modality, urban freight distribution, and intralogistics.

Keywords Innovation · Best practice · Transport · Logistics

Introduction

The transport logistics network in Europe represents the aorta of the European economy. The importance of the sector for the EU market has been recognized by the Commission in the White Paper on Transport (six countries out of the global top-10 logistic performers are from the EU in 2012). However, high fuel prices, the

D. Ciprés (✉) · L. Polo · A. Capella
Aragon Institute of Technology (ITAINNOVA), C/María de Luna 7, 50018 Saragossa, Spain
e-mail: dcipres@itainnova.es

L. Polo
e-mail: lpolo@itainnova.es

A. Capella
e-mail: acapella@itainnova.es

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need for sustainability, more service, and costs requirements, represent new challenges that require constant innovation.

Innovation in transport logistics can be defined, as an extension to the established "logistics" definition provided by the Council of Supply Chain Management Professionals, as: "the implementation of a new or significantly improved organizational method (business model), process (logistics practice) or technological application within the context of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements." Innovation has historically played a vital role in increasing efficiency (e.g., the containerization of the industry), and numerous further innovations are needed to nurture intermodality and co-modality, as road transport continues to grow (Behrends 2009).

While other industry sectors have experienced rapid growth of productivity, the transport logistics industry has seen relatively small improvement in terms of efficiency. One large factor behind this is the lack of interest in innovation in freight transport, compared to other sectors. Research shows that other industry sectors spend from 4.8 to 17.8 % of their turnover on research and innovation, compared to only 1.1 % for the transport industry (Wagner 2008). Main reasons for that are:

- the lack of clarity to many supply chain members of where the potential for improvement lies and what type of innovations can enable operational improvements (Nilsson 2006; Sternberg et al. 2011),
- the large proportion of SMEs within the freight transport and logistics services, combined with the significant challenges faced by SMEs in participating in EU research and innovation programs (as noted in the Green Paper of a Common Strategic Framework for EU Research & Innovation Funding—COM(2011)48).

Besides this scarce investment in innovation, usually existing R&D projects stop with the implementation of a prototype or pilot, and research results do not turn into real innovations. In order to bridge the gap between pilot implantation and marketable solutions, there are some actions that are being funded by European Commission. One of these actions is the Logistic Innovation uptake project (LOGINN project).

The LOGINN European project, started in November 2012, is a collaborative project funded by the European Commission under the Seventh Framework Programme, Theme 7, Sustainable Surface Transport (reference: 314338). It undertakes several activities aiming at fostering collaboration among the involved stakeholders of the logistics domain (industry, SMEs, public authorities, investors, and research organizations) regarding the promotion of innovative transport logistics solutions.

The objective of this contribution is to present a selection of best practices identified from the LOGINN project that support the companies' productivity and competitiveness and boost the cooperation and collaboration in the transport and logistics sector.

The paper is organized as follows. In section "Solution Directions to Foster Transport Logistics Innovation", we present solutions directions from the LOGINN project to foster transport logistics innovation. In section "A Methodological Approach for Best Practices Identification in the Framework of the LOGINN Project", a methodology approach for best practices identification and classification is described. In section "Best Practices", we present an overview of some best practices included in the inventory of best practices developed in the framework of the LOGINN project. Finally, section "Conclusion" shows conclusions and future work.

Solution Directions to Foster Transport Logistics Innovation

The LOGINN approach for supporting logistics innovation achievement involves three interlinked and mutually reinforcing dimensions: innovative business models within the supply chain, innovative logistics best practices, and innovative technologies.

Business Models

Globalization and increased customer demands during the past decades have led transport logistics to assume a series of different business models in order to meet the challenges faced. The business model concept became prevalent in the mid-1990s. The emergence of the Internet played a significant part in that, as it gave companies (and supply chains) the ability to find additional was of creating value for their customers. In the framework of the LOGINN project, we consider the business model as a representation of the way the members of a supply chain use their competencies and resources to increase customer and shareholder value. Thus, innovative logistics business models should consider:

- Innovative ways to reach the customer (e.g., DHL's Bring.Buddy initiative employing crowd sourcing for urban deliveries, etc.),
- Innovative configurations of the supply chain providers (e.g., the migration from the large transport operator to the 3PL and 4PL providers, to the Lead Logistics Provider, and to the flexible networks of smaller 3PL providers, the emergence of virtual supply chains, etc.),
- Innovative supply chain coordination mechanisms (e.g., the evolution from the centralized to distributed monitoring and control provided by the "installation" of knowledge on the cargo itself).

Logistics Practices

A second dimension of logistics innovation is best practices. Best practices can be defined as those practices that:

- Deliver tried-and-tested solutions to known problems (Szulanski 1996),
- Reflect accumulated, reusable patterns and components, tools and platforms (Next Practice Research Institute 2011),
- Provide curricula content, precise techniques, and methodological strategies (Peters and Heron 1993).

From a logistics and innovation perspective, we can define a Best Practice as a solution that uses an innovative approach to improve freight transport sustainability in economic, environmental, or social terms. Some examples of logistic best practices are Collaborative Planning, Forecasting & Replenishment (CPFR), Postponement, Cross-Docking, Quick-Response, logistics-driven packaging, or Vendor Managed Inventory (VMI) (Andraski and Haedicke 2003; Maknoon and Baptiste 2009; Choi and Sethi 2010; Kreng and Chen 2008). An innovative logistics practices inventory can be used as an instrument for the transfer of knowledge throughout the European freight transport industry. The methodology approach and some examples of innovative logistic best practices identified in the LOGINN project are the focus of the following sections.

Innovative Technologies

A third dimension of logistics innovation is innovative technologies, as new technological developments (mainly in terms of ICT) are able to improve overall functionality of freight transportation on European level. It covers a wide spectrum of areas, from information and communication technologies, to engine technologies, to intermodal transshipment and material handling technologies, virtual enterprises management techniques to Internet of Things (Tsai et al. 2010; Sanchez and Perez 2005; Shi et al. 2011).

It is important to remark that, besides the content of each dimension, what is even more important to stress is their mutually reinforcing character. ICT has provided new tools for supply chain actors to introduce new practices and new business models; further stretched ICT boundaries to turn themselves from theory to reality.

In the framework of the LOGINN project, an inventory of innovative logistic business models, best practices, and technologies has been created and uploaded to a collaborative platform (LOGINN Virtual Arena). The objective is to get innovation results to logistics companies, transport operators, stakeholder organizations, and technology providers that are interested in adopting transport logistics innovations.

In the following sections, we focus in logistics practices dimension, and describe the methodological approach used and show some examples of innovative logistic practices.

A Methodological Approach for Best Practices Identification in the Framework of the LOGINN Project

Definition of Best Practices

The identification of a best practice is encouraged for several pragmatic reasons. It identifies the best way of doing something in contrast to an inferior or less effective approach. It prevents people from "having to reinvent the wheel", and it gets more practitioners to use the best way (Duignan 2009). Best practices also can be conceived as a promising or exemplary practice, often recommended by experts or leaders in a field (Peters and Heron 1993). Best practices are intended to help practitioners who wish to improve the quality of their service (Peters and Heron 1993; Edge and Richards 1998). A best practice is also a vehicle, by which research can be translated into a form that meets the needs of practitioners, policy makers, and pre- and in-service training agendas (Szulanski 1996; Peters and Heron 1993).

Classification of Best Practices

Duignan (2009) suggests classifying best practices according to the following categories:

1. A practice which practitioners know is feasible to implement, because they have implemented it.
2. A practice which practitioners think probably improves outcomes (but they are not making a strong high-level outcomes/impact evaluation attribution claim for it).
3. A practice which independent evaluators (or reviewers) of some sort think probably improves outcomes (but they are not making a strong high-level outcomes/impact evaluation attribution claim for it).
4. A practice for which someone has made a strong high-level outcomes/impact attribution claim (i.e., they have claimed that they have proof that the practice improves high-level outcomes).

Selected Areas

In the framework of the LOGINN project, best practices from four areas have been collected: e-freight, co-modality, Urban Freight Distribution (UFD), and intralogistics, as the European Commission has remarked their relevance for the consecution of sustainability in European transport.

In fact, in its White Paper for Transport (March 2011), the European Commission has set e-freight as one of the key initiatives in the quest for a Single European Transport Area supported by a competitive, secure, and sustainable transport system. In this context, the EC is funding research and pilot projects to investigate possible e-freight solutions and their benefits.

The co-modality is a notion introduced by the European commission in 2006 in the field of the transport policy to define an approach of the globality of the transport modes and of their combinations. For the European commission the co-modality refers to a "use of different modes on their own and in combination" in the aim to obtain "an optimal and sustainable utilization of resources."

Urban Transport has been a priority for the EU Commission in 2007. The growing significance of urban freight transport (UFD) and logistics is related to increased population and sustained economic growth in urban areas. The main policy objectives arising from these challenges are for transport and travel to become: cleaner, more efficient, including energy efficient, safer, and more secure (Action Plan for the Deployment of Intelligent Transport Systems in Europe 2008).

"Intralogistics" describes the organization, realization, and optimization of internal material flow and logistic technologies. Energy efficiency issues in intralogistics are becoming increasingly important as they are the most cost-effective ways to enhance security of energy supply, and to reduce emissions of greenhouse gases and other pollutants. The EU Commission has proposed that all Member States establish a national energy saving obligation scheme appropriate for their circumstances.

Basic Resources

Regarding information search, different sources of information and project's databases have been consulted for best practices identification.

As far as public-funded projects are concerned, the basic resources used are CORDIS (Community Research and Development Information Service) at European level. As far as private-funded projects are concerned, projects carried out by leading R&D centers at the European level have been taken into account, as well as projects developed by transport and logistics companies at the regional level.

For the identification and analysis of innovative logistic best practices, almost 100 projects (mostly European ones) have been reviewed. From them, 63 projects have been selected for further analysis and in depth reviewing. They have been analyzed and they have been considered as a good source for best practices due to features such as:

- Innovative aspects of the projects,
- Contribution to the logistic areas selected,
- Solid partners.

Best Practices

In the framework of the LOGINN project, an inventory of best practices has been developed and disseminated through the platform LOGINN Virtual Arena (http://www.logisticsarena.eu/), which is a platform developed in the LOGINN project in order to become a virtual meeting point for all the value chain actors.

In this contribution, we present a sample of best practices that are fostered in the LOGINN Project in the context of the particular areas selected. It is not the aim to complete the overview of solutions, but to present and show some examples of best practices that have the potential to increase transport logistics efficiency in each of the selected areas.

Interoperability Between E-Freight Systems (E-Freight)

There are many data sources available which will be aggregated: data from container security devices, port communities, logistics networks, terminal operators, etc. In order to support decision processes in the logistics chain, we need to combine data sources and consolidate these data to valuable information. It involves providing connectivity among systems and using common standards.

Based on this interoperable set of e-freight systems, shippers, beneficial cargo owners, LSPs as well as customs authorities will be offered information that will make logistic chains to have shorter lead times and higher reliability. We will unlock valuable information that is available somewhere throughout the logistics chain.

Interoperability between systems is only useful if it leads to improved processes. With this practice, we focus on better integration of customs processes, better interfaces between sea and hinterland, as well as better control on the hinterland part of the logistics chain which is often the largest cause of variability.

Cargo Bicicle Delivery in the 'Last Mile' (Co-modality)

Almost 100 % cargo transport in cities is done by motorized vehicles, ranging from personal cars to commercial delivery vans and trucks (lorries). However, these heavy vehicles often transport very light goods. A large share of the cargo being moved in and out of cities could be transported by cargo cycles.

Freight traffic takes up a large portion of total daytime road transport in cities, often as high as 50 % in large cities, and up to 90 % in very large cities such as London and Paris. The "last mile" is currently regarded as one of the most expensive, least efficient, and most polluting sections of the entire logistic chain. This is because traffic congestion makes the driving cycle very irregular, leading to very high fuel consumption and a loss of time.

Some positive ecological and social consequences of substituting cargo cycles for delivery vans are: important fuel savings, less pollution, less noise, more space in a more enjoyable city, less congestion, and less serious accidents. There are as many economic benefits as there are ecological and social benefits, though they are not so obvious at first sight.

Cargo cycles operating in the city are as fast as vans and trucks, due to the fact that they are less affected by traffic congestion, because they can often take faster routes where trucks and vans cannot go, such as pedestrian streets, alleys, or bicycle paths. Because cargo cycles are less affected by variable traffic conditions, journey times are more reliable. Moreover, they are able to enter the city 24 h a day, while many Europeans cities have set very strict time windows for loading and unloading of trucks and vans. Cargo cycles have generally no difficulty finding a place to load or unload and can often stop right in front of the door or even enter a building. In addition, cargo cycles are much cheaper than vans.

Traffic Forecasting for Congestion Reduction (UFD)

Transport congestion problems contribute 70 % of pollutants to urban environments. The transport sector by itself consumes up to 30 % of the total energy in the EU. These figures suggest that if Europe is to reduce its CO_2 emissions by making an efficient use of energy while improving the quality of life in European cities, novel approaches for the optimal management of urban transport complexity must be developed and adopted in the transport sector.

Congestion is one of the most significant contributors to air pollution and can have devastating effects on the environment as well as individuals. Congestion usually occurs repeatedly in specific areas. According to a study published on PubMed.gov, this will cause increased pollution concentrations in those specific areas. Besides, during congestion, vehicles burn gasoline for large periods of time without traveling far. According to the Environmental Protection Agency, this is a waste of energy and increases the need for more gasoline.

With traffic forecasting practices, drivers can avoid congestion areas and changes in traffic organization can be made in order to reduce pollution zones.

Plant Floor Visibility (Intralogistics)

A lack of near-real-time visibility across all ends of production leads to fragmented communication and delayed response to production-critical issues.

Operations managers require access to near-real-time information on disparate intralogistic processes. Making timely decisions can prevent lag time and help managers address lapses in performance, address equipment downtime, identify additional resources requirements, and quickly identify areas that require operational improvements.

With this purpose, it is necessary to gather, analyze, and respond to vast amounts of production-related data in a short time. In order to make this in an agile way, it is mandatory to maximize visibility of processes across each end of the production spectrum, enabling managers to participate in operational decision-making.

Advanced technologies facilitate visibility on processes. Mobile connectivity can ensure that data is available anytime, anywhere for faster, more intelligent decision-making that can help manufacturers and distributors gain a competitive edge.

Conclusion

This contribution describes a methodology for the identification and classification of innovative logistics best practices in the framework of the European project LOGINN, as well as a first rough analysis of drivers and barriers of each practice.

The scope of the best practices selection is limited to four areas such as co-modality, urban freight distribution, e-freight, and intralogistics as they constitute a priority for European Commission. A sample of four best practices, one of each selected area, has been identified and described in depth.

Future work focus will be to identify knowledge on what the drivers for successful logistics innovations are and how the barriers to innovation adoption can be mitigated and transferability increased between different sizes of operators, small to large, type of operation, and geographical location in Europe.

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References

Action Plan for the Deployment of Intelligent Transport Systems in Europe (2008)

Andraski JC, Haedicke J (2003) CPFR: time for the breakthrough? Supply Chain Manage Rev 7:54–61

Behrends S (2009) Sustainable freight transport from an urban perspective. Chalmers University of Technology, Gothenburg

Choi TM, Sethi S (2010) Innovative quick response programmes: a review. Int J Prod Econ 127:1–12

Duignan P (2009) What is 'good practice'? Outcomes Theory Knowledge Base Article No. 237

Edge J, Richards K (1998) Why best practice is not good enough. TESOL Q 32(3):569–576

Kreng VB, Chen FT (2008) The benefits of a cross-docking delivery strategy: a supply chain collaboration approach. Prod Planning Control 19(3):229–241

Maknoon MY, Baptiste P (2009) Cross-docking: increasing platform efficiency by sequencing incoming and outgoing semi-trailers. Int J Logistics Res Appl 12:249–261

Next Practice Research Institute (2011) Next practice. London, England: Author. Retrieved from http://npri.wikispaces.com/next+practice

Nilsson A (2006) Essays on joint replenishment and multi-echelon inventory systems. Luleå University of Technology, Licenciate Thesis

Peters M, Heron T (1993) Why the best is not good enough: an examination of best practice. J Spec Educ 26(4):371–385

Sanchez A, Perez M (2005) Supply chain flexibility and firm performance: a conceptual model and empirical study in the automotive industry. Int J Oper Prod Manage 25(7):681–700

Shi RL et al (2011) The game analysis on risks of logistics enterprises participate in logistics finance. Adv Mater Res 335–336

Sternberg H, Lumsden K, Stefansson G (2011) Decreasing operational waste in motor carrier operations—the role of information and enablers conference proceedings till ITS Europe 2011. [Nr. 154234]

Szulanski G (1996) Exploring internal stickiness: impediments to the transfer of best practice within the firm. Strateg Manag J 17:27–43

Tsai MC, Lee W, Wu HC (2010) Determinants of RFID adoption intention: evidence from Taiwanese retail chains. Inf Manage 47(5–6):255–261

Wagner SM (2008) Innovation management in the German transportation industry. J Bus Logistics 29:215–231

Lab-Enriched Logistics Education—Current Status and Future Opportunities at the Example of the Chair of Industrial Logistics at the Montanuniversität Leoben

Susanne Altendorfer and Helmut Zsifkovits

Abstract Learning factories and laboratories are a great enrichment for university education and training. Many universities worldwide use laboratories to support the education. Especially the logistics area is highly qualified to be supported by laboratory-enriched education. This paper highlights some trends in didactics and the benefits of laboratories on the example of a logistics laboratory at the Chair of Industrial Logistics.

Keywords Learning factories · Learning on the model · Logistics lab

Introduction

The learning process has strongly changed over the last years. Self-determined learning and practical exercises dominate the new way of education and learning that has found its way at many universities worldwide. Especially the area of Logistics and Industrial Engineering is privileged for practical, self-determined learning and teaching strategies. Here, learning factories are one possibility to establish innovative learning environments for education and training (Steffen et al. 2013).

In this paper we will show some trends in university didactics that have a great impact on the way education and research is performed at universities. Then we will present the intention and goals behind lab-based logistics at the Chair of Industrial Logistics. With a future outlook the paper is concluded.

S. Altendorfer (✉) · H. Zsifkovits
Industrial Logistics, Montanuniversität Leoben, Franz-Josef Strasse 18,
8700 Leoben, Austria
e-mail: susanne.altendorfer@unileoben.ac.at

H. Zsifkovits
e-mail: helmut.zsifkovits@unileoben.ac.at

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Educational Background

The learning process, especially occupational learning, is strongly coined by new paradigms: self-determination, practical doing and learning by doing are just some examples. These new developments lead to what we call nowadays university didactics. It combines learning aspects with findings of the area of psychology and brain research (Scheibe and Tenorth 2010).

Since then, many learning theories to improve teaching and learning have been developed. Thus the noun “didactics” has the meaning of “organizing the learning process to enable self-determined learning” (Schenk et al. 2006). The main focus is on applied teaching and learning with learning goals and content as well as new methods and media usage in focus.

Figure 1 highlights the connection between the way the content is taught (information transfer method) and the level of understanding (level of learning). This clearly shows the importance of active doing and practicing for understanding and learning.

To secure long-time results in learning, active doing has to be the focus. Especially learning factories and laboratories support this development. Furthermore with this practice the constantly growing requirements from industry can be satisfied. Students and potential employees learn in the laboratories practical things that they can directly use later in their working context.

Learning on the Model in Logistics

In many areas of university education and advanced training, the results of modern university didactics are intensively used and universities try to integrate learning factories, training- and research laboratories more extensively into the curricula and act more applied-orientes.

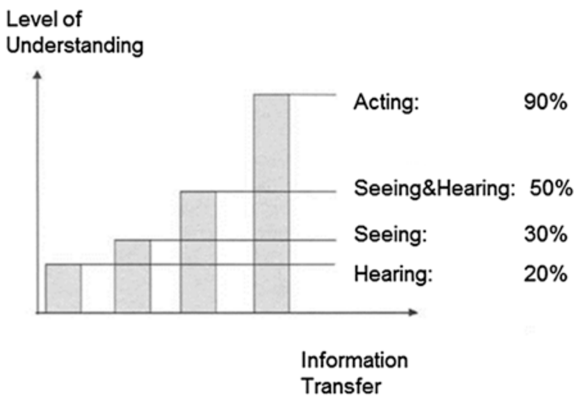

Fig. 1 Connection between the level of understanding and the information transfer method (Schenk et al. 2006)

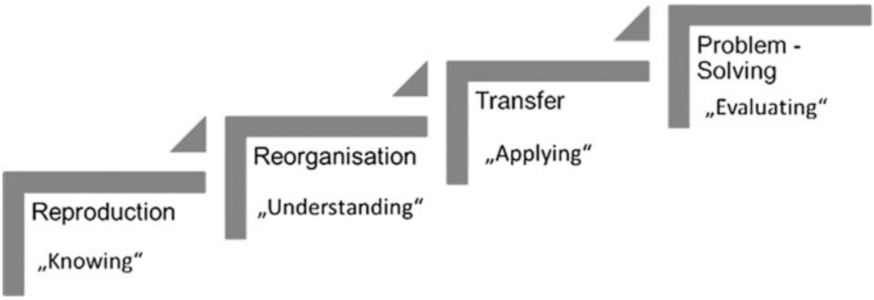

Fig. 2 Learning targets (adapted after (Bloom 2001))

The field of logistics is ideal to establish learning factories and laboratories, due to its complex task setting, resulting from the "close and complex connection between actors and systems" (Matzler et al. 2006). These relationships are often not transparent, non-linear, delayed and difficult to reproduce with respect to their cause-and-effect relationship (Pfäffli 2005). Especially these complexities urge logistic experts to react more flexibly and to act proactively in order to achieve holistic solutions. Here an integrated education and training is necessary to enable the students to reach the highest level of learning—the level of problem-solving, as shown in Fig. 2.

Figure 2 shows the different levels of learning targets. As already described above it is nowadays extremely important to reach the level of transfer and even better the level of problem-solving. Here holistic problems can be solved in a self-determined way. And laboratories and learning factories are positioned at the third and fourth level, whereas classical lectures and seminars are positioned at level one and two in Fig. 2.

Universities in general already follow this approach and technical universities with a logistics area even more apply laboratories and learning factories. There are a number of research institutions worldwide that have already established learning and experimental manufacturing facilities in their laboratories (Wagner and Al Geddaway 2012). Learning factories are innovative learning environments for education and training, especially in the logistics area. Real work systems can be created in realistic production environments in order to gain practical experience and knowledge. Besides universities, this opportunity is used by manufacturing enterprises or consulting firms who also establish learning factories (Steffen et al. 2013).

Logistics Laboratory at the Chair of Industrial Logistics

The Chair of Industrial Logistics realizes a logistics laboratory in terms of a learning factory. Here students get the opportunity to work on different tasks that directly respond to real-life requirements. The problem situation will be readjusted in the laboratory whereas the focus is on the interconnection of different logistic areas. Thus cross-functional thinking and acting is strengthened. And students can apply theoretical knowledge on real situations. Furthermore, the students have the chance to get to know different technical systems, e.g. radio-frequency identification (RFID) solutions. Here they can evaluate and test different RFID systems (hardware, software, etc.) and set up use cases. Different effects of solutions and technologies can be tested in a protected environment. Through the self-determined actions students can apply their knowledge in a more practical way. Furthermore, the understanding is enforced.

Thus the Chair of Industrial Logistics aims to set up a comprehensive laboratory, which can be used in the context of education and training for students and for industrial partners.

Areas of Education and Research for a Logistics Laboratory

The learning factory at the Chair of Industrial logistics has its foci along the material and information flow. Thus a comprehensive perspective on logistic systems and processes will be available. The main areas are illustrated in Fig. 3.

To enable an as practical training as possible and to give the students the opportunity to meet a number of areas and technologies and solutions providers, it is intended to create a wide product mix within the laboratory. The set-up of the

Fig. 3 Main areas of the logistics laboratory

laboratory is modularly designed. Thus different areas can be either separately or jointly examined.

Some tasks that can be performed within the learning factory are:

- Logistic processes can be modelled and realized with different process modelling software systems
- Material flows can be defined and modelled
- RFID systems can be tested and evaluated
- Products can be provided with RFID or barcode labels
- Products with RFID tags can be tracked along the material flow
- The usability of RFID tags with different materials can be evaluated
- Different kinds of simulation software can be assessed and tested
- Storage systems can be evaluated on the model
- Training on different logistics systems

The Chair of Industrial Logistics put a lot of emphasis on the integration and participation of industrial partners. On the one hand, different technical and software systems can be tested and used and on the other hand research projects can be directly performed with partners and students. Hence answering current research questions is possible. Thus both parties, the university and the industrial partners, profit from these synergies.

Benefits of the Logistics Laboratory

The benefits of a logistics laboratory are manifold and are oriented according to their users and user-groups.

Benefits for the Students

The primary focus group is the student. Students do not only profit from new learning aspects and methods but also from the interaction with the industry:

- Performing projects with real tasks and questions
- Getting new contacts to industrial companies and possible future employers
- Getting a deeper system knowledge by using the different systems in the laboratory
- Real system environments

Furthermore, the lab-based education will also result in a better understanding and problem-solving competence in the students. This will also be directly reflected in the final marks.

Benefits for Industrial Partners

As the Chair of Industrial Logistics also aims to integrate and cooperate with industrial partners, the benefits for companies that participate and engage in the learning factory are manifold:

- Make use of synergy in research and development (R&D)
- Long-lasting cooperation in R&D projects
- Concentration of core competence and outsourcing of research tasks to the university factory.
- Training of employees in the working context
- Early integration of students in industrial projects

Furthermore, companies should not only work together on projects but the laboratory also offers the possibility to address current questions and problems and to get them answered. Thus the laboratory is also positioned as a valuable partner for small and medium enterprises that do not have the resources to research current problems on their own.

The learning factory is also intended to be used as training environment for companies to train their employees in specific areas. The learning factory here has the advantage that in the training the same content and environment can be put into practice, which the participants also find in their working environment.

In the future the laboratory is intended to also become a virtual laboratory. Here, it should be possible to conduct research without being directly in the laboratory. A further extension to this virtual laboratory is that the laboratory is connected to other laboratories at other universities and applied research could be performed without the hindrance of national borders. Exactly in the field of Logistics and supply chain management, university-wide laboratories are of great interest.

Conclusion and Future Research

This paper gave a short overview of the development in university didactics and on the usage of learning factories in general and on the usage of a learning factory at the Chair of Industrial Logistics in detail. In the future, learning factories will gain even more importance and become an essential part of the curricula. At the Chair of Industrial Logistics, a strong focus will be put on learning factories in the following years. A main goal is to establish a virtual decentralized laboratory with industrial and university partners within the next years. First concepts and ideas are already under development and can be presented for the first time in spring 2014.

References

Bloom B (2001) Taxonomie von Lernzielen im kognitiven Bereich. Beltz

Matzler K, Bidmon S, Schwarz-Musch A (2006) Didaktische Aspekte der Arbeit mit Case Studies. In: Ausbildung in der Logistik. DUV. Wiesbaden

Pfäffli B (2005) Lehren an Hochschulen: Eine Hochschuldidaktik für den Aufbau von Wissen und Kompetenzen. Haupt Verlag, Bern

Scheibe W, Tenorth H (2010) Die reformpädagogische Bewegung: Eine einführende Darstellung. Beltz, Weinheim und Basel

Schenk M, Reggelin T, Barfus K (2006) Innovative Lehrmethoden in der universitären und außeruniversitären logistischen Aus- und Weiterbildung. In: Ausbildung in der Logistik, DUV. Wiesbaden

Steffen M, Frye S, Deuse J (2013) Vielfalt Lernfabrik. Morphologie zu Betreibern, Zielgruppen und Ausstattung von Lernfabriken im Industrial Engineering. Wt Werkstatttechnik online. Springer VDI Verlag. Wiesbaden

Wagner U, Al Geddaway T (2012) The state-of-the-art and prospects of learning factories. In: 45th CIRP conference on manufacturing systems 2012. doi:10.1016/&j.procir.2012.07.020

Supply Chain Management of Mass Customized Products: Analysis Through Automobile Industry

Arshia Khan and Hans-Dietrich Haasis

Abstract Automobile industry like many other industries is rapidly moving toward mass customization. However, the phenomena of mass customization did not prove to be fruitful for all the companies that adopted it. Success of this mass customization depends upon supply chain management along with proper strategies. There is no proper model for automobile industry yet that explains the optimal level or extent to which different strategies should be applied with proper supply chain. This study will try to bring out this gap by doing the case study of leading German mass customized automobile companies.

Keywords Mass customization · Strategies · Supply chain management

Introduction

Mass customization has replaced or supplemented mass production in many parts of the world. The main focus of mass customization is to meet individual customer demand with minimal loss of efficiency (Liu and Deitz 2011). With increased available choices and varying demand among customers, mass production is no longer a successful idea in the modern world. So to improve efficiency and market share companies round the world are focusing toward mass customization.

In the case of automobile industry, this idea of customer preference gained importance in the end of twentieth century. With the overall trend of giving customer choice a significant importance, automobile industry also started moving toward mass customization, and Ford and BMW can be regarded as pioneer in this

A. Khan (✉)
International Graduate School and Institute of Shipping Logistics, Bremen, Germany
e-mail: khan@isl.org

H.-D. Haasis
Institute of Shipping Logistics, Bremen, Germany
e-mail: haasis@isl.org

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regard. Now in the modern times almost all major leading automobile companies allow their customers to build their own car from a set of available options. The process is called mass customization as it combines the features of mass production and customization. Among all the leading companies, BMW and Ford are found to be most successful in carrying out the mass customization process. Mass customization for BMW proved to be a very successful idea as company profits raised by $5.34 billion in 2013 as compared to $2.2 billion in 2004. BMW also gained trust of customers by providing desired products in as short as 12 days. Result of customization at other companies is not that much fruitful and Adam Opel failed to have significant market share in spite of producing a highly customized automobile.

Mass customization gave different results to different companies; it can be due to the reason that there are several strategies that can be used to carry out mass customization and different companies focused on different strategies. Most common strategies used in mass customization are modular product design, Internet integration, and postponement (Mula et al. 2004). To carry out efficient mass customization, modularization is being used in modern times, and modular product designs are the key to carry out cost saving mass customized production. Modularity is the degree to which system's components may be separated and recombined in which a wide variety of products can be configured and assembled. The greater the extent to which the product can be modularized, the greater can be the degree of customization, and however, the greater would be the complexity in managing the supply chain of the product (Mikkola 2007). Furthermore, the more the efficient and modular product architecture is, the less the cost it will take. Volkswagen claims to save $1.7 billion annually through effective modular product architecture (Bremner 1999). Another strategy important for mass customized products is postponement that is to carry out the final steps of production after customer places the order. Postponement can be time postponement or form postponement; in the earlier case, final steps of the production are delayed until the final order is received from the customer and the product is shipped later, while in the postponement product form it is shipped in the semi-finished form and the final steps are usually done by the end distribution section (Zinn and Bowersox 1988).

Furthermore, the role of an efficient supply chain becomes very important in carrying out mass customization through the above-mentioned strategies. All different strategies for mass customization can only give efficient result if the supply chain management is flexible and time saving. Importantly, supply chain should be as much flexible as possible because this would allow greater degree of customization. Keeping all these constraints in view, there is a need to develop a model that explains how to deal with different strategies and how to carry out efficient supply chain management in dealing with the strategies.

Problem Analyses

In case of automobile industry, many companies followed mass customization but the success story has not spread to all of the companies. This is because mass customization is not as simple as mass production. It requires carrying out efficient strategies in time and with minimal loss of efficiency.

Modularization is the key strategy in mass customization; the greater the extent to which the product can be modularized, the greater the customization is possible, but the greater the modularization is, the more problems associated with it will occur. It would then need more time and management to produce a final product. This also holds for the postponement strategy; the greater the degree of postponement is, the greater the delay in delivering orders will be.

Another important issue for carrying out effective customization is the level of inventory stocks. Although mass customization in contrast to mass production focuses on less inventory stock to maintain less cost, the tsunami shock of 2011 in Japan opened new questions in this regard. Japan is the producer of many spare parts which are used in automobile production. After the tsunami, a question was raised about how much should be the level of inventory stocks. A shock in the supplier country can disrupt the whole supply chain; therefore, a new concept arose concerning the mass customization level of inventory stock, which is also important.

Keeping all the constraints in view, companies have to organize supply chain management in such a way that it allows optimal level of modularization, postponement, and inventory stock with maximum flexibility and minimum loss of efficiency. Development of a model that meets the following needs for automobile industry can be very helpful.

Research Question

Supply chain for automobile companies should be managed efficiently allowing maximum flexibility. In this regard, research questions could be

- What should be the level of modularization?
- Which and how postponement strategy should be used?
- What should be the level of keeping inventory stock?
- How to manage all these factors with the efficient supply chain management?

Methodology

To address the questions mentioned above, we need to build a model. This model can be built by doing case studies of leading German mass customized automobile companies like BMW, Adam Opel, and Volkswagen. The model can be developed by analyzing the data available in annual financial reports of these companies and further by comparing the strategies that these companies have adopted and the results they have gained.

Conclusions

The model developed by the above-mentioned techniques above can help the companies carrying mass customization to select optimal strategy, to manage supply chain, and to reduce cost. Such a model can even help the successful companies in selecting the right strategy.

References

Bremner R (1999) Cutting edge platforms. Financial Times Automotive World, 30–38

Liu G, Deitz GD (2011) Linking supply chain management with mass customization capability. Int J Phys Distrib Logistics Manage 41(7):668–683

Mikkola JH (2007) Management of product architecture modularity for mass customization: modeling and theoretical considerations. Eng Manage IEEE Trans 54(1):57–69

Mula J, Poler R, García JP (2004) Supply chain production planning in a mass customization environment. In: Second world conference on POM and 15The annual POM conference, Cancun, Mexico

Zinn W, Bowersox DJ (1988) Planning physical distribution with the principle of postponement. PLANNING 9(2):111

Development of Global Supply Networks to Market Integration

Dmitry Zhuravlev and Hans-Dietrich Haasis

Abstract Global business opportunities require companies to work with suppliers and customers worldwide. The supply chain management (SCM) assumes increasing significance for the world community, at the same time there is competition not between companies but *global supply networks*, which are increasingly replacing supply chains. As a result, competition between companies in global markets increasingly means competition between networks; however with globalization, corporate planning has turned out to be under the strong influence of distribution networks, in the focus of attention of which is not a product but *customers*' *value*. This article considers the logistics systems from the point of view of conveying value by means of supply networks decentralized control systems and centralized adoption of global networks.

Keywords SCM · International management · Global networks

Description of the Tasks and Definitions

Practically every company commercially interested in sales activity faces challenges with international market expansion. The complexity and uncertainty of expanding into the global network deters some businesses from making use of these opportunities. But at the same time, this process could become helpful for business consolidation.

At first, the establishment of representative offices abroad can be a simple solution to work on the international market. However, external control of logistic systems including representational resources in accordance with current market

D. Zhuravlev (✉) · H.-D. Haasis
University of Bremen, FB7, Bremen, Germany
e-mail: zhuravlev_dmitry@yahoo.de

H.-D. Haasis
e-mail: haasis@uni-bremen.de

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needs is certainly a new challenge. Effectively addressing these challenges requires system analysis and operations research. The use of these methods provides the following advantages: creation of integrated management and monitoring systems to monitor the movement of goods and services, development of systems for logistic services, optimization of resources, execution of other tasks, such as products distribution and products marketing. Implementation of system analysis and operations research is supported by several modeling techniques and widely used in logistics.

Flows Planning

In marketing its goods and services, a company studies material flows, as well as financial and information flows. On their way from the primary source of raw materials to the final consumer, these flows pass through different production, transport, and storage units. Managing tasks for material flows are executed individually within each unit. Certain units represent so-called "closed systems" which are technically, economically, and methodologically isolated. Business management within the closed systems is carried out by planning and management methods of economic and production systems and could easily be described in relevant sciences. These methods are still used within the logistic approach on the market level in material flow management. However, the transition from independent isolated systems to *integrated logistic* requires methodological management base of expansion on the external level (Marakov 2007).

This base is relatively new according to the science development. The management theory has developed through three stages in the past years (Remer 2004): from the classical approach of management, the neoclassical approach of corporate governance, to a tendency to look at companies from a *system perspective*.

A system perspective is valuable for the company's effective operations. For example, a system perspective supports improved insight into three variable components (flows): *goods* (*material*) + *information* + *finance*. Definition of the role of each component and share in the sales activity will show a degree of cooperation and interplay between partners in the distribution networks from a system perspective (see Fig. 1).

The actual market needs can be determined through tasks of sales activity, which also cross with flows planning concept (Zhuravlev 2012a, b):

- *Customization*
- *Rationalization* refers to the choice of rational distribution channels of goods with a focus on maintaining and expanding markets.
- *Minimization* refers to the total cost of goods in the economic cycle, including the costs of trade and consumer services (Zhuravlev 2012a).

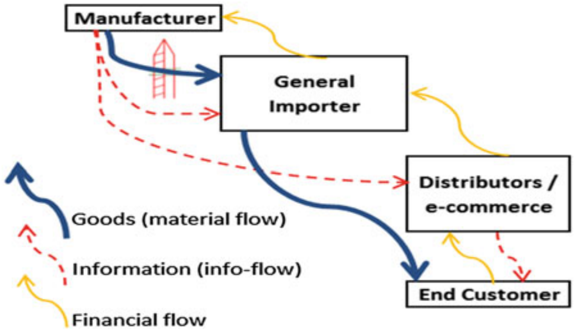

Fig. 1 Example of the interaction by flows planning from a system perspective: Drop-shipping schema by international expansion

Global Supply Networks Management as an Instrument to Mature

The company's decision of expansion on the new market can be based on principally new logistic ways, where the allocation of the corporate distributional center will add to the company's marginal profit through customers' consolidated costs and ensure accurate delivery in accordance with the market needs. The increase of export deliveries depends on the growing medium-sized businesses, which are able and ready to offer products and innovative solutions for international consideration.

An international distribution structure would be possible on the basis of logistics solutions as additional options for indirect distribution on the market through to opening an own distributional channel in the new segment and, therefore, legitimate and legal steps to establish a distributional center (Zhuravlev 2010). For a successful market entry, functioning and efficient logistics are essential. Although planning and control of logistics activities are usually made with the commercial companies, implementation of logistics will be done by service providers. Here, it can be stated that many companies have built and expanded their core competence characteristics of global supply networks integrations, like flexibility, quality, service increase, etc.

This has led to the spread of the outsourcing concept, i.e., the involvement of external organizations, to realize the work of the client to be used as core competencies. Modern production and logistics concepts are characterized by innovation (innovative technologies), self-organization (organizational structures with sufficient dynamics), competence (development of activities with which the company is most competitive), virtuality and interaction (participation in defined network structures, supply chains, virtual company, the widespread use of Internet technologies) (Ivanov 2005). In practice, however, there are systems that combine elements of supply chains and virtual enterprises–global supply networks.

And here comes the question, how to consider the idea of cooperation at the new level, retaining existing intercountry barriers and restrictions. In this case, in addition to reducing cost (minimization), customization, and rationalization of logistic routes we are faced with another parameter—*the risks* of a new market penetration (or *unstable foreign economic situation*), whose reduction should form the basis of the newly organized structure. Classic models of export-oriented companies may be described with the following schemes (see Fig. 2).

In this case, the new model should be to minimize the risk, with emphasis on the risks to goods and finance, by providing a new market all the original components remain unchanged. In this context, cooperative creation of such a structure would be most effective (see Fig. 3).

The global supply network system implies a managed hub and is responsible for the following tasks (see Table 1): (a) minimizing costs at the expense of coordination and integration of key business functions and (b) increasing the value contribution by fulfilling the individual needs of customers.

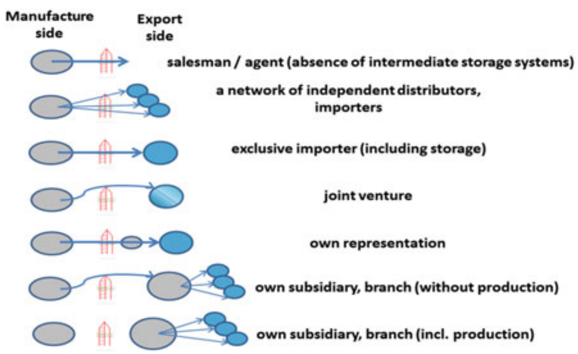

Fig. 2 Classics models of export steps

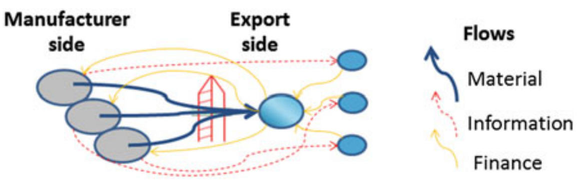

Fig. 3 Market-oriented model of logistics system in flows planning

Table 1 Advantageous properties for the achievement of the tasks of the company

	Advantage in value	Advantage in management of business processes
External tasks	Increasing the value of the offer	Assignment and coordination of Cooperation of the partner companies in the integrated logistics system
Interior tasks	Minimization of own costs	Harmonization of business departments

Conclusion

The cooperating partners adopt and pursue common goals, which they realize through a mutual integration of their resources. Cooperation objectives can be broadly responsive to two fields. Firstly, it includes the objectives, which relate to the individual companies, such as cost reductions, time savings, quality and flexibility improvements. Secondly, included objectives are identified across companies as improving competitive position and the innovation ability. Of particular importance due to shortage of information is the access to strategic innovations and information flows.

References

Ivanov DA (2005) Supply chain management: conception, models. State Polytechnic University, St. Petersburg
Makarov V (2007) Logistics, lecture course. State Polytechnic University, St. Petersburg
Remer A (2004) Management: system und Konzepte, 2 Aufl. Bayreuth, pp 91–94
Zhuravlev D (2010) Logistics solutions to sales policy development in international markets. INGECON, St.-Petersburg, pp 510–515
Zhuravlev D (2012a) Supply chain management in foreign markets. 5(156):49–55
Zhuravlev D (2012b) Concept development: global supply networks management in the context of the interaction between Germany and Russia, pp 141–144

Dynamics in Demand of Qualifications and Competences in Logistics—Actual and Future Challenges for Human Resource Managers

Sebastian Wünsche

Abstract Logistics is an important business sector for the German economy. But it is influenced by so-called social and economic megatrends that lead to rising qualification and competence requirements. In this context it could be asked, if existing qualification and competence profiles do fit these quickly rising new requirements. This extended abstract discusses first approaches and attempts to find out, if misfits between new qualification and competence requirements and existing qualification and competence profiles indeed exist. Furthermore, first ideas of follow-up problems for employees and human resource managers in logistics are sketched.

Keywords Human resource management · Logistics sector · Qualifications · Competences · Megatrends · Qualitative skill shortage

Introduction

Depending on the general development of the economy, logistics can be seen as a growth industry with a huge demand for employees, in particular for logistics/supply chain managers and qualified personnel (see, e.g., BVL 2013; Kille and Schwemmer (2012)). But due to the demographic shifts in society, we can also expect in the logistics sector a 'war for talent', meaning that qualified people will become a scarce resource in future. Furthermore, there are major technological developments in automation for material flow systems and International Technology (IT), which significantly affect the required qualification and competence profiles of future logistics employees, too (Katz and Margo 2013). Beneath the demographic shift and technological advancement, other so-called social and

S. Wünsche (✉)
Chair of General Economics and Logistics Management, Wilhelm-Herbst-Str. 12, 28359 Bremen, Germany
e-mail: swuensche@uni-bremen.de

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economical megatrends influence the logistics sector, e.g., globalization, rising environmental consciousness, and so on (Kotzab and Unseld 2009). Logisticians have to attend to a lot of new issues that come with these megatrends. Social and business megatrends result in a trend of quickly rising requirements regarding demanded qualifications and competences (Oxford Research 2010; Jasper and Wählisch 2004). In other words, employees in logistics have to cope with more and more complex problems and situations in this context. However, employees have an existing portfolio of qualifications and competences as a toolkit to solve these problems. It can be questioned, if new job requirements sooner or later rise above the existing job qualification and competence profiles—eventually they actually do. This development would lead to a qualitative skill shortage going along with the quantitative skill shortage caused by the demographic shift. The reason for not finding the needed qualifications and competences is a misfit between new, quickly rising job requirements and existing qualification profiles. Taking into account these thoughts, the following questions can be asked:

> Is there a misfit between qualification and competence requirements and profiles and which problems for logistic companies can be derived in that context? Where are possible problem-solving starting points for human resource managers in logistics?

Literature Review and Modeling Ideas

A combined keyword search of logistics and human resource management searching terms within the scientific databases of WISO-NET and business source premier led to 132 relevant reviewed journal articles that discuss human resource management matters in logistics. Social megatrends and their effects on human resource management aspects in logistics do not attract much attention. This is especially the case when talking about qualification and competence aspects. The problem of qualification- and competence-related misfits has not been discussed yet, but putting together different fragments and connections leads to the assumption, that they do exist. Impressions from the literature and the introduced basic problem led to a first model sketch, shown in Fig. 1.

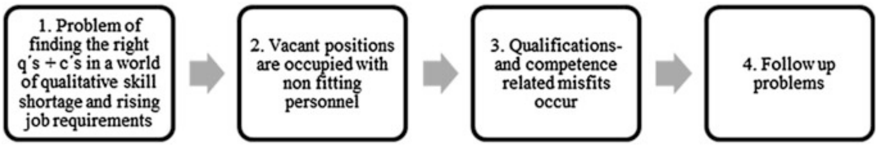

Fig. 1 Outcome of qualification- and competence-related misfits

Methodological Approach

To solve the introduced problem and validate the prior modeled thoughts, qualification and competence profiles and requirements have to be confronted with each other. For this reason, a mixed method approach will be used. The research will take place as a case study in cooperation with a German logistics provider that kindly agreed to be available for the study. To give the following research steps a frame, different instruments have been used. The following research methods have been structured along with qualifications and competences proposed by Frey and Balzer (2007) and job advertisement observations done and presented at the LM2013 conference by Kotzab and Wünsche (2013). Furthermore, the classification of jobs 2010 published by the GFLMA (2011) has been used to make differences between requirement and hierarchy levels. In the first step qualification and competence requirements for now and the future have to be found. For this, leading human resource managers from the company have been interviewed in a structured and guided way. Table 1 shows the interview characteristics. Afterwards a requirement profile has been built from the answers, which has been approved by the responsible persons.

In the second step, a survey has been held to find out the existing qualifications and competences within the company. Employees of all positions and departments have been asked for assessment of used behavior during their work. The survey has been designed by proposals of Frey and Balzer (2007). Table 2 shows the key facts of the survey.

Table 1 Interview characteristics

Kind of interview	Structured and guided
Conversional partner	Human managers from the company
Generated data	Information about required qualifications and competences within the company along different hierarchy levels
Interview date	17.06.2013

Table 2 Survey characteristics

Kind of survey	Scale-based survey, 94 questions
Asked subjects	Employees of all positions and hierarchy levels within the company
Generated data	Information about existing qualifications and competences within the company along different hierarchy levels by self-assessment
Asking period	12.08.2013–18.10.2013
Possible number of respondents/actual number of respondents/return rate	332/105/31.62 %

Afterwards average Is-qualification and competence profiles have been built from the answers for different occupational categories. In the final step, both profiles have to be compared with each other to identify, whether there are misfits between them or not.

First Results

Currently work is in progress, but first results from the research described above confirm observations discussed in the literature and it can be assumed that misfits between existing qualifications and competences and requirements exist. On the basis of estimations done by the human resource management experts, the following statements can be derived.

- The trend of rising requirements regarding qualifications and competences can be confirmed for the sample company. It can be said that requirements rise hierarchy level-comprehensive.
- Only in rare exceptional cases a requirement can be described as sinking in importance.
- Even at the lowest hierarchy level (mainly low skilled workers) only a few competences are disposable.

References

BVL (2013) "Logistik ist…", available at: http://www.tag-der-logistik.de/logistik-ist-mehr/logistik-ist. Accessed 26 Mar 2013

Frey A, Balzer L (2007) Beurteilung zu sozialen und methodischen Kompetenzen. Die SMK-Reihe. Available at: www.kompetenzscreening.de/Beurteilungsbogen_smk_FreyBalzer_Beschreibung2007.pdf. Accessed 3 July 2013

GFLMA (2011) Klassifikation der Berufe 2010. Band I: Systematischer und alphabetischer Teil mit Erläuterungen. Nürnberg.

Jasper G, Wählisch B (2004) Wettbewerb um Nachwuchs & Fachkräfte. Generationenübergreifender Dialog für berufliche Orientierung und Entwicklung, 1. Aufl. Hampp, München

Katz L, Margo R (2013) Technical change and the relative demand for skilled labor: the United States in historical perspective. Working paper

Kille C, Schwemmer M (2012) Die top 100 der Logistik: Marktgrößen, Marktsegmente und Marktführer in der Logistikdienstleistungswirtschaft, Ausg. 2012/2013., DVV Media, Hamburg

Kotzab H, Unseld HG (2009) Megatrends für den Gütertransport. Wirtschaftspolitische Blätter 56 (1):826–831

Kotzab H, Wünsche S (2013) Competences and qualifications of logistic managers—an empirical analysis of job postings in Germany, papers during LM2013 conference, 13 Sept 2013, University Bremen

Oxford Research (2010) Querschnittsstudie zur Entwicklung der Qualifikationsanforderungen in 19 Wirtschaftssektoren. Available at: ec.europa.eu/social/BlobServlet?docId=4687&langId=de. Accessed 21 Jan 2013

Part VI
Frameworks, Methodologies and Tools

Forecasting of Seasonal Apparel Products

Michael Teucke, Abderrahim Ait-Alla, Nagham El-Berishy, Samaneh Beheshti-Kashi and Michael Lütjen

Abstract Demand forecasting of fashion apparel products has to cope with serious difficulties in order to get more accurate forecasts early enough to influence production decisions. Demand has to be anticipated at an early date due to long production lead times. Due to the absence of historical sales data for new products, standard statistical forecasting methods, like, e.g., regression, cannot easily be applied. This contribution applies selected methods into improve forecasting customer demand of fashion or seasonal apparel products. We propose a model which uses retailer pre-orders of seasonal apparel articles before the start of their production to estimate later, additional post-orders of the same articles during the actual sales periods. This allows forecasting of total customer demand based on the pre-orders. The results show that under certain circumstances it is possible to find correlations between the pre-orders and post-orders of those articles, and thus better estimate total demand. The model contributes to the improvement of production volumes of apparel articles, and thus can help reduce article stock-outs or unwanted surpluses.

M. Teucke (✉) · A. Ait-Alla · N. El-Berishy · S. Beheshti-Kashi · M. Lütjen
BIBA—Bremer Institut für Produktion und Logistik GmbH, Planning and Control of Production and Logistics Systems (PSPS), University of Bremen, Hochschulring 20, 28359 Bremen, Germany
e-mail: tck@biba.uni-bremen.de

A. Ait-Alla
e-mail: ait@biba.uni-bremen.de

N. El-Berishy
e-mail: elb@biba.uni-bremen.de

S. Beheshti-Kashi
e-mail: bek@biba.uni-bremen.de

M. Lütjen
e-mail: ltj@biba.uni-bremen.de

N. El-Berishy · S. Beheshti-Kashi
International Graduate School for Dynamics in Logistics (IGS), University of Bremen, Hochschulring 20, 28359 Bremen, Germany

H. Kotzab et al. (eds.), *Dynamics in Logistics*,
Lecture Notes in Logistics, DOI 10.1007/978-3-319-23512-7_63

Keywords Forecasting · Seasonal products · Apparel industry

Introduction and Problem Description

This contribution is concerned with demand forecasting problems of fashion apparel suppliers and fashion retailers, to whom the suppliers sell their garments. Seasonal and fashion products, which comprise roughly 95 % of all apparel products, are characterized by regular, seasonal exchanges, or updates of the product assortment at least twice a year (Thomassey et al. 2005). Their sales periods, extending only over a few months or weeks, are short in comparison to their long production lead and delivery times. Once their sales season has ended, many of these articles can only be sold with large price reductions or not anymore at all. The long delivery times are caused by geographically distributed supply chain, due to outsourcing of manufacturing to low wage countries, e.g., in Southeast Asia, while highest consumer demand remains in Europe and North America (Gereffi and Memedovic 2003).

Seasonal articles are often sold by fashion brand suppliers to retailers in a business model characterized by fixed seasonal cycles with fixed dates for product offers, orders, and delivery. The principal steps are: first collection of retail orders for each product variant, or stock-keeping unit (SKU) by the brand supplier during a defined pre-order period, then booking of production capacities at the manufacturer and initiation of production orders, based on aggregated pre-order volumes of the retailers as well as sales forecasts by the supplier; at a later date delivery of the ready-made garments to the ordering retail shops at the beginning of the actual sales periods, and after that delivery of additional, so-called post-orders of the retailers during the sales periods (Fissahn 2001). Due to long production lead times, production orders have to be placed at an early date, when customer demand for the products and their variants is not fully known. Once the sales season of a product has begun, retailers may post-order additional quantities of successful articles and variants, of which they can sell larger numbers than anticipated.

However, reproduction of successful products is not possible due to the long delivery times. The sales season will end before the reproduced articles arrive in the shops and outlets. Retailers, who have to react flexibly to modified customer behavior, increasingly require from their suppliers the same flexible reaction to demand fluctuation, despite the long production lead times. For that reason, products may be produced in larger quantities than if only based on pre-orders. The part of the production volume, which has been produced in excess to pre-ordered volumes, is offered directly from the warehouses to so-called post-orders during the sales season, until stocks run out or until the sales season is over. The apparel suppliers try to factor in post-orders of articles during the sales time into demand estimates in addition to pre-orders of the products by retailers before the start of the sales seasons (Ahlert and Dieckheuer 2001).

In Fig. 1 the arrival dates of the pre-orders and the post-orders, which cover the life cycle in one season, are illustrated. The input data has been taken from product orders and deliveries in a winter season by a German fashion apparel distributor, who sells fashion apparel products to retailers and will be used as a case study within this contribution. The data shows a clear split between pre-orders and post-orders for the products. The pre-order period extends from approximately March to June. During this period the company obtains pre-orders from the retailers. In addition to the pre-orders, retailers have the possibility to post-order products after the start of the sales period at the end of August. Both, pre- and post-orders are made at SKU level. To meet total customer demand, the case company has to consider the potential post-orders in their production plan, which is based on information gained from the pre-orders. Since the post-order product quantities amount to about 30 % of the whole order quantity of one season, reliable forecasting of the post-order quantity is important for the case company.

The described situation motivates a strong need for accurate forecasting of customer demand for each apparel stock-keeping unit before the start of their sales periods, but also results in difficulties of demand forecasting. Customer demand is volatile and may vary broadly for different variants of the same product. Demand fluctuations are difficult to predict (Quick et al. 2010). Established statistical forecasting methods are difficult to apply due to short sales times; at time of production order placement, no sales data exists as a basis for extrapolation. Specifically developed demand forecasting models, such as the comprehensive model developed by Thomassey et al. (2005), Thomassey (2010), may be difficult to use, due to

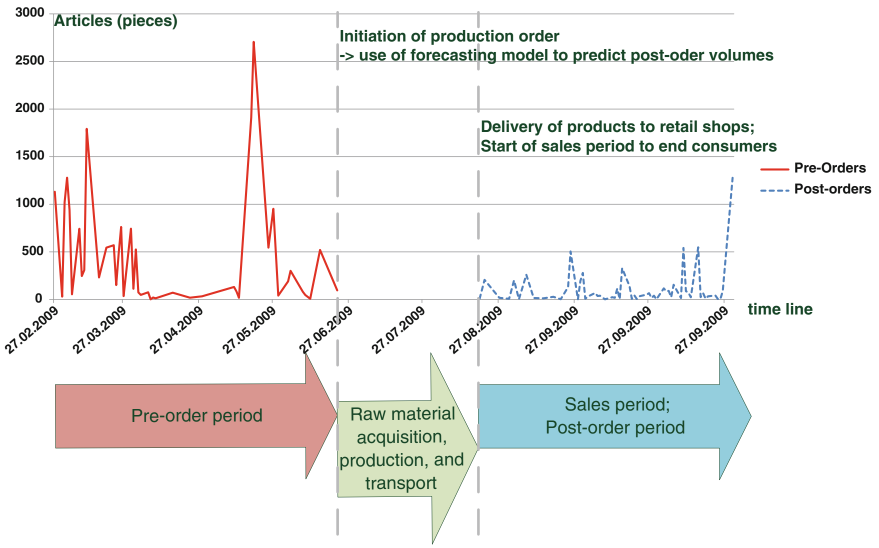

Fig. 1 Shedule of pre-order/production and post-order

their inherent complexity, which is necessary to deal with these problems. Most of these models have not been integrated into standard business software yet.

Demand forecasting errors still have serious economic effects for resulting either in stock-outs or product obsoleteness. It is estimated that roughly 30–40 % of the articles produced for a sales period have to be written off at the end of the sales period, whereas on the other hand, part of customer demand cannot be satisfied, with corresponding loss of potential sales revenues (Hoyndorff et al. 2010).

The main aim of this contribution is to point out some of the specific difficulties of apparel demand forecasting. In particular, a model is presented that allows finding relations between pre-orders of seasonal apparel articles and post-orders of those articles developed and applied to a preliminary set of real data. With this model, a better forecast of total demand of such articles is possible.

The content of this paper is structured as follows: following this introduction, the second chapter provides a literature review of existing demand forecasting models. The third chapter describes a model for finding statistical relations between pre-order volumes of apparel articles, and post-order volumes of those articles, using decision tree and support vector machine. The model is applied to a case study from the apparel industry. The contribution ends with a summary of the main results and an outlook on further work.

Apparel Demand Forecasting

Demand forecasting is considered as an important input of production planning and supply chain planning models. Forecasting of potential sales is important for many aspects of business operations (Mentzer et al. 1999). This chapter gives an introduction into common standard forecasting methods and then proceeds to existing forecasting models developed specifically for apparel demand forecasting. Recent studies have focused on artificial neural networks (ANN) for sales forecasting and reported better performance compared to conventional approaches (Sun et al. 2008). In spite of the promising results in the field of prediction, most ANNs applied for sales forecasting, for instance the back propagation neural network (BPNN), bear also drawbacks,such as over-tuning or time-consuming computation. Therefore, Sun et al. introduce the application of the so-called extreme learning machine (ELM) for fashion sales forecasting. The ELM was proposed by Zhu et al. (2005), due to its advantages such as faster learning compared to the standard gradient-based learning algorithm. In comparison to traditional learning algorithms ELM requires less human intervention and reaches smaller training errors (Huang et al. 2011). Sun et al. (2008) applied their new approach on real data from a Hong Kong fashion retailer and concluded that the ELM outperforms the BPNN algorithm and considered it as a stable and a promising tool for fashion retailers.

Other studies apply the evolutionary neural network (ENN) for forecasting in fashion retail and conducting real-data analysis. This hybrid combination of evolutionary computation and neural networks provides accurate predictions and seems to be a promising approach in the case of noisy data and influencing factors such as sale promotions or changing weather conditions (Au et al. 2008). Thomassey et al. (2005), Thomassey (2010) introduce a model that consists of two automatic systems (mean and short term forecasting). In order to deal with the idiosyncrasies of the apparel industry such as the lack of historical data, they also propose to apply soft computing methods: fuzzy inference systems and neural networks. The fuzzy logic is applied in the mean term model to treat with the challenges of explanatory factors such as weather or competition. In a three step approach the factors are at first removed from the historic data, and then employed again after the future forecast is performed (Thomassey 2010). For short term forecasting a mixed technique of neural networks and fuzzy systems are applied in order to adjust the mid-term forecast. The model was applied to data from a textile distributor. In a comparative study, the results gained by this model achieved more accurate results in both short-term and mid-term forecasts than classical methods and a multiplicative seasonality model.

Mostard et al. (2011) introduce in their work a new approach which differs from the described models. They focus on pre-order demand information and apply three methods to advance demand forecasting: preview division, equal division and top-flop division. Their findings reveal promising forecasts for all three methods, among which, the top-flop approach produces the most robust predictions. A comparison to expert judgments shows that they perform better than the described methods, however, it is reported that the results should be treated with caution. In addition, the results did not differ significantly (Mostard et al. 2011).

On conclusion, traditional forecasting methods can be applied only with difficulty to fashion demand forecasting because less of historical data. In this regard, soft computing methods have been found to be a promising approach in this field. In particular, the learning capacity of artificial neural networks seems beneficial. Different forms of learning algorithms, for instance an extreme learning machine or an evolutionary neural network, are successfully applied. Fuzzy logic methods as well as combinations with neural networks gain more relevance. In addition, the integration of pre-order information as well as expert judgments has produced better forecasts. Most of the described works consider the computational learning time as the crucial factor. However, in this paper the focus is on the ability of a model to deal with few and noisy data and still obtain useful results.

Post-order Quantity Forecasting Model

In this section, a two-phase model for forecasting demand resulting from post-orders (Fig. 2) is described. First, a decision tree is applied to historical case data in order to identify those articles that will be post-ordered by classifying the pre-ordered articles into two classes: Class A includes all articles that can be post-ordered, while Class B is formed by all articles that cannot be post-ordered. The decision tree procedure, which carries out classes of similar descriptive criteria

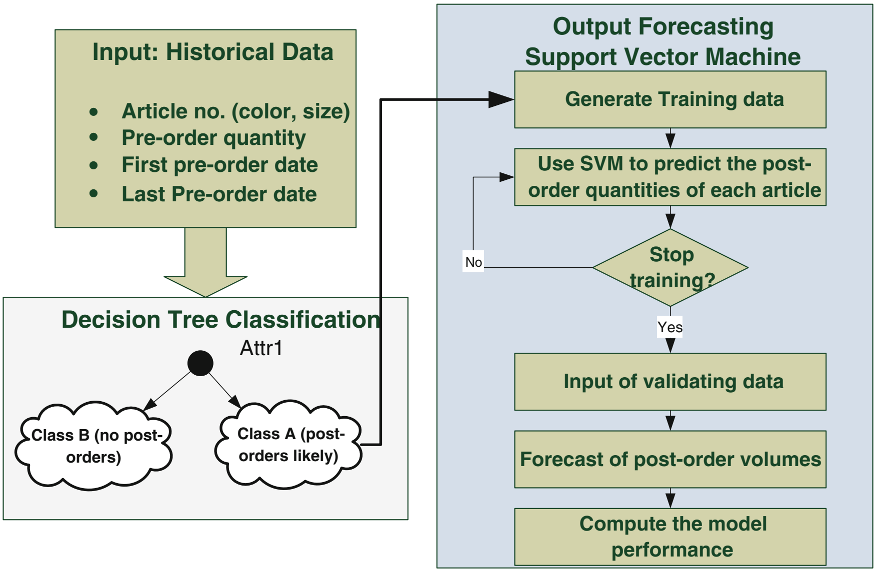

Fig. 2 Decision tree and support vector machine

of historical items, allows determining the articles susceptible to be post-ordered based on the classification of the pre-order historical data.

Second, after the classification of the pre-orders by means of the decision tree, training data of articles of Class A will be generated. A training dataset contains, in addition to administrative information about the pre-orders, the post-order volumes of each article. For the forecast of the post-order volumes, a support vector machine (SVM) is used, which is trained during the training process. After training, the SVM is evaluated and the performance of the model is calculated. This model is then applied to a set of historical data consisting of 9300 records (pre-order positions), detailing 460 pre-orders by 304 customers from 13 countries with a total volume in excess of 19,000 articles from a collection of winter articles during the winter season 2009.

Decision Tree Classification

Applying standard regression methods to our data is difficult due to the lack of sufficient historical data to validate these methods. In the proposed model, we try to extract relevant features of different pre-orders so that it is possible to determine a priori the set of articles most likely to be post-ordered. Relevant factors, which may affect the classification of pre-orders and for which data is available, are listed in Table 1.

Table 1 Factors affecting the classification of pre-orders

Factors	Description
Article ID	The Identifier of an article in the history data
Number of orders	Number of orders per article performed during the order period
Pre-order volume	Quantity pre-ordered per article during the order period
First date	First date of ordering of an article ID
Last date	Latest date of ordering of an article ID
Article order period	Last date—first date: length of order period of article ID
State	Indicates if the Article Id has been post-ordered or not

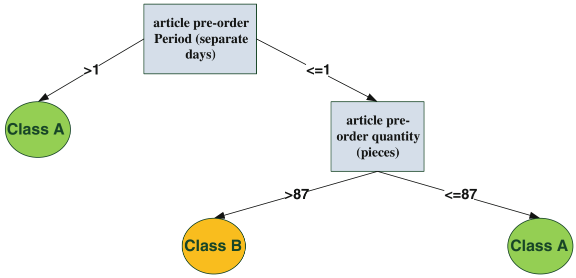

Fig. 3 Possible results of the tree decision classification

These important input factors are further evaluated through a tree method in order to classify the pre-ordered articles into two classes Class A (articles susceptible to be post-ordered) and Class B (not to be post-ordered), as shown in Fig. 3.

According to the decision tree method, it is possible through simple if-then rules to get the explanation of the relationship between input information of pre-orders (Table 1) and the target variable (classification). Based on the data set used in this work, the articles, which have been ordered in an ordering period longer than at least 1 day (ordering period >=1) or with pre-order quantity of less than 87 units will be post-ordered after the main order period. Applied to the case study, about 85 % of all articles will be post-ordered based on this classification.

Application of the Support Vector Machine

After the classification of the pre-orders using a decision tree, the next step is forecasting of the post-order volumes. To this end a support vector machine model has been applied. For the training process of the SVM model, a subset of 930 pre-order records have been taken as input to generate training data. After training the SVM with these data records, the SVM has been fed with all pre-order data of

Class A in order to predict the post-order volumes of the articles, which are then compared to actual post-orders of the sales period for validation of the model.

Table 2 and Figs. 4, 5 and 6 demonstrate the results of the proposed model. The overall results of SVM on the test set are collated in Table 2.

It can be observed that SVM can predict the post-order volumes of the test data set with acceptable accuracy, though it tends to slightly over-estimate them. The actual value of post-order volumes is about 28 % of the pre-order volumes; the predicted post-order volume is 31 % of the pre-order volumes. The prediction performance is evaluated using mean absolute error (MAE), which measures the deviation between the predicted and the actual values. The results of the SVM model are grouped into article IDs (Fig. 4), colors (Fig. 5) and sizes (Fig. 6). The figures show that the model can also predict with acceptable accuracy the distribution of the post-order volumes between the different articles, colors and sizes, above-average post-order volumes.

The model can with reasonable accuracy predict even stronger variation in post-order volumes, in particular over the different colors, but also over the different sizes.

The value of this predictive ability may be sensed from that ignoring the possibility of post-orders for articles at all would result in a loss of 28 % of articles sales and thus, profits. The predictions can also be compared to a simple rule of thumb, whereby a uniform overhead of 28 % is evenly added to all pre-order volumes, in order to account for the average post-order volumes, without

Table 2 Results of SVM on the test set

Volume of pre-ordered articles	Actual volume of post-ordered articles	Volume of post-ordered articles predicted by SVM
14.028	3.961	4.331 (exceeding the actual volume of post-ordered articles by 9.3 %)
100 %	28 %	31 %

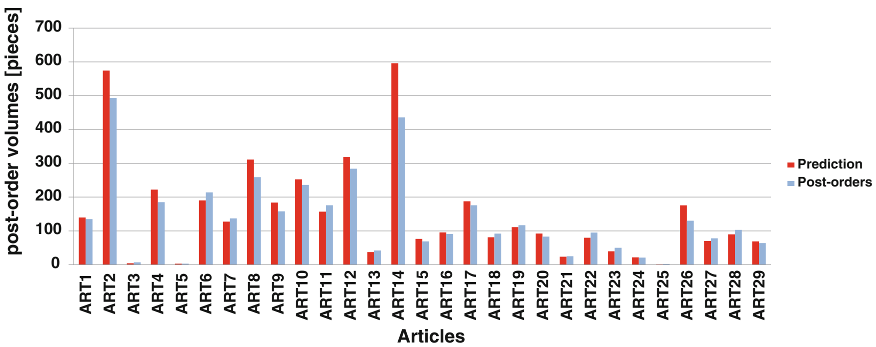

Fig. 4 Relation of predicted to actual post-orders volumes, grouped by articles

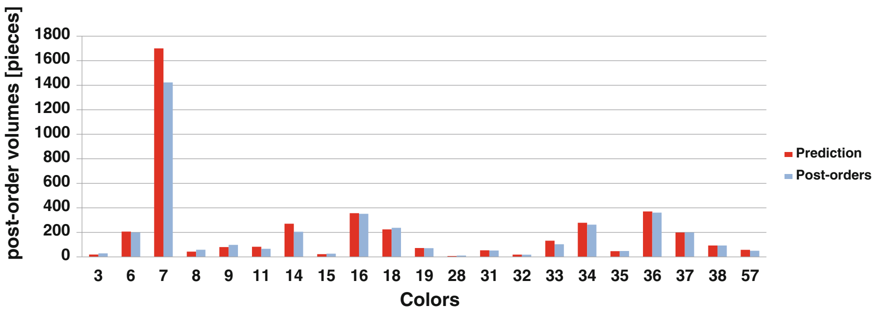

Fig. 5 Relation of predicted to actual post-order volumes, grouped by colors

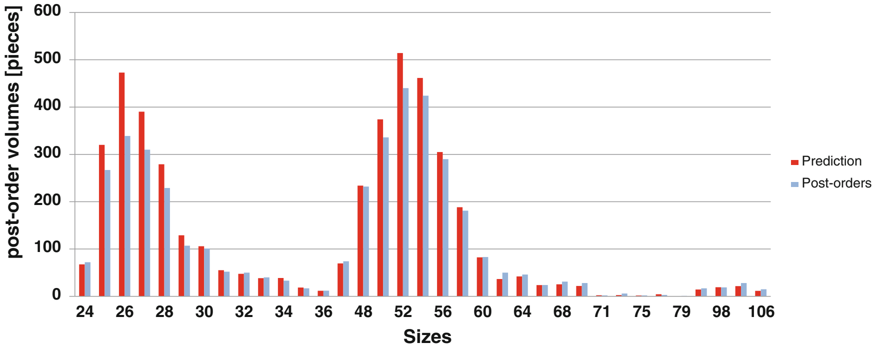

Fig. 6 Relation of predicted to actual post-order volumes, grouped by sizes

consideration of the variation in the ratio between pre-orders and post-orders over the different articles, colors, and sizes. This rule of thumb results in unfulfilled demand (and thus lost sales or profits) for those articles, where the post-order to pre-order volume rate is higher than 28 %, and at the same time in write-offs of unsellable pieces, where this rate is lower than 28 %.

The comparison in Table 3 shows that, applied to the case study's data, the SVM prediction dominates the rule of thumb, resulting uniformly in better (lower) values for both, unfulfilled demand and write-offs of unsellable pieces, over the different articles, colors, and sizes.

Table 3 Comparison of unfilled demand and write-offs of unsellable pieces between SVM and rule of thumb

	Grouped by articles		Grouped by colors		Grouped by sizes	
	Lost sales	Write-offs	Lost sales	Write-offs	Lost sales	Write-offs
Rule of thumb	1.009	1.009	499	499	586	586
SVM	126	496	66	436	59	531

Conclusion

In this paper, a two-step model for post-order demand forecasting has been proposed. First a decision tree has been used to determine the set of articles from the pre-orders for which post-orders are to be expected during the sales season. Second, a support vector machine has been implemented to predict the post-order volumes for those articles. The computational results obtained from a set of real data of a German fashion company show that it is possible to find relations between pre-orders of seasonal apparel articles and post-orders of those articles, and thus better estimate total demand. Thus, the proposed model can deal successfully with such a type of forecasting problem. However lack of sufficient data prevented a more complete validation of the model. As future work, additional tests are necessary, which cover not only one, but many seasons, for more reliable validation of the model's applicability.

References

Ahlert D, Dieckheuer G (2001) Marktorientierte Beschaffung in der Bekleidungsindustrie. FATM, Münster

Au KF, Choi TM, Yu Y (2008) Fashion retail forecasting by evolutionary neural networks. Int J Prod Econ 114:615–630

Fissahn J (2001) Marktorientierte Beschaffung in der Bekleidungsindustrie. Dissertation, Münster University

Gereffi G, Memedovic O (2003) The global apparel value chain—what prospects upgrading by developing Countries. Austria, Vienna

Hoyndorff K, Hülsmann S, Spee D, ten Hompel M (2010) Fashion logistics. Grundlagen über Prozesse und IT entlang der Supply Chain. Huss-Verlag, Münster

Huang G-B, Wang DH, Lan Y (2011) Extreme learning machines: a survey. Int J Mach Learn Cybern 2:107–122

Mentzer J, Bienstock C, Kahn K (1999) Benchmarking sales forecasting management. Bus Horiz (42)3:48–56

Mostard J, Teunter R, de Koster R (2011) Forecasting demand for single period products: a case study in the apparel industry. Eur J Oper Res 211:139–147

Quick J, Rinis M, Schmidt C, Walber B (2010) SupplyTex—Erfolgreiches supply-management in KMU der Textil- und Bekleidungsindustrie, Aachen

Sun ZL, Choi TM, Au KF, Yu Y (2008) Sales forecasting using extreme learning machine with applications in fashion retailing. Decis Support Syst 46(1):411–419

Thomassey S (2010) Sales forecasting in clothing industry: the key success factor of the supply chain management. Int J Prod Econ 128(2):470–483

Thomassey S, Happiette M, Castelain JM (2005) A short and mean-term automatic forecasting system- application to textile logistics. Eur J Oper Res 161:275–284

Zhu QY, Qin AK, Suganthan PN, Huang GB (2005) Evolutionary extreme learning machine. Pattern Recogn 38:1759–1763

Industrial Performance Assessment Through the Application of a Benchmarking and Monitoring System

Marcos Ronaldo Albertin, Heráclito Lopes Jaguaribe Pontes, Enzo Morosini Frazzon and Enio Rabelo Frota

Abstract The purpose of this paper is to describe a multiple criteria benchmarking and monitoring system for assessing the performance of industrial sectors. The referred system was designed for comparing and monitoring companies' performance against market requirements. As an illustration, data collected during a three-year period for a specific local productive arrangement of Ceará, Brazil are showcased. The findings indicate the opportunities and needs for collective strategic actions by the companies and sectors in order to promote local development.

Keywords Bechmarking · Industrial performance · Local develpment · Information systems

Introduction

During recent decades, changes promoted by globalization have highlighted companies' inabilities to internally obtain the competences needed for surviving. As a consequence, the relationships with other companies are no longer seen just as market transactions, but rather as opportunities to gain complementary assets, technologies and competences. Thus, there is a rapid growth in inter-firm relationships such as collaborative networks and supply chains. For instance, organization in clusters has been intensively studied in academic literature (Lehtinen and Ahola 2010). In this paper, this kind of organization is referred to as local pro-

M.R. Albertin · H.L.J. Pontes · E.R. Frota
Departamento de Engenharia de Produção, Campus do PICI, CT, Federal University of Ceará, Campus do PICI, CEP 60455-990 Fortaleza, Ceará, Brazil

E.M. Frazzon (✉)
Departamento de Engenharia de Produção e Sistemas, CTC, Federal University of Santa Catarina, Campus Universitário João David Ferreira Lima, CEP 88040-900 Trindade, Florianópolis, Brazil
e-mail: enzo.frazzon@ufsc.br

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ductive arrangements (LPAs). Hon (2005) describes the different kinds of manufacturing systems as single machine, group of machine (cell, line), supply chains and production networks. This paper focuses on the interaction of local actors as suppliers in supply chains and their quest for competitive advantages through collaboration in productive arrangements (PAs). According to Polenske (2004) many analysts assure that companies can meet the challenges of global competition by establishing improved competitive or collaborative activities. For Balestrin and Verschoore (2008) the competition–cooperation dichotomy marks the relationships between organizations today. The analysis of different PAs and their collective and individual performances represents a good opportunity to research, because there has been little exploration about integrated development actions in supply chains. For the performance analysis, a metric system is necessary. The literature on this subject of performance assessment emphasizes intra-organizational measures, which conflict with the emphasis on inter-organizational collaboration, which is dominant in the literature addressing, extended enterprises (Zhou and Benton 2007). Albertin et al. (2010) developed a computational system to share information in a competitive and collaborative environment using an Internet benchmarking methodology called Benchmarking and Monitoring System of Productive Arrangements (SIMAP). Effective benchmarking requires standards or criteria for measuring performance across the broad range of organizations. SIMAP measures the relative performance levels of similar operations or activities from local or interconnected organizations. It shows individual and collective gaps and local development opportunities.

Benchmarking is defined by Xerox as a continuous and systematic process of evaluating companies recognized as industry leaders, to determine business and work processes that represent best practices and establish rational performance goals (Camp 1989). Analysing the evolution of benchmarking, Kyrö (2003) proposes a new and more complete definition: “Benchmarking refers to evaluating and improving an organisation’s, its units’ or a network’s performance, technology, process, competence and/or strategy with chosen geographical scope by learning from or/and with its own unit, other organisation or a network that is identified as having best practices in its respective field as a competitor, as operating in the same industry, cluster or sector or in the larger context with chosen geographical scope” p. 222.

Thus, benchmarking can be sector-, region-, supply-chain- or global-based. Benchmarking studies can provide several benefits (Zhou and Benton 2007): (1) Allowing companies to learn from others’ experiences; (2) helping companies to analyse their own levels of performance relative to the competition; (3) identifying the companies with the highest (or lowest) levels of performance and studying them to gain insights into the activities that correlate with high (or low) performance. Inter-firm knowledge sharing and learning improve supply chains’ performance in today’s business environment. It is important to highlight that benchmarking does not automatically provide a solution. The organization still has to find the right measures for comparison, analyse the causes for performance gap and search for innovative solutions. The main objective of this paper is to describe a multiple criteria benchmarking and monitoring system for assessing the performance of industrial sectors. It should evaluate PAs and propose actions to benefit not only a singular enterprise but a group of enterprises. The concept and methodologies of Internet benchmarking are presented. As an illustration, data collected during a three-year period for a specific local productive arrangement of Ceará/Brazil are showcased.

Benchmarking and Monitoring System (SIMAP)

The SIMAP is an interactive benchmarking tool created to help companies, developing agencies and policy makers to identify challenges and opportunities for improving their performance. Through a significant sample of collected data, the system allows for a more productive dialogue among government and companies, based on information updated dynamically, avoiding inefficient and unfocused actions. To sum up, a company can compare itself with the average of the registered companies, in the state and country where they act. It can also identify benchmark companies, which are reference of efficiency (performance) and effectiveness (results) to other companies that belongs to the same link (have the same process). Besides systemic competitiveness SIMAP's proposal is supporting action at the meso-level (Messner 1996; Altenburg et al. 1998). It was originally developed to promote the development of the automotive industry of the state of Rio Grande do Sul (RS-Brazil), and now is being used as a tool to increase the supply of local content in many regional PAs in the state of Ceará (Albertin 2003).

Some fundamental features of the system include: possibility of dynamic feeding an online database surveying information on 46 criteria that are grouped into seven subsystems as follows: Integrated Management System (GP01), Production Management (GP02), Products Management (GP03), Strategic Management (GP04), Logistic Management (GP05), Human Resources Management (GP06), and Financial Management (GP07) as shown in Fig. 1. The first subsystem GP01 has five criteria as shown in Appendix A. Each criterion has a growing performance metric adapted from Likert scale of five levels (0, 25, 50, 75 and 100), featuring categorized qualitative data. These criteria represent performance and best practices. For example, the criterion "ISO 9001" can only be answered with: NA (not applicable), 0 % (informal procedures), 25 % (documented procedures), 50 % (formal program development), 75 % (performs internal audits) and 100 % (company certified). The criteria and performance levels derive from the requirements established in the Malcolm Bridge Award, as well as in the Toyota Production System, ISO /TS 16949 and ISO 9001. Each subsystem was set based on interviews with companies and professionals to identify the most important tools. A minimal or desirable performance (requirement) to delivery to a focal company was identified for each PA. The data was collected by interviews, technical visits and mainly by Internet. As a method to analyse the collected dates we are using: (a) bars graphics and means and (b) individual and collective visual gaps analyses. The performance of a company (bar chart) and the mean comparison of performance in

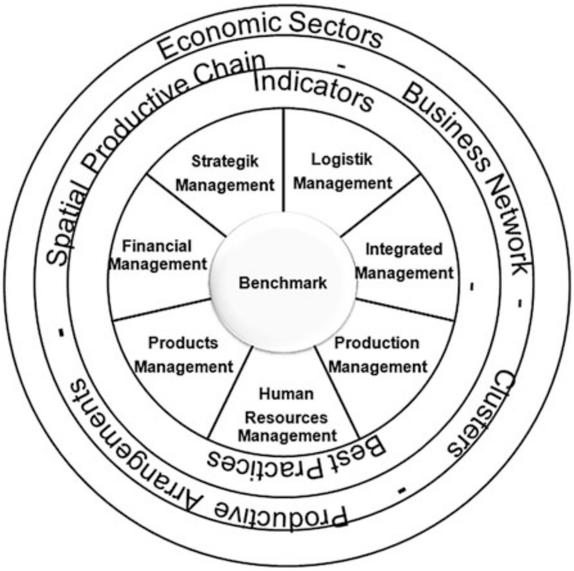

Fig. 1 Application of SIMAP

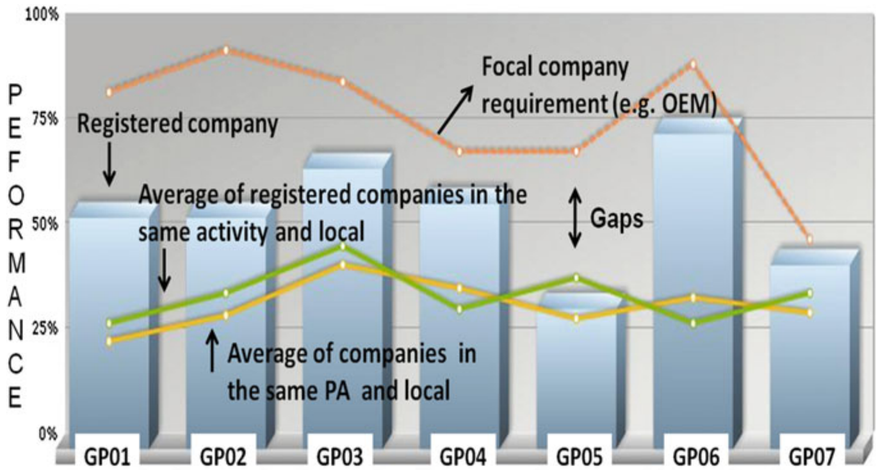

Fig. 2 Individual performance (*Bars*) and the average performance (*Line*)

the GP01 to GP07 subsystems of all registered companies on the local automotive supply chain in the State of Ceará are observed in Fig. 2.

The system architecture of SIMAP, which was adapted from the work of Johnson et al. (2010), is represented in Fig. 3. The represented architecture aims to show what we have described above. SIMAP aims to provide an online

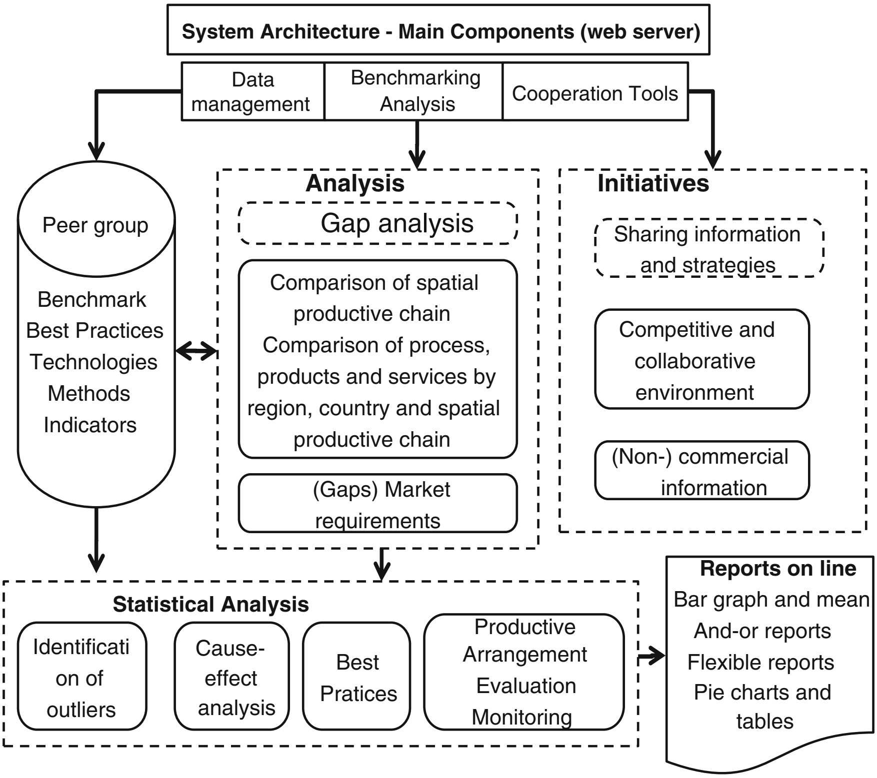

Fig. 3 SIMAP system architecture (Adapted from Johnson et al. 2010)

benchmarking analysis that addresses the need for the performance assessment tools mentioned above.

With this innovative tool any firm with Internet access can participate and view the individual performance analysis results in real-time. It is observed that the inclusion of data in SIMAP occurs with the indication of the location, which can be territorial state, region or country, as represented in the axis “territory” in Fig. 4.

This figure illustrates the possible comparisons in SIMAP. The axis “activities” provides the benchmarking by activity (link) of companies compared to other links of the same or different PA. It is possible, for example, for a machining company to compare itself with the average performance of other states and countries, and with its direct competitors in the same PA (territory) or in the same country. It is possible to draw a value chain, a supply chain, cluster or other types of productive arrangements (PAs), and make restricted or unrestricted access comparisons. A total of 285 entries were made in Ceará companies operating in 18 production chains. Supply chains with more registered companies are metal-mechanic (56), construction (49), automotive (35), textiles and clothing (30) and food and beverage (23).

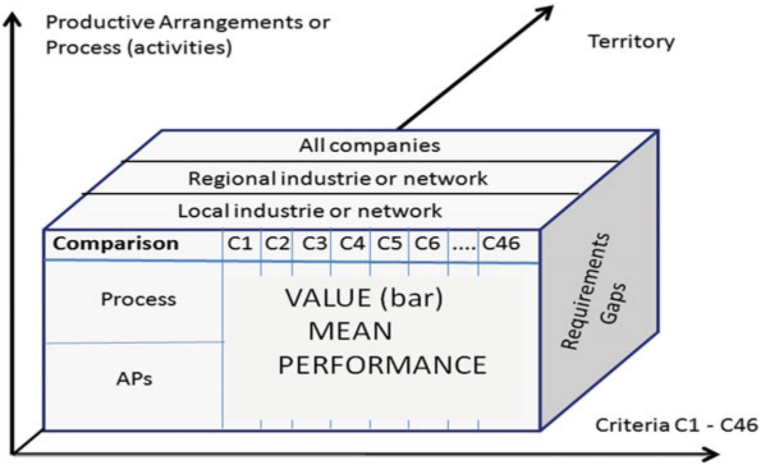

Fig. 4 Possible comparisons on SIMAP

Industrial Performance Assessment

In this section we present results and analysis of the study. The graphs were generated from SIMAP with the database of June/2012. The average performance of firms by size in Ceará is shown in Fig. 5. It can be observed that the average performance of large companies is around the range of 50–75 %, the performance of medium-sized companies is close to 50 %, while the performance of small businesses oscillates around 25 %. The range of 25 % indicates an effort towards the formalization and standardization of processes. The overall performance of all companies from Ceará registered in SIMAP is represented by the 3rd line (overall average) in the range between 25 and 50 %.

The automotive (AUT) sector is very competitive and dynamic. The requirements to provide this chain led by major automakers are globalized and were based

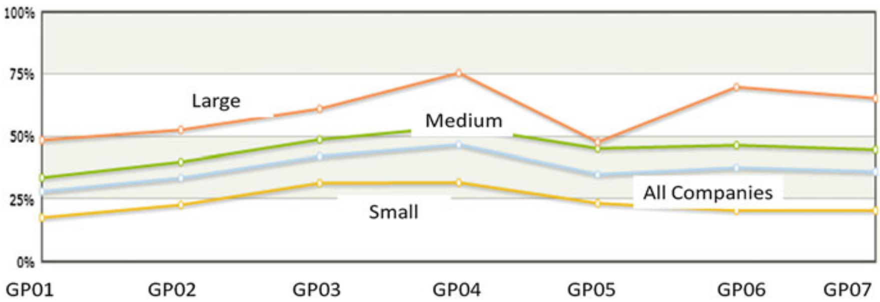

Fig. 5 Average performance by size in Ceará

on the ISO/TS 16949. In Ceará, cars of the types Jeep and Buggy are manufactured in small quantity and auto parts. In 2007 the automotive factory of Troller Special Vehicles was merged into Ford Motor Company, creating new challenges for the local supply chain. In Fig. 6 we see that the benchmarking company performance (bar graph) is much higher than the rest of this AP.

The differences between the performance (continued line or bar graph) and industry market requirements (dotted line) are called bottlenecks or gaps. As shown SIMAP allows viewing "online and on time" gaps for any company registered for free. Gaps are considered technical barriers to supply the local production chain. The gaps in the criteria subsystems Integrated Management (GP01) and Product Management (GP03), by company size, are represented in Figs. 7 and 8. Legends can be found in the Appendix.

It is observed that there are gaps in all sizes of company, for the criteria C1 through C5, and that they are larger for small businesses. The certification to international standards ISO 9001 (C1) is not implemented yet in most of the state.

Figure 8 shows the gaps of Production Management subsystem (GP02). The gaps for the criteria C6 through C15 are smaller for medium and large companies

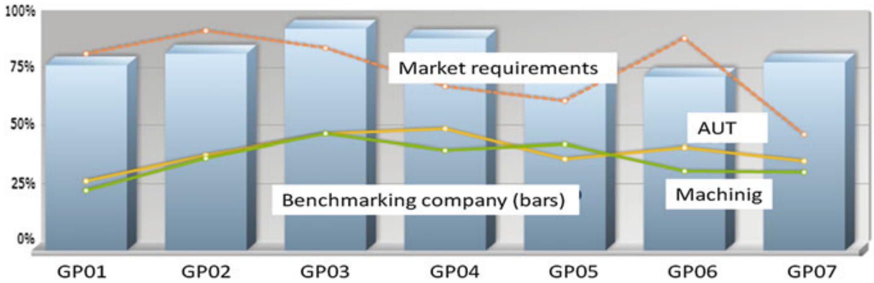

Fig. 6 Company "benchmarking" and automotive PA

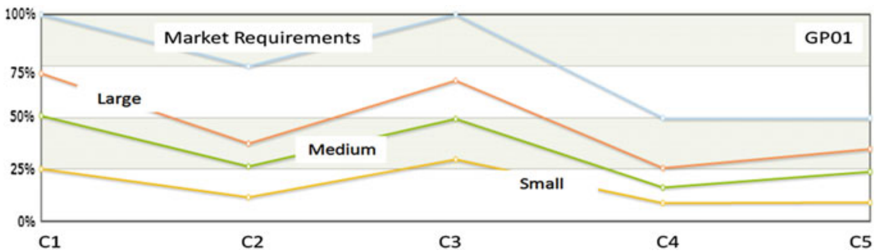

Fig. 7 Gaps for the automotive PA (AUT) considering the subsystem GP01

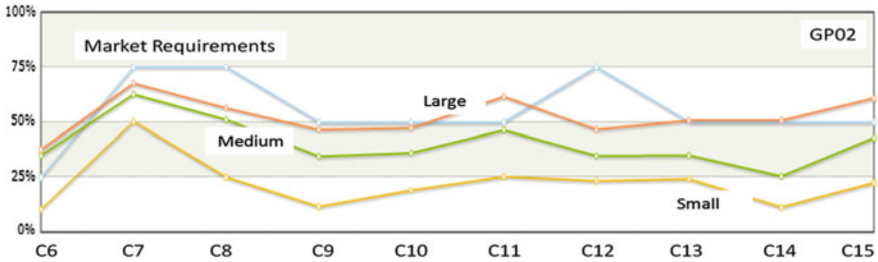

Fig. 8 Gaps for the automotive PA (AUT) considering the subsystem GP02

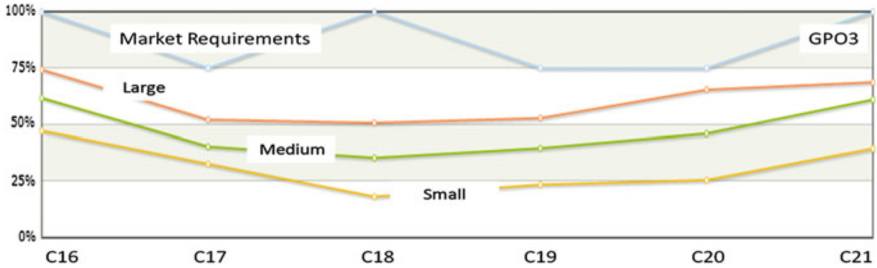

Fig. 9 Gaps for the automotive PA considering the subsystem GP03

and significantly large for small businesses. The gaps are larger than the criteria capability studies (C8) and maintenance (C12) (Fig. 9).

The Product Management subsystem chart above is comprised by the criteria gaps for C16–C21. The highest development of products and processes through functional teams is in the criterion C18. It is observed that the requirements to provide the automotive industry are equal for any company, regardless of size. The small-sized companies work with informal procedures, which are not documented, and its processes are shown to be unstable.

Discussion

The purpose of this paper was to describe a multiple criteria benchmarking and monitoring system for assessing the performance of industrial sectors. After three years of data collection, the average performance of 285 companies was presented using 46 criteria, which display best practices and performance indicators. The performance analysis was segmented by small, medium and large-sized companies, comparing: (i) the average performance of these groups of companies separately, (ii) the performance of the "Benchmarking Company" and (iii) the minimum supply requirements that are requested by leading companies in the PAs. As an illustration, data collected for a specific automobile AP of Ceará, Brazil was showcased. The findings indicate the opportunities and needs for inserting the Ceará companies in supply chains led by large local companies operating or being installed in the state, considering the use of best practices found in globalized production systems. It was observed that there is a big difference in the use of best practices between the small and medium/large businesses. The average performance of Ceará small businesses indicates that they are in transition to standardization for Quality and Process Control. The processes of small businesses are unstable and they generate excessive costs with control, rework and scrap. The average performance of small-sized companies (1–99 employees) falls short of most supply requirements of regional or national leading companies, but it can be improved by benchmarking of companies that stand out. The benefit of SIMAP system is to promote individual and collective actions those impacts on an AP. The following information could be obtained online: (a) individual performance in 46 criteria and their 7 subsystems with the Likert scale (0–25–50–75–100 %); (b) average performance of companies registered in the same PA, or even in the same activity or in the same territory; (c) individual and collective gaps analyses and (d) visualizationof competitive positioning after some actions.

Appendix A

See Tables 1, 2 and 3.

Table 1 Integrated management system (GP01)

GP01	0	25	50	75	100
C1. ISO 9001 C2. ISO 14001 C3. 5S C4. SA 8000 C5. OSHAS 18000	Informal procedures	Documented procedures	Formal program deployment	Conducts internal audits	Certificated

Table 2 Production management (GP02)

GP02	0	25	50	75	100
C6. Setup time	Informal procedures	Documented procedures	Time < 60 min	Time < 40 min	<10 (SMED)
C7. Production planning and control (PPC)	Informal procedures	Electronic sheets (Excel, Calc, etc.)	Software	MRP and MRP II	ERP
C8. Capability studies	Informal procedures	Instable process	Stable process	CEP	Cpk > 2
C9. Quality costs	Unknown	Monitors	1–10 % revenue	<1 % revenue	<0.5 revenue
C10. Process control	Informal parameters	Formal parameters	Monitored parameters	Calibrated instruments	Capability studies
C11. Part per million (PPM)	Unknown	Known	1–10 %	<1000 PPM	<500 PPM
C12. Total preventive maintenance	Corrective	Maintenance plan informal	Preventive	Predictive	TPM
C13. Just in time	Not use tools	One tool	Two tolls	Three tools	Many tools
C14. Suppliers development	Informal procedures	Formal procedures	Monitors performance	Training programs	Establishing partnership
C15. Average age of equipment	Unknown	More than 20 years	Between 10 and 20 years	Between 5 and 10 years	More than 5 years

Table 3 Products management (GP03)

GP03	0	25	50	75	100
C16. Use of technical norms	Unknown	Knows and use partly	Uses the main	Always use	Uses 100 % and update
C17. CAD–CAE-CIM	Unknown	Known	Uses CAS	Uses CAD e CAE	Uses CAD-CAE-CIM
C18. Multifunctional groups	Doesn't perform	Uses informally	Documented procedure	Implemented	Always uses
C19. Time to market	Doesn't control	Informal control	Monitor	Competitive	Is benchmark
C20. Methodology for development of new products	Unknown	Informal	Documented	Continually improve	Concept uses of lessons learn
C21. Suppliers and customers partnerships	Doesn't perform	Informal	Formal	Suppliers	Suppliers and clients

References

Albertin M (2003) O processo de governança em arranjos produtivos: o caso da cadeia automotiva do RGS. Doutorado - Faculdade de Engenharia de Produção UFRGS, Porto Alegre

Albertin M, Telles B, Aragão D (2010) Methodology for monitoring of productive arrangements. In: Dynamics in logistics: second international conference, LDIC 2009. Springer, Bremen

Altenburg T, Hillebrand W, Meyer-Stamer J (1998) Building systemic competitiveness. German Development Institute. Reports and Working Papers 3, Berlim

Balestrin A, Verschoore J (2008) Redes de cooperação empresarial: estartégias de gestão na nova economia. Bookman, Porto Alegre

Camp RC (1989) Benchmarking: the search for industrial best practices that lead to superior performance. Quality Resources and ASQC Quality Press, New York, Milwaukee

Hon KKB (2005) Performance and evaluation of manufacturing systems. CIRP Ann Manuf Technol 54(2):139–154

Johnson A, Chen WC, Mcginnis LF (2010) Large-scale internet benchmarking: technology and application in warehousing operations. Comput Ind 61(3):280–286

Kyrö P (2003) Revising the concept and forms of benchmarking. Benchmarking Int J 10(3): 210–225

Lehtinen J, Ahola T (2010) Is performance measurement suitable for an extended enterprise? Int J Oper Prod Manage 30(2):181–204

Messner D (1996) Staat, Markt und Netzwerksteuerung für systemische Wettbewerbsfähigkeit, 15. Gerhard Universität, INEF Report, Duisburg

Polenske K (2004) Competition, collaboration and cooperation: an uneasy triangle in networks of firms and regions. Reg Stud 38(9):1029–1043

Zhou H, Benton WC Jr (2007) Supply chain practice and information sharing. J Oper Manage 25(6):1348–1365

Tactical and Operational Models for the Management of a Warehouse

Neil Jami and Michael Schröder

Abstract This paper deals with the modeling, routing, and managing aspects of a warehouse with parallel aisles and cross-aisles, in which we assume a picker-to-part process. Pickers either retrieve in the aisles-stored products to fulfill a customer order, or do some nonurgent activity. The main contribution of this paper is the consideration of constraints, which are often disregarded by other papers. We study in particular the consequences of some 'working conditions' for the pickers on the overall solution quality. We analyze a warehouse layout designated to vehicle routing. We study the organization of products into locations, given some statistical forecasts on the future orders. Then we describe a management strategy to regulate the number of pickers doing the picking activity. Finally, an algorithm is proposed as a solution and tested by simulation experiments.

Keywords Warehousing · Simulation · Optimization · Dynamic process

Introduction

Warehousing is an important part in a logistic process (Roodbergen 2001). A careful designing and planning of a warehouse provides a better service for lower cost. We study here the order picking process, as it is known as the most time-consuming task in a warehouse (Tompkins et al. 1996). Order picking has been widely studied for decades on the designing of the warehouse, the storing strategies, and the control of the pickers (De Koster et al. 2007).

N. Jami (✉) · M. Schröder
Fraunhofer Institute for Industrial Mathematics (ITWM), Fraunhofer Platz 1,
67663 Kaiserslautern, Germany
e-mail: neil.jami@itwm.fraunhofer.de

M. Schröder
e-mail: michael.schroeder@itwm.fraunhofer.de

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The designing of the warehouse is a complex task with few structured approaches (Backer and Canessa 2009). We consider here the most common design of the warehouse composed of parallel aisles and cross-aisles. Concerning the organization of the storage area, we refer to Roodbergen and De Koster (2001), De Koster et al. (2007). The control of the pickers raises two questions, namely the routing of the pickers and the management of the number of needed pickers. Several papers propose efficient heuristics to solve the routing problem (Roodbergen and De Koster 2001; Hall 1993; Ratliff and Rosenhal 1983; Theys et al. 2010). However, there have only been a few papers about a dynamic management of the pickers. Our work is close to the one of Mazalov and Gurtov (2012), who considered a queuing model with a dynamic number of servers depending on the queue length. Both works assume that we can call additional pickers or send them back to do some nonurgent activities in the warehouse, in order to minimize the number of pickers while optimizing the service quality. However, instead of running simulations to find out the maximal number of pickers we need, we fix the number of pickers present in the warehouse, and evaluate the service quality under different working constraints.

The contributions of this paper are the following. First, current control strategies for the pickers disregard their situation. Pickers are asked for an intensive work and a high flexibility. Our main contribution is to provide a compromise between the service quality, the number of pickers at disposal, and the picker's flexibility. The second contribution is a storage strategy for a given order forecast and warehouse design. The third contribution is the modeling of car-traffic like routing regulation in the warehouse in order to facilitate dense picker movements.

In this paper, we first complete the warehouse model to define exactly how the pickers move. Second, we study a strategy to store products efficiently in the warehouse. Then, we present a multicriteria problem, which is to determine how many pickers are needed to fulfill efficiently the orders. The number of pickers is then dynamically adapted. Finally, we describe an algorithm for the management of pickers and simulate it under different conditions.

Description of the Warehouse

We consider a rectangular layout composed of several *parallel pick aisles* (Roodbergen and De Koster 2001), which is one of the most common structures for a warehouse. The warehouse is subdivided into several blocks separated by *cross-aisles*. A cross-aisle does not contain any product location, but can be used to travel from a pick aisle to another. Two other cross-aisles are also present at the front and at the back of the warehouse. The products are placed into locations on both sides of each pick aisle. These locations can be, for example, pallet racks or stacking blocks (Roodbergen 2001).

The proposed warehouse layout is intended for a *picker-to-part* system with carts or other vehicles, i.e., the pickers are supposed to move from location to location to retrieve the products corresponding to a pick list, and finally bring the products to a packing station called *depot*. We can argue that placing the depot in the middle of the frontal cross-aisle provides better travel times (Merkuryev et al. 2009). To facilitate the traffic in the warehouse and speed up the retrieval of products, the aisles will be wide enough to let carts cross to each other. Several pickers can then pick up products in the same picking area.

The aisles and cross-aisles are divided into two unidirectional corridors. For example, we only let the pickers move in the right corridor of the aisle in traffic direction, as shown in Fig. 1. A picker can freely change corridors to move in the opposite direction, or move out of the corridor to the side of the aisle to pick up a product without disturbing the other pickers movements.

An interesting point of this layout is that there always exists a shortest path from a location L_1 to a location L_2 using at most one cross-aisle. Therefore, the shortest path from a location to another can be computed in constant time $O(1)$.

A last problem to deal with is to determine in which sequence the products of an order should be retrieved. This task is an instance of the Travelling Salesman Problem (TSP) (Lawler et al. 1985), which is NP-hard. The shortest path to take begins and ends at the depot and must go through every location corresponding to an ordered product. A lot of work has been done in this domain, especially when

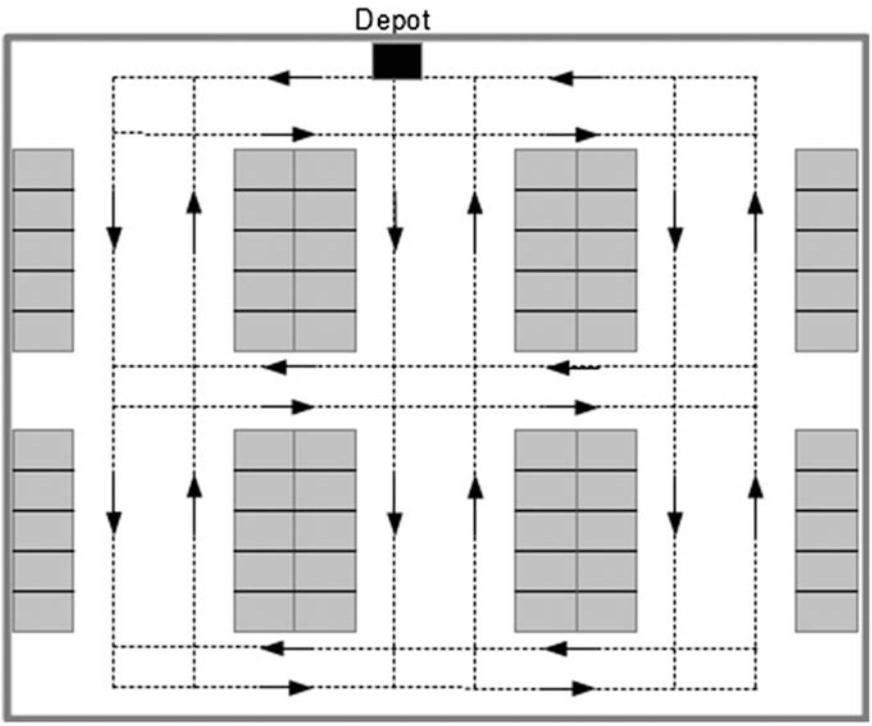

Fig. 1 Layout of the warehouse. The *dashed lines* represent the corridors, and the *arrows* give the movement directions

there are only two or three cross-aisles (Roodbergen and De Koster 2001). In our simulation, the TSP has been solved by enumeration, which is fast enough to compute the sequence of less than eight products. For higher numbers of products, we refer to more efficient algorithms (Ratliff and Rosenhal 1983; Theys et al. 2010).

Positioning the Products

In this section, we present a strategy to position the products in the warehouse locations. For this purpose, we must predict which products will be the most frequently ordered and which products will be often ordered together. Indeed, frequently ordered products should be placed as close to the depot as possible, while products which are often ordered together should be placed close to each other. This step is independent of the design of the layout, as we just have to know the shortest path between each pair of locations.

We assume here that some forecasting method could generate a large set of orders representing the future orders. Then we optimize the positioning of products according to this sample. From a *sequence function* S giving the retrieving sequence of the products for each order, we can compute a *transition probability matrix* $P(S)$ so that $P_{i,j}$ is the probability that the next product to pick up after product P_i is P_j.[1]

Our objective is to determine the position of each product. This product organization is characterized by the *position matrix* X, where $X_{i,j} = 1$ if the product P_i should be located in the location L_j, $X_{i,j} = 0$ otherwise. We denote by D the (already known) *distance matrix* providing the distance $D_{i,j}$ between each pair of locations (L_i, L_j). The *average path length* $Z(P, X)$ to fulfill an order is

$$Z(S,X) = \sum_{i,j} (X^T \cdot P(S) \cdot X)_{i,j} \cdot D_{i,j} \tag{1}$$

The objective is to find an optimal value of X, i.e., a value minimizing the average path length. We have to solve the following optimization problem:

$$\min_{S,X} Z(S,X) \tag{2}$$

under;
S gives the products retrieving sequence for each order
$\forall(i,j): X_{i,j} \in \{0,1\}$
$\forall i: \sum_j X_{i,j} = 1, \quad \forall j: \sum_i X_{i,j} \leq 1,$

[1]We set for example that the product noted P_0 represents the depot, whose location is fixed.

We already saw that for fixed product position X, the optimal path for each order is the solution of a TSP. For given X, computing the solution S' of a TSP for each order of the set provides a new transition probability matrix $P(S')$. Since the new product sequence for each order is optimal, we have

$$\forall S, Z(S', X) \leq Z(S, X) \tag{3}$$

On the other side, when the sequence function S is known, (2) becomes a quadratic assignment problem (QAP) (Finke et al. 1987). Given S, solving QAP provides a new positioning of products X' so that

$$\forall X, Z(S, X') \leq Z(S, X) \tag{4}$$

Given a sample of orders to fulfill, the following heuristic organizes efficiently the products in the warehouse:

1. Initialization:
   (a) Set an initial sequence function S.
   (b) Compute X solution of the QAP minimizing $Z(S, Y)$.
2. Optimization loop:
   (a) Compute S' solution of the TSP minimizing $Z(Y, X)$.
   (b) **If** $Z(S, X) = Z(S', X)$: **stop** the loop. **Else** $S := S'$
   (c) Compute X' solution of the QAP minimizing $Z(S, Y)$.
   (d) **If** $Z(S, X) = Z(S, X')$: **stop** the loop. **Else** $X := X'$.

The computed solution is locally optimal. The algorithm terminates because of the following observation: at each step, we compute the best sequence function S for the given positioning matrix X, and then update the value of X. Since the value $Z(S, X)$ of the solution improves at each step, we cannot compute twice the same matrix X until the last step. Therefore, the number of steps is limited to $|X| + 1$, where $|X|$ is the number of possible product organizations.

This heuristic can be accelerated by fixing a maximal number of iterations and a precision error ϵ so that we stop the algorithm when $Z(P, X) \leq Z(P, X') + \epsilon$. Finally, the initialization step can be replaced by more meaningful values for S and X.

Dynamic Picker Management

In the two previous sections, we studied how to minimize the service time, i.e., the time needed to fulfill an order, assuming that this time is proportional to the length of the travelled path. In this section, we consider a different problem. We suppose that the products are already well positioned in the warehouse, and that we can quickly compute the path to travel to pick up products and fulfill the corresponding order. We denote by $\mu = 1/Z(P, X)$ *the service rate* resulting from the position of the products and the computation of the shortest path to fulfill an order.

We are interested in the number of pickers that are required to carry out this picking activity. By *manager,* we refer to a decision maker who decides when to call pickers to the depot to do the picking activity, and when to make a picker leave the picking activity to pursue other tasks. The manager can either a human being or computer algorithm.

Among the different activities assigned to the pickers, the picking activity is one of the most critical and requires a lot of efforts (Roodbergen and De Koster 2001). Therefore, it is usually the most costly one. For this reason, it is important to use as few pickers as possible while providing a good service. We define here the objectives of three different stakeholders: the clients want to get the best service possible, the pickers in the warehouse ask for good working conditions, while the manager wants to minimize the costs of the picking activity while obeying the objective of the other groups.

Having the best service usually means minimizing not only the average service time, but also the worst case waiting time, as large service times may create strong dissatisfaction of clients.

The pickers' working conditions are considered as constraints, because they are supposed to be guaranteed to them, and do not need to be further optimized. The number of pickers is limited, and the pickers are guaranteed minimal activity durations as well as an arrival delay. So, a picker must not be affected on the picking activity for duration below γ, and a picker leaving the picking activity should not be called back for duration β. Furthermore, called pickers dispose of a delay δ to finish their current activity and go to the depot.

Before introducing the key performance indicators (KPI) to measure the efficiency of picker management, we present some theoretical results.

We consider a queuing model for the waiting orders. The waiting orders are then recorded in a queue and treated in their arrival sequence. We denote by λ the average arrival rate of the orders. The optimal number of pickers that should be on the picking activity is $\alpha = \lambda/\mu$. If we always use less than α pickers, then the orders will arrive faster than they are fulfilled. The queue will thus grow infinitely, so as the waiting time of the orders, following the theorem of Little (Little 1961):

$$\mathrm{E[Lq]} = \lambda \cdot E[\mathrm{Wt}], \tag{5}$$

where E[Lq] denotes the average queue length and E[Wt] denotes the average waiting time of an order.

Thus, the manager must minimize the number of active pickers while keeping it on average above α. An active picker is either *busy*, i.e., fulfilling an order, or *idle* if he waits for an order to arrive, which happens when the queue is empty. We say here that a strategy to manage pickers has an *optimal cost* when the queue length does not grow indefinitely and the picker costs are minimal. The following theorem provides sufficient conditions for a strategy to have optimal cost:

Theorem *Consider a strategy providing in average n_a active pickers and n_i idle pickers:*

- $n_a \le \alpha$ *if and only if* $n_i = 0$.
- $n_a \ge \alpha$ *if and only if the queue does not grow up indefinitely.*

Proof We consider a probabilistic model with the following notations:

- Δ: considered time period where the pickers work while orders arrive.
- $\tau = n_a\, \Delta$: sum of the picking activity durations of all pickers.
- $\Omega_\Delta = \lambda\Delta$: number of orders arrived during period Δ.
- $R = \mu(n_a - n_i) \le \lambda$: the order fulfillment rate.
- $\Omega_\tau = \Delta R \le \Omega_\Delta$: number of orders fulfilled during period Δ.

Suppose first that $n_i = 0$:

$$\alpha = \lambda \cdot \mu^{-1} = \left(\Omega_\Delta \cdot \Delta^{-1}\right) \cdot \left(n_a \cdot \Delta \cdot \Omega_\tau^{-1}\right) = \Omega_\Delta \cdot \Omega_\tau^{-1} \cdot n_a \ge n_a$$

Suppose instead that $n_a < \alpha$. The order fulfillment rate $n_a\mu$ is smaller than the order arrival rate $\lambda = c\mu$, and thus the queue length will in average keep growing up. There will always be waiting orders and thus no idle picker.

Suppose now that α is an integer and $n_a = \alpha$. If we had $n_i \ne 0$, the order fulfillment rate $\mu\ (n_a - n_i)$ would be smaller than the order arrival rate $\alpha\mu$. There would be no idle picker, which is a contradiction. Therefore, $n_i = 0$ if and only if $n_a \le \alpha$.

Consider the second rule of the theorem. The queue does not grow up indefinitely if and only if the order arrival rate $\lambda = \alpha\mu$ is not strictly greater than the order fulfillment rate $\mu\ (n_a - n_i)$. When the queue is growing up, there are no idle pickers. Therefore, the queue does not grow up indefinitely if and only if $\alpha \le n_a$.

Minimizing the number of active pickers is actually not a good criterion, since it is not clear how to have in average α active pickers, while minimizing the queue length. This theorem points out that minimizing the costs actually means having in average zero idle pickers. Therefore, it makes more sense to minimize the *wasted manpower*, i.e., the number of active pickers that are idle. The criterion of wasted manpower is simple to minimize, as we just make sure that no active picker is idle. We can then freely optimize the other criteria.

In practice, the minimal duration γ of the picking activity may make it impossible to make a picker leave while the queue is empty; hence he will be idle for some time. Likewise, the minimal duration β before he can return to the picking activity can increase the maximal waiting time for orders.

The calling delay of the pickers increases also the difficulty, as a picker also loses some time every time he is called to come to the depot. Thus, we should also minimize the *call frequency*, i.e., the frequency of calling pickers to the depot to do the picking activity.

Another interesting objective is to maximize the average number of the pickers that have been inactive for duration greater than β, and therefore can be called to the depot. This improves neither the cost nor the service quality. Nonetheless, it indicates a certain comfort in the management, as it shows how many pickers are not necessary for the picking activity with the given strategy, and how well unexpected increase of the order arrival rate can be dealt with.

We define the five KPI of a strategy to manage pickers as the following:

- The wasted manpower (WMp): the average number of idle active pickers.
- The average waiting time of an order (AWt).
- The maximal waiting time of an order (MWt).
- The call frequency (CF): the rate of picker calls.
- The extra manpower (EMp): the average number of inactive pickers that can be called to the picking activity.

We finally present an algorithm to efficiently manage the number of pickers. This algorithm is nevertheless generic and must be calibrated to meet the real objectives of the manager. The algorithm obeys two rules of the theorem to provide an optimal cost. The algorithm decomposes the set of possible queue lengths into several intervals (I_n) so that

- The interval I_n is the set of queue lengths where n pickers can be active. The value of n only changes if the queue length gets a value outside I_n.
- There are no active pickers if and only if the queue is empty.
- Interval I_n must not be larger than interval I_{n+1}.
- The final decision to make a picker leave occurs when he finishes fulfilling his current order.

If the queue length exceeds the interval bound of the current number of active pickers, the algorithm calls an additional picker. If the queue length falls below the interval bound, the algorithm will make leave the next picker who finishes an order. If the intervals overlap, then the current number of active pickers also depends on its previous value and is chosen to minimize the call frequency.

Simulation

We implemented a simulation model to test our algorithm on randomly generated data. The order arrival is generated with a Poisson process, with in average between 75 and 90 incoming orders per hour. The order generation and the warehouse dimensions are set to obtain an average order fulfilling time of $\mu^{-1} = 4$ min. The optimal average number of active pickers is then [5, 6]. At the beginning of each test, the queue is supposed to be empty and none of the eight pickers at disposal is active. Each simulation lasts 5 hours, which is long enough so that the initial state of the process has a minimal importance in the results. The time scale between each decision is 15 s. We present here simulations for two scenarios providing different working quality, as presented in Table 1. A more extensive simulation of the algorithm will be presented in an upcoming paper.

Table 1 Simulation Scenarios

Scenario 1: good working conditions	$\gamma = 10$ min, $\beta = 20$ min, $\delta = 2$ min
Scenario 2: bad working conditions	$\gamma = \beta = \delta = 0$ min

For the algorithm, we divide the intervals into two groups $(I_n)_{n<\alpha}$ and $(I_n)_{n>\alpha}$:

- $n < \alpha$: $I_0 = \{0\}$; $I_1 = \{1, 2\}$; $I_2 = \{1, 2, 3\}$; $I_3 = \{2, 3, 4\}$; $I_4 = \{3, 4, 5\}$; $I_5 = \{4, 5, 6\}$
- $n > \alpha$:
  - $I_6 = \{5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15\}$
  - $\forall n,\ |I_n| = 11,\ |I_n \cap I_{n+1}| = 6$

The results of the simulations are presented in Table 2. We first note that the algorithm managed to avoid any waste of manpower. Thus, the manager can afford to ensure a minimal picking activity duration of $\gamma = 20$ min to the pickers.

The simulation with good working conditions provides a good compromise of the average waiting time, namely between 100 and 200 % of the average picking time, in order to deal with order arrival rate variations. Furthermore, the algorithm usually keeps one or two extra pickers. This is enough in this situation to face a sudden increase of the order arrival rate.

In comparison to the simulation with bad working conditions, the average waiting time is a little larger while the call frequency is slightly smaller. This means that sometimes, the algorithm would like to add a picker but cannot, resulting in a small increase of the waiting time. However, the maximal waiting time has a similar value in both scenarios. Moreover, giving better working conditions to pickers does not decrease too much the extra manpower to make it critical.

Further simulations that we do not present here also show that a high value of γ generates a significant waste of manpower, and a long duration δ emphasize this waste. A high value of β leads to higher waiting times, and this effect is increased by a low value of δ, that is for a higher call frequency.

We mention again that satisfying results require the calibration of the algorithm, which should be set depending on the requirements of the warehouse.

Finally, it is meaningful to take some picker constraints into account, namely by reducing the picker call frequency, in order to get a more accurate estimation of the service time and the picker costs.

Table 2 Simulation results

KPI	AWt (min)	MWt (min)	CF (h − 1)	WMp	EMp[a]
Scenario 1	5.25	10.0	4.9	0	1.6
Scenario 2	4.56	9.4	5.7	0	2.9

The duration of each simulation is 5 h

[a]The EMp is the only of the four KPI that we want to maximize, in order to be sure that we can always call pickers, and to see if we can reduce the number of pickers present in the warehouse

Conclusion

This paper dealt with the management of a warehouse with parallel wide aisles. We studied the three main problems of an order picking process, which are the layout of the warehouse, the storing strategies for the products and the control of the number of pickers.

For the layout, we used a car-traffic like circulation to facilitate the movement of vehicles that the pickers would use. We then presented an algorithm organizing the products into locations according to a sample of predicted orders. Finally, we considered the problem of dynamic management of picker activities. The goal was to minimize the number of pickers on the order picking activity while ensuring low picker flexibility and a good service quality.

KPI have been presented to model the objective functions of this multicriteria problem. We described a generic algorithm deciding on the number of pickers, and used it in a simulation experiment. With a good calibration of the algorithm, we can minimize the waste of manpower, while providing efficient service times and keeping available pickers for sudden increases of the order arrival rate.

An interesting topic for future research would be to study the restock of the products at the same time as their picking, in order to create a strategy allocating the pickers between these two activities. Further research can also be done on the algorithm positioning the products, in order to determine how many iterations of the loop are needed to place the products, and how much computation time it takes in different situations. Finally, it would be interesting to develop the picker's constraints to provide a better dispatching or to send tome pickers home when the order arrival rare is too low, hence reducing the picker's costs.

References

Backer P, Canessa M (2009) Warehouse design: a structured approach. EJOR 193:425–436

De Koster R, Le-Duc T, Roodbergen KJ (2007) Design and control of warehouse order picking: a literature review. EJOR 182:481–501

Finke G, Burkard RE, Rendl F (1987) Quadratic assignment problems. Ann of Discr Math 31: 61–82

Hall RWH (1993) Distance approximation for routing manual pickers in a warehouse. IIE Trans 25 (4):76–87

Lawler EL, Lenstra JK, Rinnooy Kan AHG, Shmoys DB (1985) The traveling salesman problem. A guided tour of combinatorial optimization. Wiley, Chichester

Little JDC (1961) A proof for the queuing formula: $L = \lambda W$. Oper Res 9:383–387

Mazalov VV, Gurtov A (2012) Queuing system with on-demand number of servers. Mathematica Applicanda 40(2):1–12

Merkuryev Y, Merkuryeva G, Piera MA, Guasch A (2009) Simulation-based case studies in logistics. Springer, Berlin

Ratliff HD, Rosenhal AS (1983) Order picking in a rectangular warehouse. A solvable case of the travelling salesman problem. Oper Res 31:507–521

Roodbergen KJ (2001) Layout and routing methods for warehouses. Ph.D., thesis, Erasmus University Rotterdam, The Netherlands

Roodbergen KJ, De Koster R (2001) Routing methods for warehouses with multiple cross aisles. Int J Prod Res 39(9):1865–1883

Theys C, Bräysy O, Dullaert W, Raa B (2010) Using a TSP heuristic for routing order pickers in warehouses. EJOR 200:755–763

Tompkins JA, White JA., Bozer YA., Frazelle EH, Tanchoco JMA, Trevino J (1996) Facilities Planning, 2nd edn. Wiley, Newyork, p 36–47

Improving Management Functions in Developing New Products in Medium-Sized and Large Enterprises (A Comparative Study of Bulgarian and American Processing Industry)

Bojana Stoycheva and Diana Antonova

Abstract Product and process innovations are viewed as a key factor for the competitiveness of organizations and regions and for achieving economic growth. The efforts of researchers in this area are focused on identifying good practices, related to the management of new products development (NPD), and bringing out those with high success rate. A number of studies on the NPD process prove that the increased research and development activeness (R&D) increases the comparative advantages and is the basis for market approval of industrial enterprises-innovators. This determines the interest of authors in studying the area of efficient management of the NPD process in industry. They research practices applied in Bulgarian industrial enterprises with the aim to prove the significance of the technology and organization for NPD and use it to synthesize and summarize a set of specific quality parameters for improving the management functions, applicable in medium-sized and large enterprises for the processing industry in approving their performance, compared to the competitors in the sector concerned.

Keywords Competitive advantage · Industry studies · Innovation · Innovation process · Research and development · Technological innovation

JEL Classification L250 · L600 · O310 · O320

B. Stoycheva (✉) · D. Antonova
Faculty of Business and Management, University of Ruse, Ruse, Bulgaria
e-mail: bstoycheva@uni-ruse.bg

D. Antonova
e-mail: dantonova@uni-ruse.bg

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Introduction

The efficient management of each phase, in which the innovation process has been decomposed, is directly related to the management of new products development (NPD), providing an advantage in the continuously changing environment, where the organizations function. Good NPD practices have been studied from idea generation to production by a number of researchers (Tzokas et al. 2004; Damanpour and Wischnevsky 2006; Chang and Cho 2008; Visser and Weerd-Nederhof 2010; Durmusoğlu and Barczak 2011). Cooper (1996, 1998) and Cooper and Campbell (1999) has conducted profound worldwide studies on what separates successful new products from those which fail. Researchers have directed their efforts to finding common practices and ways that could lead to the creation of new successful products by the organizations.

The authors' research is based on several earlier surveys in this field. One of the organizations, focused on improving the efficiency of individuals and enterprises for developing and managing new products, as well as encouraging their development, is Product Development and Marketing Association (PDMA). PDMA's mission is creating and spreading knowledge for managing and improving the processes for developing new products. A primary analysis of the product design state was first made by PDMA in 1982, and then in 1995 under the guidance of Griffin (1997). A third wave of research on the tendencies in new product development and good practices in the USA was done by PDMA in 2003 (Barczak et. al. 2009). G. Barczak, A. Griffin, and K. Kahn were project coordinators. The research done proves that using a formalized process in developing new products, availability of a specific strategy for this development, measuring the results, and putting in more efforts, using mixed teams, as well as applying a combination of marketing research on the market and consumer attitudes, computer-aided design, and using rewards, are practiced. This has direct influence on the success in new product development.

These surveys challenge the authors to conduct research among Bulgarian industrial enterprises with a focus on NPD process. The survey card used for the comparative survey has been developed by PDMA (2003). The general NPD process in enterprises is surveyed, as well as the management of innovation product portfolios, NPD process through outsourcing, NPD organization, and methods used.

Framework

When choosing the objects for sector analysis and the size of the organizations surveyed, we sought parallel to the surveys cited, conducted in the USA in order to achieve comparability and commensurability of the results obtained. The object of the experimental survey in Bulgaria has been medium-sized and large enterprises (selected by the number of their personnel), which according to the National Classifier of economic activities (KUD—2008) are registered in sector C —"Processing industry," and operate in the following sections: 10 "Production of food"; 16 "Production of timber, wood and cork products, excluding furniture, production of straw products and knitting materials"; 17 "Production of paper and cardboard articles"; 22 "Production of rubber and plastics"; 28 "Production of machines and equipment with general and special purpose".

The total set of companies comprises 559 organizations. The information about them has been provided by the National Statistical Institute of the Republic of Bulgaria (NSI). Since the survey has been conducted in five different sections, to submit statistically significant results for each of them, the sample should be representative for the general set of organizations and for the companies belonging to each section. To check the statistical significance, the Raosoft calculator (Sample size calculator) has been used. It makes the calculation of survey sample volume (n) possible. The statistical error embedded is $p = 5\ \%$, with confidence coefficient $\gamma = 0.95$.

The respondents of the survey proper are 234 organizations. A direct contact has been established with them on the basis of in-depth interviews. The results can be accepted as statistically significant both for the general set and for each section. The level of activeness is 63 %, and is shown in Table 1 by sections.

Answers have been obtained by respondents targeted in advance: Executive manager/manager, brand manager, or R&D manager. The choice of respondents has been based on the conviction, where this is the circle of people, who are acquainted with the wide range of activities of the respective organization.

This paper is focused on comparing the results from the survey conducted among American and Bulgarian organizations. The common process of new product development, managing portfolios of innovative products, and the organizational activities of developing new products are analyzed. In particular, the authors comment on the results obtained from rubber and plastics producers, due to the wide range of applications of their products in the manufacturing activities of Bulgarian industrial enterprises, including automotive industry and other related industries.

Table 1 Level of activeness

Section	No. of enterprises general set (N)	Estimated no. of companies surveyed (n)	Number of companies surveyed	Completion (%)	Refusals number	Refusals (%)
10	335	179	125	70	54	30
16	26	24	16	67	8	33
17	33	30	8	28	22	72
22	79	66	35	53	31	47
28	86	70	50	71	20	29
Total	559	369	234	63	135	37

Results and Discussion

A number of studies on new products prove that the level of novelty may vary. Following the methods of PDMA (Griffin 1997), we have been using the following categories of new products: Products which are world novelty; Product lines which are new for a given organization; Additions to existing product lines; Major modifications and next-generation products; Gradually improved products; Re-positioning of products; and Reduced cost products manufactured by the company. The new products in the organizations under survey fall into three categories—world novelty, adapting, and imitating innovations.

On analyzing the fuzzy front end (Stoycheva and Antonova 2012), the authors have reached the conclusion that it is of crucial importance for the Bulgarian industrial enterprises in the process of new product development, due to the following reasons: (1) The greatest opportunities for improvement of the entire innovation process are concentrated in its starting stage. If the companies are not efficient in their generating stage, in spite of their excellent technological development, there is a great probability of the product to fail in the financial, strategic, or trade expectations (Khurana and Rosenthal 1997; Koen et al. 2001; Antonova 2009; Oliveira and Rozanfeld 2010; Ho and Tsai 2011); (2) The search for efficiency on the innovation process, achieved in a relatively short time, also presupposes a strong accent on the generating stage, when the changes in the conceptual model of the new product can be achieved at a relatively low cost; (3) The possibility to create a complex procedure for evaluating new variants in the generating stage requires a constant flow of quality new product ideas, which would guarantee successful innovative solutions for the organizations in the future. In this way, costly blunders at a later stage of the innovation process will be avoided. Financial, strategic, and marketing risks will be reduced significantly.

In the American organizations, the process of new product development is highly structured. A strong accent is put on the fuzzy front-end stage. The organizations surveyed pass through the stages of the new product development process subsequently, namely, generating of ideas, screening of ideas, business analysis, tests, development and reliability of the new product, and commercialization. About 14 % of the ideas generated turn out successful. The American organizations determine accurately the time needed for the new product to go through each stage of development. Results show that American enterprises dedicate 2 years (104 weeks) on average for developing world innovative products, for adapting innovations—62 weeks and for imitating innovations—29 weeks. From the new products developed to the stage of commercialization, 54 % are identified as ultimately successful. In comparison to earlier surveys, the time for developing new products has been reduced by 42.5 %, which has contributed to their success. The situation with the Bulgarian industrial enterprises is disparate. Results show that the enterprises surveyed cannot accurately determine the time needed for developing new products, as well as the time necessary for each stage of the innovation development process. No analysis is done to identify the stage, when new ideas fall off; hence, it is impossible to determine the number of new product ideas, which have turned successful and reached market realization. The result obtained may be due to the fact that the processing industry enterprises in Bulgaria demonstrate conservative attitude to new products and focus their efforts mostly on developing adapting and imitating innovations. Only fewer than 5 % of the new products developed in these enterprises belong to the group of world innovative products. These organizations do not invest in creating radical innovations, due to a lack of financial resources. They have used a considerable financial resource and expensive equipment for their development, compensating the lack of qualified staff and working in conditions of increased risk. All this casts some doubt on the survival of the organizations today, which is hard anyway.

In particular, in the production of rubber and plastic articles, those of which are world novelties are less than 1 % (0.86 %). From the adapting innovations, product lines which are new for the organization make 15.45 %; the additions to existing product lines hold the highest percentage—27 %. The major modification and next-generation products are 13.63 %. From the imitating innovations, the share of the products gradually improved is the highest—26.45 %, followed by the repositioned products—12.17 %, and those with reduced cost 4.14 %. The results obtained confirm the general tendency and characteristic of the enterprises from the Bulgarian processing industry.

The generating and the technological aspect of NPD is becoming more and more critical element of the overall corporative strategy. This is inextricably linked to the strategic direction of the company and facilitates the identification of its competitiveness range.

The availability of a written general strategy of the company facilitates making innovative decisions. With the American organizations, 74 % of the respondents have a complete strategy in developing new products, which confirms once again the fact that these organizations pay specific attention to the process of developing new products. For Bulgaria, 71 % of the respondents' surveyed use a complete strategy for developing new products, which directs and integrates the whole development process. Although the percentage of organizations using a complete strategy is close, the difference of 9 years between the two surveys should be taken into consideration. This gap is evidence that Bulgarian industrial enterprises are lagging behind. With the manufacturers of rubber and plastic products, 74.29 % (26) from the respondents apply the entire NPD strategy. 54 % (14) of the organizations insist on being market product and technological leaders, although not all their efforts turn successful. They share that they react fast to early signals concerning opportunities. 8 % (2) of the companies describe their innovative strategy as careful observation of the activities of their major competitors. Rarely they are the first to offer new products on the market, but they are fast to follow (imitators), which guarantees higher profitability and even more innovative product modifications. 38 % (10) organizations are trying to discover and maintain a secure niche for a relatively stable product or service. They defend their position by offering higher quality, accurate service, and lower prices (Table 2).

Table 2 Duration of documented NPD process

Years	0–1	2–3	4–5	6–10	Over 10
Producers of rubber and plastic articles (%)	8	16	24	28	24

From the results obtained, it follows that the implementation of documented NPD is not an unknown phenomenon for the producers of rubber and plastic articles and it has its traditions. A significant number of the organizations surveyed (53 %) conduct a timely update of the NPD process, which leads to its overall improvement.

Development of new products is based on ideas from various sources. The data provide evidence that the main sources of innovative ideas are the consumers and clients. This is the one more proof that the organizations surveyed do not create knowledge, but expect ready solutions from the clients, which they will then develop, sure in the innovation success.

In particular, Table 3 presents the results (through a 5-point Likert scale), in the production of rubber and plastic articles, connected to identifying the source of new product ideas.

Table 3 Emergence of ideas for new products

Ideas for new products	Not at all important				Extremely important	Producers of rubber and plastic articles
Coworkers in the firm	1	2	3	4	5	2.83
User or customers	1	2	3	4	5	4.80
Competitors	1	2	3	4	5	3.57
Internal research and development	1	2	3	4	5	2.29
Cooperation with other companies	1	2	3	4	5	2.29
Suppliers	1	2	3	4	5	2.14
Internal marketing group	1	2	3	4	5	2.49
Consultants	1	2	3	4	5	2.20
Internet network	1	2	3	4	5	3.40
Top management	1	2	3	4	5	4.49
University or Research institutes	1	2	3	4	5	1.69
Internal manufacturing	1	2	3	4	5	2.94
Acquisition of new equipment	1	2	3	4	5	3.63
Professional journals	1	2	3	4	5	2.74

The results obtained confirm the general tendency that the main sources of innovative ideas are the consumers and clients. Another generator of ideas is the top management, who makes the decision whether one idea should be developed or not, taking into account the opinion of different functional departments. Acquiring new equipment, as well as tracking the branch competition activities, is also innovation sources. The results provide evidence that the relation between science and real business practice is very weak or practically nonexistent. A proof for the predominant creation of adapting or imitating innovations is the weak influence of the internal R&D, i.e., the organizations do not invest in its development.

For the American organizations, the application of nonfinancial stimuli is characteristic. The most common rewards are holiday gatherings, opportunities for future work in larger teams, as well as commendable messages in the company bulletin.

Concerning the methods used for stimulating the leaders and the members of a given innovation project, the results obtained for the Bulgarian respondents surveyed testify that besides the financial stimuli, the nonmaterial means of reward such as praise, nonfinancial rewards, project photographs, and festive gatherings are not widely used among producers of rubber and plastic products. This trend is characteristic of a number of other sectors in Bulgaria. In this respect, a system for adequate evaluation of teams, which deal with new products, should be developed. The fact that motivation is high only when a financial system of remunerations is supported has been unanimously accepted. We should not forget that the reward in NPD should be dependent on specific results. Besides, we should be aware that the reward with NPD should be related to specific results, and the formally developed system of rewards in the organizations does not work when new products are created.

Conclusion

Unlike the American organizations, the Bulgarian processing industry enterprises do not create completely new knowledge. They do not direct their efforts to developing radical innovations, but focus their production on adapting and imitating innovations. They ought to take into consideration the fact that in order to survive in a competitive environment, they should change their orientation from ready solutions, coming from outside, to generate knowledge.

The present study brings out results concerning the state of NPD process for the manufacturers of rubber and plastic ware on the territory of Bulgaria compared in general to processing industry enterprises from the USA. The results obtained outline the characteristics of the production of new products in the sector. Contrary to initial expectations, the organizations producing rubber and plastic ware have a complete NPD strategy, which determines the success of those companies both on the domestic and on the foreign markets. 74 % of the respondents apply a complete strategy when developing new products. This shows that the NPD process is approached with particular care. It is structured, currently updated, and traditional in the sector. The results give grounds for assuming that a great part of the good image and high financial results, as well as the participation in a number of international joint projects of the enterprises from rubber and plastics sector, is due to the successfully formalized NPD process.

The quality management and the establishment of an efficient system for motivating the teams, creating innovations, are important factors, reflecting the state of a company. In this respect, the Bulgarian companies have to undertake steps to build and implement a system for staff rewards, as a powerful management tool, leading to creating successful innovations.

References

Antonova D (2009) Significance of knowledge production function for industrial clustering. J Entrepreneurship Innov 1(1):1–22. http://fbm.uni-ruse.bg/jei/, ISSN 1314-0175

Barczak G, Griffin A, Kahn K (2009) Perspective: trends and drivers of success in NPD practices: results of the 2003 PDMA best practices study. J Prod Innov Manage 26:3–23

Chang D, Cho H (2008) Organizational memory influences new product success. J Bus Res 61:13–23

Cooper R (1996) Overhauling the new product process. Ind Mark Manage 25:465–482

Cooper R (1998) Benchmarking new product performance: results of the best practices study. Eur Manage J 16(1):1–17

Cooper R, Campbell A (1999) Do customer parthnership improve new product success rates? Ind Mark Manage 28:507–519

Damanpour F, Wischnevsky J (2006) Research on innovation in organization: distinguishing innovation-generating from innovation-adopting organizations. J Eng Technol Manage 23:269–291

Durmusoğlu S, Barczak G (2011) The use of information technology tools in NPD phases: analysis of effects on new product innovativeness, quality, and market performance. Ind Mark Manage 40:321–330

Griffin A (1997) PDMA research on NPD practices: updating trends and benchmarking best practices. J Prod Innov Manage 14:429–458

Ho Y, Tsai Ch (2011) Front end of innovation of high technology industries: the moderating effect of front–end fuzziness. J High Technol Manage Res 22:47–58

Khurana A, Rosenthal S (1997) Integrating the fuzzy front end of new product development. Sloan Manage Rev 38:103–120

Koen P et al (2001) Providing clarity and a common language to the "fuzzy front end". Res Technol Manage 46–55

Oliveira M, Rozanfeld H (2010) Integrating technology roadmapping and portfolio management at the front-end of new product development. Technol Forecast Soc Change 77:1339–1354

Stoycheva B, Antonova D (2012) Fundamentals and significance of generating phase in the management system of innovation process. In: 10th international scientific conference "management and engineering '12", Sozopol, Bulgaria, pp 1107–1113

Tzokas N, Hultink E, Hart S (2004) Navigating the NPD process. Ind Mark Manage 33:619–626

Visser M, Weerd-Nederhof P (2010) Structural ambidexterity in NPD processes: a firm-level assessment of the impact of differentiated structures on innovation performance. Tehnovation 30:291–299

Entering Emerging Markets: A Dynamic Framework

Tomi Sorasalmi and Joona Tuovinen

Abstract Entering emerging markets (EMs) is a huge opportunity and a risk for small and medium-sized enterprises (SMEs). This paper concentrates on the problems emerging from building a supply network in a target economic area. Cultural, legislative, and market factors make it a challenge, but SMEs also face diverse obstacles from side effects emerging from firm's internal decisions. Some of these obstacles are self-generated, and they arise from aggressive growth strategies in parallel with misunderstanding the dynamics of one's own firm—the unintended consequences of decisions. In this paper we will analyze the internal restrictions on Finnish SMEs or actions impeding or accelerating their growth in EMs. A conceptual system dynamics model is constructed so as to describe the challenges of entering EMs. The model is based on a literature review, VTT logistics experts, and interviews conducted with Finnish SMEs.

Keywords SMEs · Emerging markets · Dealers · Entry modes · System dynamics

Introduction

For many people, it has become clear that most of the growth in the near future will take place in emerging markets (EMs), and that, in order to take part in that growth, one needs to have some sort of local presence. We have, for several reasons, chosen a system's perspective in order to study the penetration of small and medium-sized

T. Sorasalmi (✉)
VTT Technical Research Centre of Finland, Vuorimiehentie 3, P.O. Box 1000, 02044 Espoo, Finland
e-mail: tomi.sorasalmi@vtt.fi

J. Tuovinen
VTT Technical Research Centre of Finland, Tekniikantie 2, P.O. Box 1000, 02044 Espoo, Finland
e-mail: joona.tuovinen@vtt.fi

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enterprises (SMEs) into EMs. Firstly, the complexity of global value networks is not limited to the number of actors and stakeholders. Dynamic complexity does not require a large number of stakeholders; it can arise from seemingly simple combinations of feedbacks, time delays, and nonlinear interactions between parts of the system. Dynamic complexity means that the actions and their effects can be far apart in time and in space, and such systems are, therefore, extremely challenging to fully comprehend without suitable tools, for example, system dynamics. Secondly, a firm operating in a new market can be seen as an entity operating as part of a system, where the interactions of these parts determine the behavior of the whole system.

Forrester (1971) defines a system as a set of parts, that operates together toward a common purpose. When making decisions, firms have to incorporate the views and needs of production, R&D, logistics, marketing, sales, and the needs of suppliers, wholesalers, and customers. Often firms focus on optimizing their own performance, because that is something that they have control over. This can, however, lead to suboptimization of the supplier–wholesaler–customer system as a whole. The current management paradigm favors competition over cooperation. From a system theory point of view, firms are a part of the whole system, thus giving insight into how to operate in a way that does not compromise the other firms operating in the same ecosystem, this often requires cooperation.

The focus of this article is on the decision-making logic of managers trying to attain growth in EMs, for instance in deciding the size of the sales force, how the available time is allocated between different tasks, etc. System dynamics is a methodology dealing with systems; it tries to connect the structure (the theory) of a system with its behavior (Forrester 1971).

Many firms fail upon entering new markets, or even penetrating their main markets. A few different behavior modes are presented in Fig. 1: the sales grew as desired (Mode 1); the sales stagnated after promising growth at a low level (Mode 2); the sales collapsed after promising growth (Mode 3); and the sales started oscillating

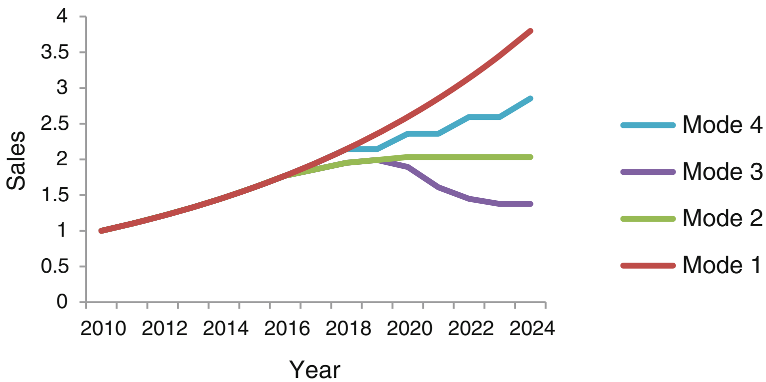


Fig. 1 Dynamic behavior modes

as growth continued (Mode 4). Understanding how to control the feedback loops leads to knowledge of how to make the system behave in a desirable way. Neither of these tasks is trivial, and in this paper we concentrate only on the former.

In this paper, we assume that the basic issues are in good enough condition, i.e., the product is good, the market segments the companies are penetrating are large enough, the timing is right, the customer needs are known, and there is already initial experience of the market. Market competition and product qualities are left outside the scope of this paper. Even if these basic issues are satisfied, there is a fair chance of failing. We also assume that the problem of penetrating into new markets cannot always be pinpointed to any particular place in the firm or in the market. If one part of the system does something, it affects the operations of other parts of the system. For example, if the sales force acquires a large number of new customers, then production and logistics may be in trouble keeping pace. This may lead to lower product quality and longer delivery times, which in turn will cause a hard time for the sales force in selling new products. The parts of the system are highly interconnected, even though in some situations it is very difficult to see that the problems we are facing now are the consequences of our own actions in the past.

A survey was conducted in order to understand the needs and difficulties that SMEs have in EMs. We will discuss the issues that were identified from the interviews and link them to the model. This shows how these issues can be dealt with in a systemic way, and how they affect the long-term development of the firm operating in EMs.

We concentrate on the strategy of building a dealer network, which is responsible for the actual sales to the customers, i.e., we approximate the sales with the number of dealers. In this case, the problem is limited to how to handle the dealer network, how the satisfaction of the dealer network affects the pressure to invest time in dealers and in the long term, how to develop the capability to satisfy dealers.

A reference mode shows how the problem developed and how it may evolve in the future and it tries to characterize the pattern of behavior over time. Generic reference modes are presented in Fig. 1. A reference mode is a helpful tool in understanding the dynamics of a problem. It leads to the structure that needs to be investigated in order to understand, what is happening to sales. We are trying to understand how the firm's own actions lead to its observed behavior, and under what conditions the desirable behavior mode is more likely than undesirable behavior.

The Model

Many firms go into new markets incrementally, so that they can learn the culture and acquire knowledge of the markets, which is also suggested as a good strategy by Johanson and Vahlne (1977). However, the company interviews suggest that the firms are implementing and preferring a more aggressive approach. Our framework tries to address some of the benefits and drawbacks of both strategies.

The example deals with a company with a relatively low unit price product and which desires a rapid growth in sales in the early years of the new venture. We have kept the framework quite general and as such it serves as a guideline to improve understanding the consequences of a firm's own actions. The unintended consequences and side effects arise, because there are only limited resources available at any given time.

The model we present here is based on variables identified from interviews conducted in six Finnish SMEs operating in EMs, at workshops held internally at VTT, and partly on literature. We have tried to concentrate on variables that are mainly controllable by the firm, for instance the size of its own sales force, the number of dealers it is recruiting, and the decisions it makes to channel the resources into developing its own capability. The aim is to identify heuristics that could help firms to react to forthcoming problems before they happen.

We started building the causal loop diagram from the perspective that a company entering EMs needs to increase its dealer network in order to achieve more sales leading to increasing revenue and profits. The structure is presented in Fig. 2. Notice the reinforcing feedback loop *Investing in New Dealers*, where the variable *Number of Dealers* describes the dealer network, that is, how many dealers the company has at the moment. This can be considered as a stock which accumulates over time. The *Number of New Dealers* is determined based on the *Number of Dealers*, *Desired Growth Rate of Dealers*, *Experience of the Sales Force*, *Average Number of Contacts a Sales Person Has*, and *Time Invested per New Dealer*. This loop is responsible for the exponential growth seen in the reference mode, see Fig. 2.

The balancing feedback loop *Limited Resources* can be responsible for the stagnation of the dealer network. When the *Number of Dealers* increases, the *Desired Number of Dealers* increases as well. In the long run, this leads to a situation in which the firm's time to invest per new dealer decreases, and therefore it becomes harder to recruit the desired number of new dealers.

In many EMs, for instance in China and Russia, the contacts play a significant role, when trying to initiate a new business deal. The need for existing contacts is highly culture-dependent. The recruiting process, i.e., finding a suitable candidate and making a contract, takes time. The time needed per new candidate depends on the *Experience of the Sales Force* and on the *Average Number of Contacts a Sales Person Has*. Also, the time taken by the recruiting process a new dealer goes through varies depending on the operating country.

On the other hand, the increasing *Number of Dealers* limits the *Time Spent per Dealer*, which leads to decreasing *Satisfaction of Dealers*. This is mainly because in many cases SMEs do not have extra resources that can be used, when needed and the increasing *Number of Dealers* puts pressure on the existing sales force, which will not have as much time to spend per dealer as they had earlier. Therefore, SMEs may easily face a situation in which they do not have the time to retain good relationships, to respond immediately to questions and support requests from the dealers, etc. Of course, the most important factor in keeping a dealer satisfied is the profits the dealer is making. We assume, that the dealer is making enough profits.

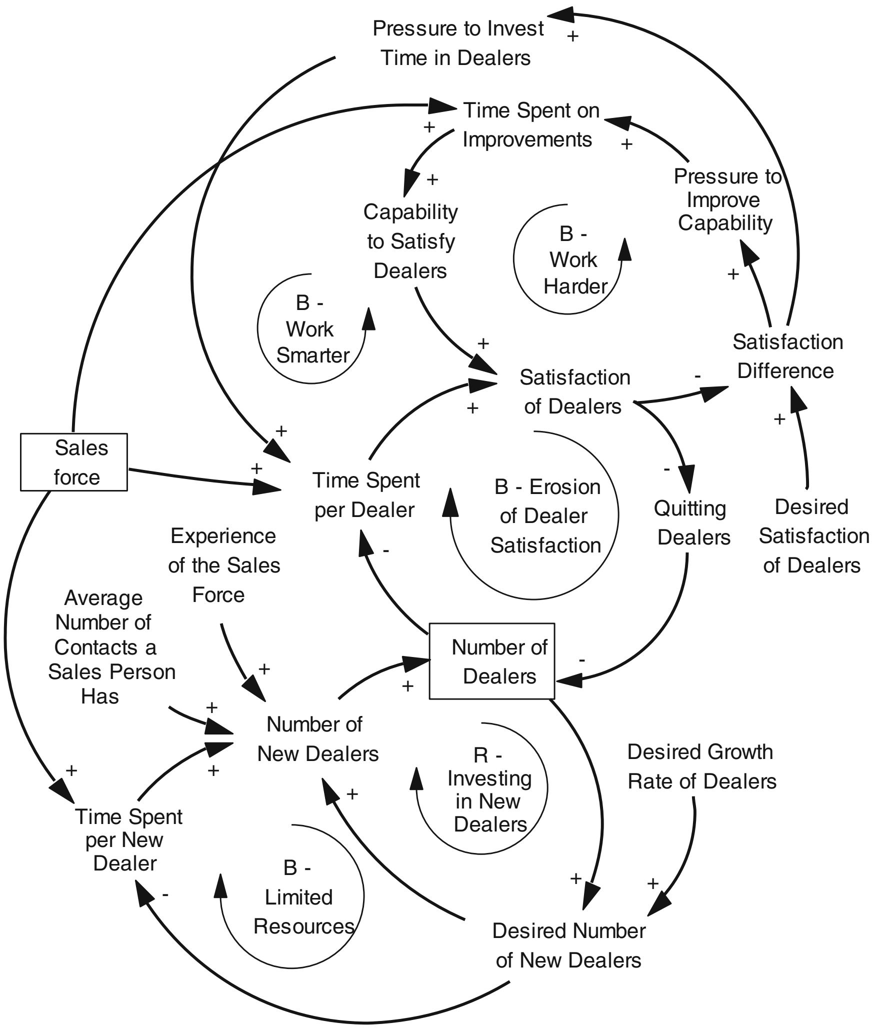


Fig. 2 A causal loop diagram presenting five feedback loops: *Investing in New Dealers*, *Limited Resources*, *Erosion of Dealer Satisfaction*, *Work Harder*, and *Work Smarter*

The decreasing *Satisfaction of Dealers* may cause an increase in the number of *Quitting Dealers* and therefore lead to lower growth or even a decline in the *Number of Dealers*. This balancing feedback loop is called *Erosion of Dealer Satisfaction*. The company interviews indicated that keeping the dealers motivated and having good personal relationships are very important. We see that this is especially important at the beginning of the relationship, i.e., before the satisfaction is supported by sufficiently large profits. This case is not trivial, as the firm may fight against its own actions. Trying desperately to increase the *Number of Dealers* causes the number of *Quitting Dealers* to increase even further; at the same time, resources are used without gaining the anticipated results.

For the *Work Harder* and *Work Smarter* loops, see (Repenning and Sterman 2001; Repenning 2002; Sterman et al. 1997). In this setting, the *Capability to Satisfy Dealer*s includes learning language, culture, business practices of the target country, developing their own after sales processes, Information and Communication Technology (ICT) systems, maintenance capacity, logistics, and other services, i.e., all capabilities the firm possesses in order to satisfy the dealers.

In case of a decreasing *Satisfaction of Dealers,* a firm has a few options of how to react, i.e., spend time directly satisfying the dealers (*Time Spent per Dealer*) or start improving the capability (*Time Spent on Improvements*) to satisfy the dealers, which will help the situation sometime in the future. If the firm is not able to satisfy the dealers, then the number of *Quitting Dealers* will increase. Thus the firm has an incentive to spend time directly on dealers, and consider hiring new people to help the situation in the future. It is possible that the firm is forcing itself into a "solution trap" where it is under constant pressure fighting against decreasing *Satisfaction of Dealers*. At the same time, the *Capability to Satisfy Dealers* is slowly eroding. In the long term, this leads to low capability, and therefore to decreasing satisfaction. The problem may be even trickier if dealer satisfaction is not easily measurable. If it is, how much delay is there, before the firm's management receives information on the actual satisfaction level? Or, is the increasing rate of *Quitting Dealers* actually the only easily observed indication of low satisfaction level?

The other approach is to channel the limited resources into improving capability. In the short term, this leads to even lower dealer satisfaction, because the time used in improving capability is time not spent on dealers. However, in the long term this enables better satisfaction with the same amount of work, and therefore frees even more resources for further capability improvements. Freeman and Sandwell identified firms' capabilities to be the key barriers to entering emerging markets for service firms; in particular, face-to-face communication, language, culture, daily work practices, and government regulations were seen to be difficult (Freeman and Sandwell 2008). The interviews show similar results. The study by Barkema et al. shows that firms entering new markets face cultural adjustment costs (Barkema et al. 1996). Johanson and Vahlne (1977) distinguish between objective knowledge, which can be taught, and experiential knowledge, which can only be learned through personal experience. They also distinguish general and market-specific knowledge, and because of the lack of the market-specific experimental knowledge from the new market, there are basically two options, to gain experience either from engaging in the markets or by hiring personnel with experience. Johanson and Vahlne state that lack of experience is an important reason for slow progress, when entering new markets and that acquiring experience takes a lot of time. Noticeable, as mentioned earlier, one interviewee stated that, when going into EMs one should go there aggressively. Even if the capability, for instance experience, to act in the new market is sufficient, an aggressive growth strategy may bring problems, if the capability of new personnel is unable to keep up with the pace and the balancing feedback loops Limited Resources and Erosion of Dealer Satisfaction, that restrict the growth.

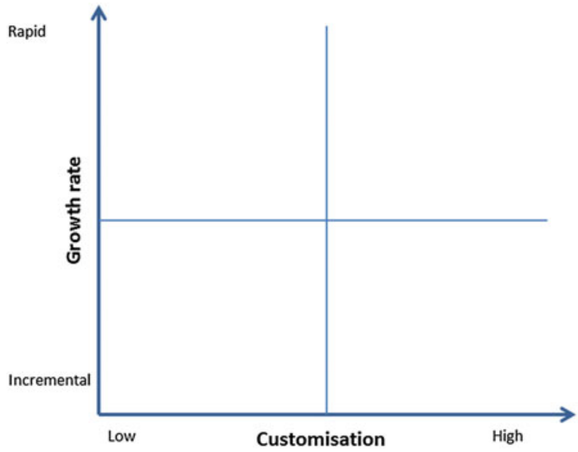
Now, at this point, we will not increase the complexity of the model presented here, even though there are various important aspects that could be included in the model, for example, the pressure on production and logistics causing longer delivery times and lower reliability. However, we will discuss one thing that cannot be excluded from the analysis and is strongly linked to the variables discussed earlier, i.e., the firm's own sales force. Firm resources and ability to invest in its sales force are strongly connected to the decision-making logic, when entering EMs. From the company interviews, a few important aspects were identified, for example, the importance of the firm's local workforce and how to commit them to remaining in the firm. This can be modeled with the same kind of structure as the number of dealers. An important question is, as the interviews show, how to commit the workforce to remain in the firm. This is challenging in some emerging economies, where the workforce is not as committed to the firm as the firm desires.

Frame for Classifying the SMEs

The next step is to develop a simulation model showing how firms incrementally shift from one domain to another. This shift can happen consciously or unconsciously. Continuous growth of customer base, for example, causes more demand for different products and features. Higher demand creates pressure on production and logistics, causing longer delivery times and lower reliability. In order to keep the same service level, firms need to increase their resources, so that longer delivery times and lower reliability do not create pressure to reduce the variability of the products. This may cause cyclical behavior, i.e., oscillation. We want to study how two dimensions, for example the customization and firm growth rate, endogenously change the domain in which the firm is operating. Our hypothesis is that these domains can be linked to the model and even nearer to the existence of different loops and loop dominances, which affect the daily operations of the company creating different problems from the same system structure. This framework may help firms identify the domain they fall into, the direction they are moving toward and what could be done to alter the direction and transition speed. This would help them to prepare for the possible problems in advance and decide to which domain they want to steer towards (Fig. 3).

In further research we will link the risk management tools, firms are using, to the different categories. Identifying when to move from one domain to another may be crucial for the firm's survival in new markets. Through understanding the transition one can anticipate the needs and start building required competences in advance.

Fig. 3 The diagram shows a division with two dimensions, i.e., value of the product and product customization



Conclusions and Future Directions of Research

The theory presented in this paper aids in an understanding, from the dealer network point of view, of why the firm's own actions may cause unintended consequences and side effects, even though the actions may seem reasonable. The causal loop diagrams presented here explain one possible structure that firms entering EMs may face. However, we have not yet built a functional simulation model that could verify that this structure can actually be responsible for the undesired behavior, and therefore we have not yet discussed the possible heuristics that could be used to avoid problems of this sort. The next steps are, therefore, to simulate the model and obtain insights and try different policies. Simulation is a powerful methodology for understanding a system's behavior.

The frame for classifying SMEs will be used to help SMEs to decide what is important now and what in near future. High growth rate, for instance, can cause pressure on production and logistics and lowering product or service customization might be the only way to handle the added pressure–especially when unable to make heavy investments. A systemic understanding is required for designing the correct market entry strategies, for instance, whether to focus on wholesalers or direct sales, accept a lower growth rate or lower customization. Simulation and systems modeling are useful tools in understanding the dynamics in entering EMs.

Future research will contain an analysis of the mainstream decision-making policies, when facing the restrictions presented in this paper, i.e., how time and resources are allocated between recruiting new dealers, working harder, and working smarter, and how decision-making can be improved. The question is a very significant one, in our opinion, because many SMEs have very limited resources available, and if going into new markets alone, they may be building a local presence for years before starting to have sales. This time spent in a new setting can be quite expensive. Thus, shortening the time needed to achieve success is crucial for SMEs.

References

Barkema HG, Bell JHJ, Pennings JM (1996) Foreign entry, cultural barriers, and learning. Strateg Manag J 17:151–166 (December 1993)
Forrester JW (1971) Principles of systems. Productivity Press, Boca Raton
Freeman S, Sandwell M (2008) Professional service firms entering emerging markets: the role of network relationships. J Serv Mark 22(3):198–212. doi:10.1108/08876040810871165
Johanson J, Vahlne JE (1977) The internationalization process of the firm—a model of knowledge development and increasing foreign market commitments. J Int Bus Stud 8:23–32
Repenning NP (2002) A simulation-based approach to understanding the dynamics of innovation implementation. Organ Sci 13(2):109–127
Repenning NP, Sterman JD (2001) Nobody ever gets credit for fixing problems that never happened: creating and sustaining process improvement. Calif Manage Rev 43(4):64–88
Sterman JD, Repenning NP, Kofman F (1997) Unanticipated side effects of successful quality programs: exploring a paradox of organizational improvement. Manage Sci 43(4):503–521

Analysis of the Effects of Intermodal Terminals for the Solutions of Urban Logistics Problems in Istanbul City

Ömer Faruk Görçün

Abstract We analyzed the urban logistics problems in Istanbul City, and we tried to show the solutions of these problems thanks to intermodal freight terminals. Istanbul is a center of trade, tourism, and industry; 60 % of total logistics activities take place in Istanbul. At the same time, capacities, infrastructures, and performance of logistics system are affecting the logistics systems and industries of European countries and neighborhoods. However, solving the urban logistics problems have become regional and global ones and especially European countries, industries, and their commercial actors cannot ignore these problems. In addition to urban freight flows, high volume of international and domestic cargo flows causes different problems related to urban logistics. On the other hand, Istanbul has the different logistics nodes as airports, organized industrial zones, business centers, whereas logistics networks and links between nodes are not required level. This study focuses on the logistics nodes, relationships, opportunities and facilities of transportation, and effects of intermodal freight terminals to solving problems of the insufficient connections between these nodes.

Keywords Intermodal freight terminals · Istanbul · Logistics nodes

Introduction: Logistics in the Istanbul

Istanbul is an important city with the economic, cultural and social assets, tourism, commercial, and industrial activities. In this city, performance and effectiveness of logistics activities are affecting the European countries, manufacturers, traders, and customers. In general, Istanbul is a metropolitan city and metropolitan cities have a key role for urban logistics within the framework of the two objectives. The first

Ö.F. Görçün (✉)
Department of Logistics, Kadir Has University, Campus of Selimpaşa,
Silivri, Istanbul, Turkey
e-mail: omer.gorcun@khas.edu.tr

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objective is centralizing of the logistics activities. Second is cumulating all of the logistics actors (Raimbault et al. 2012).

Synchronization does not require level for the effective logistics activities. Industrial and commercial zones are located in the center of this city. At the same time, these zones are not close to each other. There are a large number of logistics nodes such as organized industrial zones, industrial sites, firms, manufacturers, cargo terminals, processed and fresh food terminals, warehouses, ports, airports, rail freight terminals, and customs.

Daily, large volumes of cargo are transferred between these nodes. Whereas the logistics system is not constructed sufficiently and logistics nodes have not efficient transportation network, freight flows are directly without consolidation and transshipment. Inefficiency is the result of such a logistics system. On the other hand, these problems cause different results for firms, manufacturers, etc.

In terms of the efficiency of the urban logistics system, establishment of intermodal freight terminals has become a priority need on both of sides in Istanbul for the centralization of loads. At the same time, the use of different modes of transportation should be considered as maritime, Ro–Ro and intermodal rail transportation between these terminals. Intermodal freight rails, Ro–Ro and container lines, which are parallel to the shore, can be effective for increasing the speed of freight transport.

Logistics Locations in Istanbul Metropolitan 1–1

In Istanbul, there are a large number of logistics locations. These points have different sizes and characteristics. Firms which are located these points realize their logistics activities with their individual benefits and characteristics. As a result, logistics services may be supplied to customers at high cost levels and low level of customer satisfaction. It may be inefficient. In this city, there are eight organized industrial zones, and they are located in different points as shown in Fig. 1.

There are eight organized industrial zones, and they have a larger volume of the logistics activities and transportation. While six organized industrial zones are in Anatolian sides of Istanbul, two of them are located in the European side of Istanbul. Daily, thousands of vehicles are carrying goods to these regions and ten thousand of cubic meters carried out from these zones. Organized industrial zones have an area of 2088 ha totally. Because of insufficient connections among them, there is very busy traffic and speeds of logistics activities are low.

In addition to that, 113 small industrial sites are in this city and they have busy logistics operations. Especially spare parts logistics has a high level in these sites. These sites are not planned in terms of logistics and transportation requirements.

Other logistics nodes are cargo terminals and warehouses. In Topkapı cargo terminals, approximately 10,000 freight vehicles operate daily (IDA 2009). This terminal is located in Topkapı which is near the main road of D-100, consequently, road trucks which carried from this terminal causes the traffic jam, and it leads to

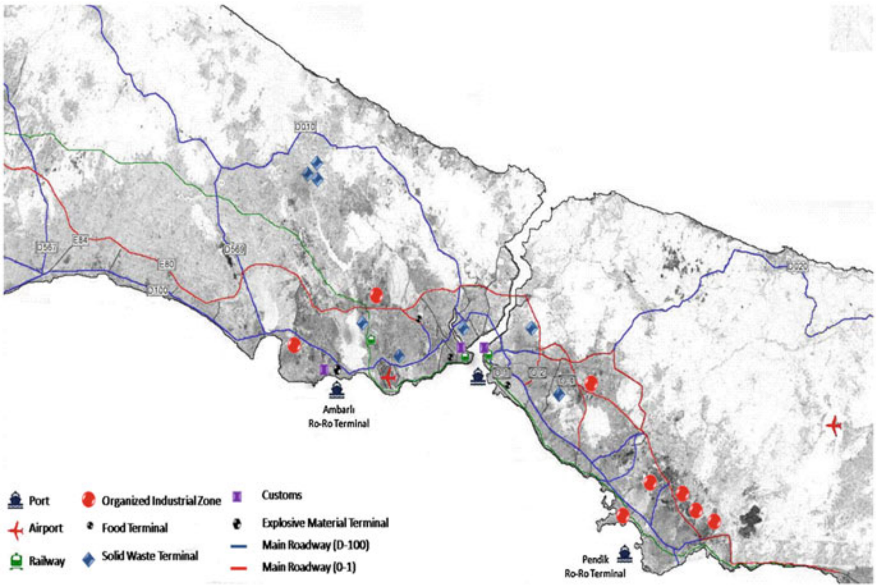

Fig. 1 Logistics nodes in Istanbul City

slow down of the total logistics flows. Fresh and processed food terminals are logistics nodes of this city. In Istanbul, there are two fresh food terminals and one seafood terminal. Numerous firms operate in these terminals. Whereas area of these terminals is extremely poor and it causes the traffic jam. 312 bonded warehouses are located in Istanbul. Despite their impacts of the urban logistics system, its capacity utilization level is very low and approximately 20 % of capacity of these warehouses is used by firms. Finally two inflammable liquid terminals are located in this city.

In Istanbul, connection and synchronization level is low between these logistics nodes. Because logistics activities are performed in different ways and organizations apply logistics solutions in accordance with their characteristics and needs, complicacy and problems are occurring in urban logistics system. Initially, traffic jam, waste of logistics sources, low customer satisfaction, order cancelations, delayed production process are happening, and they are shown inefficiency of the logistics systems.

Transport alternatives and modes are not developed sufficiently. It is one of the problems of the logistics system. Therefore, using the rate of road transportation is very high, compared the other transportation modes. 46,960 road freight vehicles pass through Fatih Sultan Mehmet Bridge and 12,050 of them are reaching to Selimpaşa–Silivri route (GDH 2012). As a result, 34,810 road vehicles are entering the center of Istanbul city. These figures show that logistics system is dependent the road transportation on a large scale.

In brief, there are lots of urban logistics problems as insufficient transportation alternatives and infrastructure, the dependence of the road transportation, insufficient logistics networks, and low level of using the railway and maritime transportation. Using level of the intermodal transportation modes should be increased to solve of these problems. This is possible with the establishment of the intermodal terminals and construction of the efficient transportation modes between them. In addition that, flows of the goods should be planned. They must be consolidated on the perspective of economies of scale.

Problems of Urban Logistics in Istanbul

A large numbers of problems may be seen on the logistics system. The effects of them are realized on different levels. These problems may happen simultaneously and they are complex characteristics. As summarized above, logistics activities cannot reach to systematic level. In addition that logistics infrastructure is not adequate levels in terms of a well-functioning system.

Second, transportation is dependent on road transportation. Approximately 90 % of goods are carried with this transportation mode. Dependence of road transportation may be caused low logistics flow rate, low customer satisfactions, and high level of logistics costs. In general, goods are carried without consolidation. In the cause of this, total transportation capacity cannot be used sufficiently. At the same time, the external cost level is very high such as these logistics activities. Especially emissions, noise, and environmental pollution may be seen on the very high level.

Solutions of Urban Logistics Problems in Istanbul

As mentioned above, freight flows do not have a planned and orderly system. However, these conditions have caused the inefficiency and other problems. For solving these problems, planning and implementation of two intermodal freight terminals that are located on two sides of Istanbul is required. On both sides, cargos and goods will be collected in these terminals. If necessary, all of the logistics activities as handling, combining, partition, labeling, consolidation etc., will be operated in intermodal freight terminals.

At the same time, these terminals will be connected with logistics nodes and between themselves thanks to different transportation modes and their combination. Especially rail and maritime transportation solutions can be used both of them. As a result, collecting and distributing should be done with road transportation between logistics nodes and terminals; railway and maritime transportation should be used in long-haul transport from terminals to terminals as shown in Fig. 2.

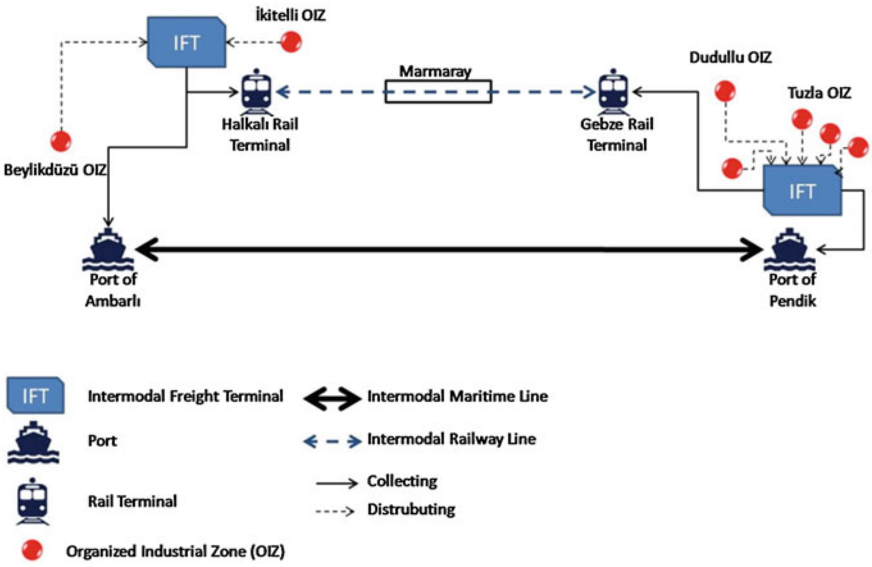

Fig. 2 Intermodal freight terminals and connections with logistics nodes

The first stage of the solution is separating of the logistics process into three parts as collecting, distributing, and long-haul transportation. Both of these sides, collecting and distributing should be done with the short-distance road transportation. On the other hand, these logistics operations should be used the cross-docking and milk run systems as much as possible. However, rail, maritime and combined transportation modes should be preferred for the long-haul transportation that is operated between Asian and European sides of Istanbul.

Intermodal rail freight transportation may be solving problems from the road transportation as traffic jam, noise, pollution, etc. In addition that, Marmaray Project provides an opportunity for continuous transportation between these sides. In brief, both of intermodal freight terminals should be connected each other with the railway transportation. They should have a link directly with the railway system. If this system can be used, we may calculate the effects to vehicle traffic and reducing the CO_2 emissions from the perspective of quantitative methods. The calculating equation is

$$r_{\mathrm{tl}} = \frac{t_{\mathrm{n}} \times w_{\mathrm{c}} \times w_{\mathrm{n}}}{rv_{\mathrm{c}}}$$

$$r_{\mathrm{em}} = \left[\frac{t_{\mathrm{n}} \times w_{\mathrm{c}} \times w_{\mathrm{n}}}{rv_{\mathrm{c}}}\right] \times r_{\mathrm{d}} \times rv_{\mathrm{e}}$$

r_{tl} = Reducing on the traffic volume
t_{n} = Number of railway operations (daily)
w_{c} = Capacity of the per wagon

w_n = Number of wagons
rv_c = Capacity of the per road vehicles
r_d = Route distance
rv_e = Emission factor of the per road vehicles

The first stage of the solution is separating of the logistics process into three parts as collecting, distributing, and long-haul transportation. Both of these sides, collecting and distributing should be done with the short-distance road transportation. On the other hand, these logistics operations should be used the cross-docking and milk run systems as much as possible. However, rail, maritime, and combined transportation modes should be preferred for the long-haul transportation that is operated between Asian and European sides of Istanbul.

According to the rules, rail freight operations can be done by train that has one hundred axles, on 5 % of slope of the railway routes (Görçün 2010). However, when we considered that per wagon has four axles and rail wagon capacity is 62 tones, daily 1550 ton cargo may be carried with 25 wagons and 8 shuttle railway operations. When this value divided the per road vehicle capacity, we can reach the reduction of the road traffic value.

$$r_{tl} = \frac{t_n \times w_c \times w_n}{rv_c} \Rightarrow r_{tl} = \frac{8 \times 62 \times 25}{20} = 620 \text{ road vehicles}$$

In the second stage, if this value multiplied by total route distance and the emissions factor of the per road vehicle, reducing the emissions value may be calculated. This route distance is 93 km with road transportation and emissions value of the per road vehicles is 176 g/km. When we apply the formula we obtain:

$$r_{em} = \left[\frac{t_n \times w_c \times w_n}{rv_c}\right] \times r_d \times rv_e \Rightarrow r_{em} = [620] \times 93 \times 176$$
$$= 10{,}148.160 \text{ g.}$$

As can be seen above, when railway transportation is used between these intermodal freight terminals, 620 heavy road vehicles cannot be seen on traffic daily. In addition that, the total CO_2 emission value may be reduced as 10,148.160 g thanks to intermodal freight rail operations.

In the same way, we considered the effects of the intermodal maritime operations between both of these terminals, 240 heavy road vehicles are transported by Ro–Ro ship. If Ro–Ro ships are used five times daily, 1200 heavy road vehicles can be transported, and 24,000 tons of cargo can be carried by this way. As seen below, when using of the intermodal maritime transportation, CO_2 emission may be reduced up to 19,641.600 g,

$$r_{em} = [1200] \times 93 \times 176 = 19{,}641.600 \text{ g}$$

Conclusion

In Istanbul, logistics system is not adequate level. Firms are operating their logistics activities without mutual benefits. In general, they considerate the individual conditions, their benefits and characteristics. These factors may be short-term and they do not provide an opportunity for solving the large-scale problems of the logistics system.

When we considered all of the parameters, three main problems can be seen as insufficient transportation alternatives, the dependence of the road transportation and insufficient logistics infrastructure as terminals, hubs, etc., all of these insufficiencies may be caused to the increasing value of financial and external logistics cost, low customer satisfaction level, low freight flow rate, external costs as air, noise, and environmental pollution, accidents, etc.

As mentioned above, these problems may be solved using the intermodal transportation and logistics system. Especially intermodal freight terminals give an opportunity for less use of heavy road vehicles. Daily road traffic may be reduced up to 1820 heavy road vehicles and approximately 30 tons of CO_2 emissions may be reduced by this way. In addition that, reduced traffic volume can be caused to the increased logistics flow rate. However, increased logistics flows may be solved the external and financial problems with together low customer satisfaction level.

References

General Directory of Highway (GDH) (2012) Report on Turkey's Motorways

Görçün ÖF (2010) Railway transportation, 2rd edn. Beta Publications, Istanbul

Istanbul Development Agency (IDA) (2009) Regional plan annex of Istanbul

Raimbault N, Andriankajaa D, Paffonia E (2012) Understanding the diversity of logistics facilities in the Paris region. Procedia—Soc Behav Sci 39:543–555

Project Balance Evaluation Method (PBE); Integrated Method for Project Performance Evaluation

Azita Sherej Sharifi and Azam Rahimi Nik

Abstract The project performance monitoring tools are not only for insuring the success of the project, but they also provide the proper input for manager decision making process. It is very difficult to find such a comprehensive and complete method which has high accuracy to rendering performance information of a given project. However, research has shown that without a prospective strategic outlook on project organization, the chance of success of a given project is reduced. This article introduces a project balance evaluation (PBE) method as a new approach to project monitoring. This method uses a modified version of the Balanced Score Card (BSC) tool and the earning value method (EVM), to evaluate project performance. With this modification, PBE acts as a useful tool for project performance management.

Keywords Performance evaluation · Project balances evaluation · Earning value method

Introduction

The failure to reach projected goals on time and within budget is the main worry of all projects. Nowadays, the concept of evaluation has changed drastically. It is necessary to use a strategic performance management system to analyze other criteria, in addition to the traditional approach, which is based on fixed input and output. A successful project evaluation needs something beyond the traditional

A.S. Sharifi (✉)
Accounting Department, Islamic Azad University, Nowshahr Branch, Nowshahr, Mazandaran, Iran
e-mail: Sharifi_1258@yahoo.com; Sharifi@iauns.ac.ir

A.R. Nik
Management Department, Islamic Azad University, Tehran Markaz Branch, Tehran, Iran
e-mail: Arnik2004@yahoo.com

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method, we have developed an earning value method (EVM), that also considers time and budget limitations of the project evaluation at the same time. The method presented here has technical elements like paying attention to time limitations, budgets, and the accomplishment of activities. In addition; this method was developed to consider the human resources situation as well as risk factors, both important elements of a successful or failed project. The project balance evaluation method use a modified version of the balanced scorecard (BSC) method and EVM with together for project performance evaluation and then presented corrected and modified method.

Theoretical Concepts

Earning Value Method (EVM) as an Evaluation Method

EVM is a suitable technique for integrating different activities in project implementation and project performance measurement and evaluation. In fact, project performance in compare with forecasted project plan will be measured. This method for resources integration, budgeting, timing, and project performance reporting from beginning to project termination will be used. EVM also considers time and budget limitations of the project evaluation at the same time. This tool creates relevant connection between time and budget limitation, with important project intervals. It can also minimize management concerns about budget and time limitation in project realization, according to specified and expected plan and goals (Solomon 2011a, b, pp. 230–239).

Timing; Advantage of EVM

Timing is intertwined with the project's success. If deadlines are not set for parts of a project cost and time are progressively wasted. These delays may be the result of a lack of clarity in the project's plan, or a lack in communication. Therefore, part of the process when selecting team members is to consider their capabilities in accomplishing project goals, based on their accomplishments of previous successful projects (Thomsett 2001, pp. 35–41). In EVM, programmed tasks are compared with real accomplished tasks (Nouri et al. 2004, pp. 184–189). In addition, in this kind of evaluation, tasks are coordinated with planned and expected time and budget. EV is an evolution tool that calculates financial and time improvements of real goals in each project. It is stated through considering performance, resources, and time as a tool beyond single-dimension criteria of traditional timing. Calculating the costs based on budgets gives us the amount of EV and real cost, as well as performance evaluation in the project's goal aspect, and finally leads to financial evaluation of initial estimation of the budget in all levels of the project. In other words, EV is a key to understand projects situation. (Frailly 2007, pp. 75–80). The second practical performance of EV is its estimating power. That means EV uses real information of the passed to predict the future performance. Using past to predict, the future has always had some problems. As a result, EV could be a useful tool by the premise that past will be repeated in the future. Most controlling systems of time and cost are based on the premise that technical necessities will be accomplished; when allowances are taken. But the EV system uses an alarming system to indicate potential problems and timing, as well as their effects on projects goals.

Notation to Important Interval of Project; Advantage of EVM

It is also obvious, that if the managers discover deviations from their project's original plan sooner, they can adopt modifying measurements. EVM is process oriented. These processes include initial, planning, executive, control, and termination process. These processes are known as internal process, which contains specific function to project goals setting. Output from one prose is input for another prose; in fact these processes interact together. In general, internal process includes scope planning, scope definition, activities definition, activities consequence, time estimated for each activity, risk management planning, work resources planning, budget and cost planning, quality, and organizational and communications planning. The realization of necessary goals indicates an efficient internal process.

EVMS Limitations

Despite improvements developed in traditional approaches based on timing and financial issues for the management of the project, the EV approach has some limitations. Project management has some limitations, while the EV approach is illustrated via a two-dimensional graph. The EV approach ignores two fundamental factors of human and risk analysis in each project. Ignoring these two factors in calculation of each method is its fundamental weakness (Barber and Miley 2002, pp. 418–423). Since, what is not described cannot be evaluated and what is not evaluated cannot be managed.

Human Factor Limitations

Human aspects, which are effective in project management, include: skills and expertise in project management, skills and expertise in programming team, abilities of programming managers for making a relationship with employer, and abilities of the employer in expressing the details of the needs. Some of these items can be considered in initial selection of project team arrangement. Meanwhile, in the process of cooperation between the employer and beneficiaries of the project in long-term period, job relations and following overlapping human needs will be developed. As a result, team activity in project teams changes in addition to relationship among team members, employer, and stockholders. If the project manager is informed of changes, uses an alarming tool and is sensitive about changes, he can use them for protecting and improving the project incomes. This is a part which was not considered designing and developing the EVMS system.

Risk Factor Limitations

Some experts believe that optimized operation is not merely a factor of strategy accomplishment. Nevertheless they also mentioned that operational management still has a particular priority. Since they found out that without suitable operational process, they would be confronted with difficulties in the strategic performance of risk management, which is one of the four main processes of operation management and plays a significant role in this area. Operation management of the project can be followed with the same concept, or interpreted to project management. Hence, in these projects, especially those which have close relationship with financial services, risk management follows important goals, for example: issues which result from credit operations benefit rate and exchange fluctuations. Risk management is something beyond abstaining from income fluctuations and cash currents. The risk management program and following it, should make the managers and beneficiaries of the project sure, that their investments bring them the minimum benefit they had in mind. With this introduction, it should be illustrated that the EV approach does not have any permanent analysis of project performance and programming risk. It should also be mentioned that risk can thoroughly change a projects life circulation in long-term projects, or projects with a high sensitivity. EV is previous oriented and forecasts in this method are based on previous data, but it cannot demonstrate future situations accurate and exact. In fact, a concentration of EV on using past information to know the current situation of the project, prediction costs, and timing of the projects future (if past clearly express future situation) is needed. This means that it does not consider any probability for a lack of access to fundamental and nonfundamental sources, when its needed (Booz 2003, pp. 13–19).

Balance Score Card; Evaluation Method

One of the most important challenges of organizations is performing strategies, which are adjusted using systematic methods. Balanced evaluation method goals help economic agencies to concentrate on all aspects of their business. The traditional approach to performance evaluation cannot reflect effects resulted from intangible assets, like cooperation between different elements of the project. Today, it is known that one of the most valuable assets of an organization is the cross functional cooperation and to offer integrated solutions, which BSC considered important in this concept (Tewart 2001, pp. 158–167).

BCS indicates that to perform a continuous approving circulation of business, four aspects of business, which include learning, growth, internal processes of business, customer, and financial issues, should be considered.

Four Aspects in Project Management

1. Financial issues: project should go on, based on budgeting.
2. Human resources: constant relationship among team members and project stockholders can lead to an effective performance of the tasks. Internal cooperation of team members is also of prime significance (Myles and Jackson 2006, pp. 1308–1316).
3. Risk: increase and decrease of risk in a project is important and its effects should be recognized.
4. Time: paying attention to deadlines of the project and an appropriate timing program should be developed (Tewart 2001, pp. 158–167).
5. Balance Score card joins related goals that organizations should achieve to compete based on innovation and intangible capabilities (Simons 2000, p. 271).

Financial Dimension

Do project incomes achieve expected benefits of the beneficiaries? Which policies should be taken for financial success to set financial limitations appropriately? Financial success means finishing the project by spending a programmed budget or an amount lower than that. But this only happens when budgeting is done based on reality and goals (EVM emphasize). Which means budgeting may have been done under or over the facts. When budgeting is not compatible with reality, it is the project manager's responsibility to attract stockholder's attention and lay the foundations for reinvestigation of budgeting. Financial goals are set as criteria for improvements of the project. These goals are set to develop financial limitations and are used as a communication tool to express project goals in particular to the people involved in the project and as a feedback for the project team, its managers, entrepreneurs, and other stockholders. When financial goals are set properly, the manager keeps the budget against real situation and reports the differences.

Entrepreneur (Customer) Dimension

Paying attention to timing needs practical and effective activities of the project team members. A good manager knows practical and effective key processes and manages sources to conduct activities. Appropriate management of sources includes human and nonhuman resources and vital activities. This management may include necessary educations or using consultants. In fact a suggested value of the project to employer and stock holders of the project is evaluated. Knowing customer needs and then offering suggested values is the most important factors of the project success.

Internal Processes Dimension

Which processes should develop and how internal processes intra-team and sources and inter-team and employer relation should be created to reach the project goals? Which traditional activities are based on engine? The engineering basis should be managed based on a technical system. Accordingly the human aspect of project management seems to be important. This deficiency is also obvious in the EV approach. The EV approach emphasizes on technical systems (technical oriented), while it should emphasizes on human systems (human oriented). If there is a good relationship among the team, the employers, and the stockholders of the project, it is more probable for the project to be successful. It becomes more important, when the project improvement trend has some difficulty, since this is the time when relationships and communications are under intensive tension, and employers and stockholders are looking for a way to escape. In this situation, the main pressure evolves from the team members.

Learning Dimension (Education of Experiences) and Innovation

How can we reach the strategic goals through the internal process? Where these questions not tested before? Are they creative in their work? Does the project team continuously improve the changes in the projects products and services? In fact elements of this point of view are components of assigned goals in three other views. When goals and units of measurement related to the employer view and internal processes of a project are assigned, the gap, between needed skills, abilities for team members, and current level of these skills and abilities will appear promptly (Table 1).

Table 1 Comparison the BSC evaluation methods and EV method

<table>
<tr><th>EVM</th><th>BSC</th></tr>
<tr><td>Ignoring the effects of intangible assets</td><td>Mentioned to intangible assets such as human factor</td></tr>
<tr><td>Point out to short-term goals</td><td>Point out to strategies</td></tr>
<tr><td>Only can alert difficulties without render a solution</td><td>Appraisal with managerial analysis</td></tr>
<tr><td>Emphasize on technical systems
(technical oriented)</td><td>Emphasize on human system
(human oriented)</td></tr>
<tr><td>It is able to do some predictions but does not consider nonoccurring factor</td><td>Disability of predicting accruable items in future accuracy and completely</td></tr>
<tr><td>Scope of internal tools of analysis is added but does not help to the analysis process</td><td>Possibility of presenting direct analysis of results</td></tr>
<tr><td>With combination of cost and timing factors helps to the modification of weighting</td><td rowspan="2">Weighting, to the effective factors on project performance
(financial, customer, process, and learning)</td></tr>
<tr><td>It only operates with the two factors (costs and timing), and then it does not mention human sources and whole dimensions of project management</td></tr>
<tr><td>Value is equivalent: earning tangible value that resulted from tangible asset
(timing and costing on money and material resources)</td><td>Value is resulted from intangible asset
(human and communication)</td></tr>
</table>

Suggested Method: Project Balanced Evaluation Approach (PBE)

The BSC approach was developed as a tool for evaluating the performance of a project and specifically measuring its improvements. It concentrates on evaluation and strategy management capabilities of the project and its goals. These goals evaluate the effectiveness of a project manager in managing the available assets, toward the completion of the project. On the other hand earned value management (EVM) is a beneficial tool to understand the relationship between time limitation, budgets and important intervals of the project. Although EVM alerts difficulties to the manager and informs them of probabilities, it does not have the ability to provide solutions for the problematic issues. BSC has been developed as a strategic management tool from the beginning to the end. It seems that these two methods have some advantages and limitations. Using the two mentioned techniques and creating new mechanisms for project performance monitoring, which would be called the project balance Method, integrated project management will be easy (Fig. 1).

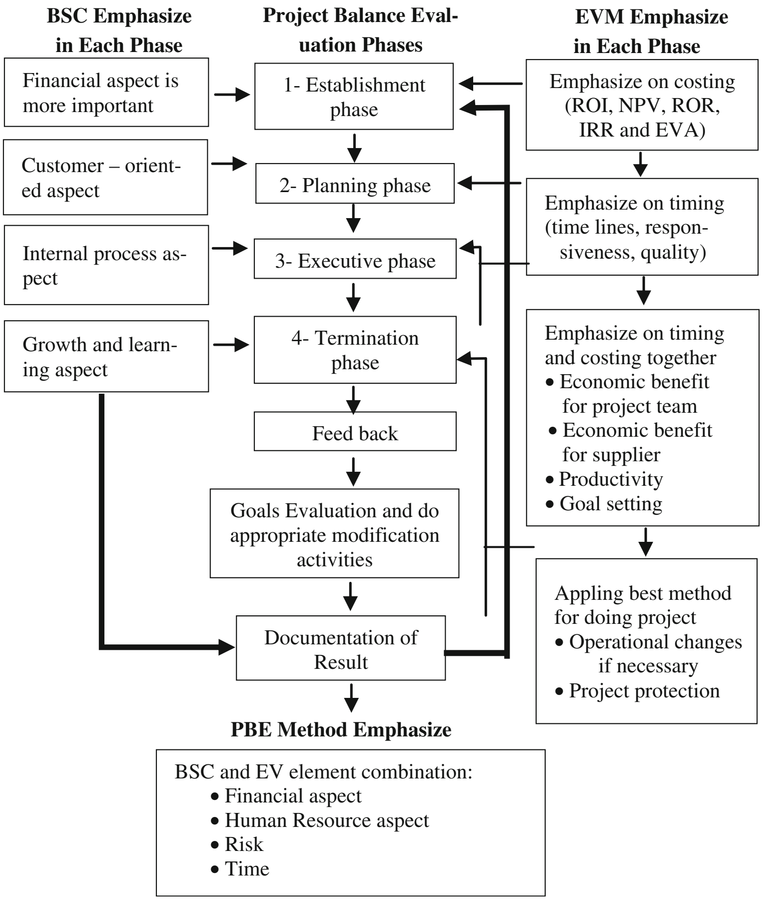

Fig. 1 Conceptual model: PBE method; Consolidation EVM and BSC method

Model Description

It is supposed that the answer of each of the questions for project views, goals, units of management, quantitative goals, and performance programs can be indicated. This way, vital factors of the project are known and no aspects would be ignored, so that the contractor tries to accomplish project goals using all facilities. The important point is that knowing critical factors of the project is not enough, these factors should lay the evaluating foundations for a better management and income amelioration. The PBE method, which integrates the two methods BSC and EV, considers short-term goals all over the phase of the life cycle of the project, strategic guidelines, technical or tangible factors, and human and intangible assets in the project evaluation, at the same time. Any way it seems that, this approach is an approximately good approach for project evaluation. With the integration of the important aspects of the two methods mentioned, project performance success managing financial, timing, human resource, and risk management will be realized.

PBE Advantages

1. Managers can use PBE to evaluate and improve their project, based on the programmed schedule, until it is successfully accomplished. Moreover PBE can be used by managers, as a tool, for communication and feedback among team members of the project, employers, and stock holders
2. For the members, PBE can introduce project operation's weak spots and finally the place of spending extra resources. It also shows sections that use the resources extravagantly. If an appropriate index of performance evaluation is designed, it can lead to a personal performance evaluation of the team members beside their relationship in public performance of the project (Solomon 2011a, b, pp. 25–28).
3. Risk evaluation would be applied in a better way, than the traditional, BSC, and EV approaches. In project management, a manager tries to guarantee achieving goals. This should happen by exerting the lowest amount of risk to the employers, stockholders, and team members. At the beginning of the project, when the complete risk analysis is done, we may be confronted with a combination of having, or not having high and low levels of financial and nonfinancial results (Barber and Miley 2002, pp. 418–423).
4. PBE method using the EV approach, which designates to cost, time, and important intervals of doing projects and considers these concepts and situations in different life cycles of a project, shows that risk evaluation should be executed through the whole project and the all the important intervals of the project, from beginning to termination. This way every possible risk in each phase will be diagnosed, analyzed, planned, followed, and controlled and an appropriate strategy, based on the situation in each phase, and will be made and applied.

Conclusion

This article is based on the premise that the management of a dynamic environment, with an undynamic tool, is impossible. Therefore attempts are made, to add the dynamism dimension to evaluation tools. In this, environment prediction tools are needed that know regions, which are potentially problematic. It is predicted that if PBE is used properly; it can be introduced as a management evaluation tool. That means the manager should regularly check the PBE while the project is running. One of the most important features of PBE is offering an easy method to understand and categorize problems in a projects life cycle. Concentrating on problems that can have the aspects of financial, customer, internal process, growth, and risk variable profile, a manager can offer a position to correct the future intentions. PBE is designed to be a tool for evaluating management programming and persuade managers to follow the occurrence of problems and their reasons, along with creating correction strategies, to remove them. Therefore PBE is more powerful than EV, which can just help managers to find problems and limited predictions. In addition this model considers time, cost, and satisfaction (internal and external human technical and human or tangible and intangible, at the same time) in all phases of the projects life cycle, so it seems that this model is more efficient for project evaluation. Therefore, it is predicted that PBE should be adapted for project management, since a manager should have a strategic approach. On the other hand, the layout of this approach differs from the layout of the organization levels. These layout differences of management signify in four dimensions including finance, time, human resources, and risk factor.

References

Barber E, Miley F (2002) Monitoring project progress. Aust J Econ 21(4):418–442

Booz AH (2003) Earned value management Tutorial. Department of Energy-USA, USA, pp 13–19

Fraily D (2007) Tutorial and earned value management system. Softw Proj Manage 75–80

Myles A, Jackson K (2006) Risk project management, feedback and learning activities. J Basic Apply Sci 3(12):1308–1316

Nouri S, Mahmoodi A, Shahriari F (2004) The principals and concepts of project planning and management. Elmo Sanat university publication, Tehran, pp 184–189

Solomon PJ (2011a) Improving the quality of EVM information. J Softw Eng 230–239

Solomon PJ (2011b) Past to EVM acquisition reform DOD AT & L 25–28

Simons R (2000) Performance measurement and control systems for implementing strategy. Prentice hall Inc, Englewood Cliffs, pp 271–287

Tewart W (2001) Balanced score card. Proj Manage J 32(1):158–167

Thomsett J (2001) A factorial approach to control the construction phase of small projects. Polytechnics Di Milano-Department of Management Economics, Milano, pp 35–41

Static Versus Dynamic Control of Material Flow in In-Plant Milk Run System

Mohammed Alnahhal, Muawia Ramadan and Bernd Noche

Abstract This paper presents a framework using analytical equations and simulation to choose the best material flow control system based on inventory cost and starvation performance. The study concentrates on in-plant milk run system and compares between traditional material flow control systems such as push and traditional kanban; and a new and more dynamic system which is an electronic kanban. A new electronic kanban system, called adjusted electronic kanban (AEK) that can utilize RFID technology has been proposed to deal with milk run trains shortages to decrease starvation of assembly lines. Simulation results showed that push system is effective when the variability in material consumption is not so high. Moreover, regular kanban is effective if there is sufficient trains' capacity, but electronic kanban gives lower inventory levels. In the case of severe trains' capacity shortages, AEK was found to be the best alternative.

Keywords Material flow · RFID · Milk run · Assembly line

Introduction

In assembly lines, forklifts are usually used to feed stations with parts and materials from a warehouse since they have the flexibility of moving the needed parts. However, they deliver relatively large amount of materials for the same station and hence need a huge space near the stations which sometimes is very scarce (Baudin 2004). Just in Time (JIT) philosophy suggests delivering small amount of materials

M. Alnahhal (✉) · M. Ramadan · B. Noche
Transport Systems and Logistics, Duisburg-Essen University, Essen, Germany
e-mail: mohammed.alnahhal@stud.uni-due.de

M. Ramadan
e-mail: muawia.ramadan@uni-due.de

B. Noche
e-mail: bernd.noche@uni-due.de

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frequently when they are needed. For this purpose, another transporter, tugger train, is more appropriate (Droste and Deuse 2011). The movement of tugger train depends on the principle of in-plant milk run systems which represent route-based, cyclic material-handling systems that are used widely to enable frequent and consistent deliveries of containerized parts on an as-needed basis from the warehouse or supermarket to multiple line-side deposit points on the factory floor (Bozer and Ciemnoczolowski 2013).

Many studies investigated static control of material flow using in-plant milk run trains based on the fact that the demand of each part at each station is previously known at the beginning of the shift (Golz et al. 2011; Emde et al. 2012; Emde and Boysen 2012). So they used push system. Other studies used kanban system to regulate the flow of materials in in-plant milk run environment (Bozer and Ciemnoczolowski 2013; Ciemnoczolowski and Bozer 2013; Faccio et al. 2013a, b). Besides using regular kanban and after the advancements in the radio frequency identification (RFID) systems, using dynamic control such as electronic kanban has become widespread in factories. In this study, we investigate determining the most appropriate type of material flow control based on the work conditions. We also investigate the use of electronic kanban and its advantages and proposed types to fit the situations of limited capacity of the train and space for the line-side inventory. The rest of the paper is categorized as literature review, push system, pull system, simulation results, and conclusion that deal about using push system and regular kanban, the push system and its limitations, the pull system, the results of simulation, and the conclusion and recommendation for future research, respectively.

Literature Review

While investigating in-plant milk run, some studies such as (Satoglu and Sahin 2012; Domingo et al. 2007; Álvarez et al. 2009) assumed using kanban system to feed the stations with parts. On the other hand, in push system, many studies concentrated on three basic decisions which are tugger train routing, scheduling, and loading. The main common decision between the two systems is loading problem in which the types and quantities of bins (containers) that are loaded in each cycle (route) of the train are determined. The loading problem was investigated in a study by (Emde et al. 2012) assuming that routing is given as input. On the other hand, (Alnahhal and Noche 2013) studied loading problem simultaneously with routing and scheduling problems. In loading problem, the capacity of the train sometimes is not enough to load all the needed bins in the current cycle (route) time. So some of the containers must be loaded in previous nonbottleneck routes, and this, however, increases the inventory holding costs. So the system must be carefully designed to reduce inventory costs.

In kanban system, in a study by Bozer and Ciemnoczolowski (2013), stability conditions were derived with respect to the capacity of the tugger, and the time utilization of the driver/material handler. They also derived the distribution of the number of containers requested per milk run, which allows the model to estimate the probability of exceeding the physical capacity of the tugger or the prescribed cycle time. In a study by Ciemnoczolowski and Bozer (2013), the number of kanban required in the milk run system was examined, and analytical approximations were derived both for the number of kanban required and for predicting workstation starvation. Faccio et al. (2013a) studied the kanban system for a decentralized inventory supermarket feeding mixed model assembly lines. They concentrated on the special attributes of such a system and they provided an innovative procedure to optimally set all decision variables related to such a feeding system. Faccio et al. (2013b) continued the work on the previous environment and performed design and simulation of this feeding system.

None of the previous studies concentrated on using electronic kanban to regulate material flow through milk run train or the conditions for which it is wise to use it instead of regular kanban or push system. So this study investigates the conditions that are more suitable for each of the three systems. These conditions are mainly related to the capacity shortages in trains and stations' line-side space for inventory, and also the degree of variability in parts consumption.

Push System

Push system depends on the previous knowledge of the demand of stations. Using simulation, push system was found to be not stable regarding line-side inventory. To explain that, suppose that there is a route for a train serving a certain station every 40 min and the bin capacity is 30 parts, and suppose that the station demand of parts is represented by time between demand arrivals (TBDA) which is deterministic with value of 1 min. For a zero starvation of the station, the bin demand will follow a pattern that is very close to (2, 1, 1, 2, 1, 1 …). The calculations for that are shown in Table 1 for the first six train routes.

If TBDA is random, the same previous pattern can be used to represent the average demand of bins, and this was done by Bozer and Ciemnoczolowski (2013). Using such a pattern in push system causes sometimes line-side inventory to increase severely with time, because this pattern ignores the variability in demand. Figure 1 shows the effect of using the pattern on the size of line-side inventory.

Table 1 Example bins demand per route

Train route	1	2	3	4	5	6
Accumulated demand of parts	40	80	120	160	200	240
Accumulated demand of bins	2	3	4	6	7	8
Bins demand	2	1	1	2	1	1

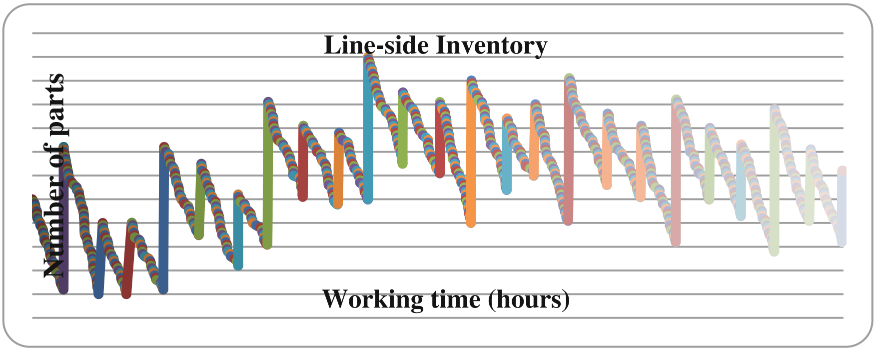

Fig. 1 Performance of push system when parts consumption variance is high

TBDA was assumed to follow exponential distribution. The time from warehouse to the station was assumed to follow a normal distribution, norm (10, 2) minutes. The initial line-side inventory was assumed to be 40 parts to cover the demand until the train comes for the first time which was assumed to be after 40 min of the beginning of shift. As it is obvious in the figure, starvation of the station is variable over time. For example, starvation is zero after the second hour.

Generally, the higher the variability in demand, the higher the maximum line-side inventory (MLSI) is. Suppose that the average and standard deviation of TBDA are μ and σ, respectively, the average and standard deviation of arrival rate are λ and ρ where $\mu = 1/\lambda$, and the working time in minutes during the day and starvation probability are ω and δ, respectively. Given ρ, we want the standard deviation of the total number of demanded parts (consumption) during the day, ρ_T, multiplied by a factor z (could be 3) not to exceed one bin capacity, B, for example. Based on the famous central limit theorem, the total number of demanded parts during the day can be represented by normal distribution. Because of starvation effect, average and standard deviation of the total number of demanded parts are $\omega(1-\delta)/\mu$ and $\sqrt{(\omega(1-\delta)/\mu)}\rho$, respectively. The value of ρ can be determined based on restriction (1) from which we conclude that increasing starvation will increase the possibility of stability.

$$\rho \leq \frac{B}{z\sqrt{\omega(1-\delta)}}\sqrt{\mu} \tag{1}$$

If the TBDA is normally distributed, then ρ, which is in this case the standard deviation of the inverse of normally distributed random variable, needs to be computed. Generally, if the random variable X is normally distributed, the random variable Y, where $Y = 1/X$, was found to follow lognormal distribution for which the normal distribution has average of ln $(1/\mu)$ and standard deviation of σ/μ. Generally, the lognormal distribution has variance as in Eq. (2)

$$\sigma_l^2 = \left(e^{\sigma_n^2} - 1\right)e^{2\mu + \sigma_n^2} \tag{2}$$

where σ_l and σ_n are lognormal and normal distribution standard deviations, respectively. In our case, the variance of lognormal distribution can be defined using Eq. (3). Then using restriction (1), we can test the stability of the system.

$$\rho^2 = \left(e^{\left(\frac{\sigma}{\mu}\right)^2} - 1\right)e^{2\ln\left(\frac{1}{\mu}\right) + \left(\frac{\sigma}{\mu}\right)^2} \tag{3}$$

The initial inventory (I) should coincide with the starvation level. Assuming we have the period (P) until the starting of the first train movement from the warehouse and assuming that s_i which is the time needed to reach the station i from the warehouse is fixed, initial inventory must be as in Eq. (4)

$$I = \lambda(P + s_i) + z_\delta\sqrt{P + s_i} \tag{4}$$

where z_δ represents the service level corresponding to the starvation probability δ. To guarantee that the train will not be required to supply number of bins that is more than train capacity, K, loading problem introduced in the study by Emde et al. (2012) can be used. During that, when total number of bins is higher than K, some bins are loaded before they are actually needed in nonbottleneck routes.

Pull System

If the variance of TBDA is low, push system can be used. However, if that variance is relatively high, kanban system is the best candidate. The problem of regular kanban system is that in some routes the total number of kanban (number of bins) is more than the capacity of the train. Suppose that we have five stations as a part of the route of the train. Each station has a demand of 1 or 2 bins during the cycle time, C, as in the previous example. In this case, the total number of needed bins is fluctuating over time from 5 to 10. But what if the capacity of the train is just 7 bins for example? In a study by Ciemnoczolowski and Bozer (2013), it is assumed that if the capacity is not enough for some periods, the kanban for the first stations should be satisfied, and the rest of kanban will have the priority in the next cycle. This strategy was found to be accepted if the average of demand is less than or equal to K. However, if this average is higher than K, then a new strategy will be needed. But even in the first case, the starvation probabilities of the stations at the end of the train route are a little bit higher than others.

Another strategy to send the signal of parts consumption dynamically to the warehouse is using electronic signals. Because in electronic kanban system, signals containing demand information are sent until the last possible moment, it decreases the MLSI because the uncertainty period in the system is decreased. In regular, kanban there is no way to send demand information to the warehouse except when the train arrives at the station and then arrives at the warehouse. The advantage of using electronic kanban will be obvious for stations with small s_i values. However, if this value is close to C, electronic and regular kanban systems will be almost the same. Increasing MLSI with increasing s_i value representing the distance (in time units) from warehouse to station can be explained due to increasing the time period between consuming a part and reaching the compensating part from the warehouse to that station.

Another aspect to consider is the initial inventory near every station. As will be seen later, it was found using simulation that initial inventory should be not only full bins but also some parts plus the full bins to decrease MLSI. The electronic signal should go to the warehouse when the consumed parts equal the bin capacity. For example, suppose that $B = 30$ parts and $I = 45$ parts. The signal must be sent when the station consumes the first part and also the 31st part in the line-side inventory (16th part in the bin). To do so, in electronic kanban, we may use RFID tag with each part. Another cheaper strategy is to estimate the part consumption. So the tag is only for the container and the time of the 16th part is estimated based on the average consumption rate. We will call the first system as *part-based electronic kanban*, and the second one *time-based electronic kanban*. For the previous example if the full bin is consumed in about 30 min, the signal is sent to the warehouse 15 min after consuming the first part in the bin. This system increases MLSI just a little bit more than that for *part-based electronic kanban*. In regular kanban system it is not easy to use parts plus full bins in initial inventory.

As found using simulation, there are several factors affecting MLSI which are:

- Type of material flow control: regular kanban causes higher levels of MLSI than that for electronic kanban
- Station position (in electronic kanban): the longer the distance (in time unit) between the warehouse and the station, the higher the MLSI
- Electronic kanban type: time-based electronic kanban causes higher levels of MLSI than that for part-based electronic kanban.
- Bin capacity: larger bin capacities causes larger MLSI
- Material demand: larger demand causes larger MLSI.

The ideal situation for the minimum possible level of MLSI is when part-based electronic kanban is applied for a station that is very close to the warehouse when the bin capacity is one and assuming unlimited capacity of the train. In this case the MLSI which appears each time the train arrives at the station is the same for all the routes for the same station. This is because any consumption in the material will be compensated exactly in the next time the train arrives at the station. So in this case, utilization ($U = 1 - \delta$) for the station can be estimated using Eq. (5) assuming that arrival rate of parts demand follows Poisson distribution.

$$U = \frac{C - \sum_{i=1}^{\infty} \frac{iC}{MLSI + i} f\left(MLSI + i, \frac{C}{\mu}\right)}{C} \tag{5}$$

where $f(k, \lambda) = P(X = k)$ is the probability mass function (pmf). The term C/μ represents the average demand during the cycle if $\delta = 0$. The term $C/(\text{MLSI} + i)$ represents the real average of TBDA in a cycle in which the number of demand arrivals is more than MLSI. Equation (5) uses very simple logic: finding the probability that the actual demand is more than MLSI by i parts multiplied by the time these i parts take. This value is then summed over all possible values of i. The summation represents average time of starvation per cycle. Only the first few values of i are important because the probability of having MLSI + i will almost be zero when i is large. Further research can concentrate on finding MLSI in not ideal situations for which, in this study, results were obtained based on simulation.

Adjusted Electronic Kanban (AEK)

As in regular kanban, the system of regular electronic kanban works fine when the average demand of stations during the shift is less than the train capacity; however, if the average demand is higher than the train capacity, we need a new system which is AEK assuming using normal levels of initial inventory. The problem of this shortage of capacity can be because of trains failure or any other causes. As in regular electronic kanban, parts-based or time-based signals can be used.

In this system, the signal sent to the warehouse contains an additional piece of information which is the time of the signal. The first K signals are satisfied by the next route of the train. Other signals are kept until the second next route of the train where these signals have the priority to be satisfied in that route. So the principle first come, first served (FCFS) is used. On the ground, to facilitate using AEK, electronic boards can be used to show for the material handler only the needed bins in the current route for each station. Even in the case that the capacity of the train is greater than or equal to the demand of all the stations served by the same train, this technique is better than regular electronic kanban, since it distributes the starvation on all the stations with the same percentage.

The advantage of using AEK will be more obvious when the capacity of the train is lower than the average parts demand. Assuming that the setting of AEK is set to have equal utilization probabilities among the stations, this utilization can be estimated using Eq. (6), where N is the number of stations. This can be done using time-based AEK with small deviation from the original one. Thus it is not necessary for the signal to be sent to warehouse after the estimated time of parts consumption as explained before. Actually this time can be adjusted to get the equal utilization probabilities for all the stations. We call that *time-adjusted electronic kanban*. The initial inventory levels can also be altered from those levels in the original AEK.

In this study, times were adjusted using simulation. Future research can concentrate on how to exactly determine these times of the signals.

$$U = \frac{KB\mu}{NC} \tag{6}$$

Simulation and Results

Simulation was performed using Promodel Software. At first, we check using simulation the performance of time-based AEK system in the case that the K value is equal to or higher than the average demand but lower than the maximum demand, and compare it to the normal electronic kanban in its ideal situation (unlimited train capacity and using part-based electronic kanban). Then we compare these two systems to regular kanban assuming unlimited train capacities. The two cases are investigated for a starvation level of 3 ± 0.5 %. To get this level of utilization, several trials with different starting inventory levels were tried until the appropriate one was found. Simulation was done for the following scenarios:

- TBDA: Exp (1) min, Exp (3) min, Exp (7.5) min
- B: 0.25, 0.5, 0.75 of cycle average demand
- C: 30 min, 45 min, 60 min.

The number of trials was 20 and the simulation time was 40 h. The average values were obtained. The cycle time was divided by 5 and the stations were assumed to be in the middle of these five periods. For example, if the cycle time is 60 min, the five stations will have $s_1 = 6$, $s_2 = 18$, $s_3 = 30$, $s_4 = 42$, and $s_5 = 54$ min. K value for each one of the 27 scenarios was chosen to be equal to average demand of the train rounded to the upper integer number. Besides these 27 scenarios, other scenarios were performed assuming that the initial inventory can only be full bins. Results showed that, in full bin scenarios, MLSI is about 20.4 % higher than that for normal scenarios in the case of using electronic kanban.

Results showed that the increases in MLSI (in parts unit) because of considering the limited capacity of the train using AEK were from 0 to 2.86 %. This shows that if K is greater than or equal to average demand but lower than maximum demand, it cannot make any severe problem in the increase of MLSI if AEK is used. Results for normal electronic kanban also showed that the average increases in MLSI from station 1 to 2, to 3, to 4, and to 5 were 6.2, 4.7, 2.6, and 3.1 %, respectively, because of the increases in s_j values. For AEK, these percentages were 5.5, 4.1, 2.9, and 2.6 %. This shows that the longer the distance from the warehouse, the higher the MLSI is. This means that in the case of using electronic kanban, the stations with small space for line-side inventory should be at the beginning of the route. On the other hand, regular kanban has stable performance, and the differences among stations are just because of the randomness effect. Generally, the performance of AEK was found to be better than regular kanban even if we assume unlimited train capacity in regular kanban and limited capacity in AEK and even if we assume using parts plus full bins in initial inventory for the two systems. Results showed that, on average, the increases in MLSI from using AEK to regular kanban for the same station are 22.2, 13.3, 7, 2.8 %, and 0 for stations 1, 2, 3, 4, and 5, respectively. In the case of unlimited capacity in electronic kanban, these percentages are 29.8, 19.3, 11.2, 7, and 2.5 %.

The effect of increasing the bin capacity was obvious in the results. On average, increasing bin capacity from 0.25 to 0.5 of the cycle average demand increased MLSI by 11.1 % for normal electronic kanban and by 9.2 % for AEK. Increasing the bin capacity from 0.5 to 0.75 of the demand increased MLSI by 9.2 % for electronic kanban and 8.5 % for AEK. This shows that decreasing bin capacity is advantageous regarding inventory level.

Another way to check the effect of using AEK under condition in which K is less than the maximum demand and greater than or equal to average demand during the cycle is by trying to keep the initial inventory levels as in normal electronic kanban, and then measure the increase in starvation. The average values for each scenario were computed. The minimum one was 0.36 % and the maximum one was 1.4 %. For individual stations, the increases were from 0 to 3.15 %. So the effect is very small. This is because any shortage in a station inventory will most probably be compensated in the next route where the stations with the unsatisfied demand have the priority to be satisfied in that next route.

In the case that K is less than the average demand of the stations, regular kanban performance is deteriorated. The utilization levels of the stations were found in the case in which $C = 60$, $\mu = 3$, $B = 15$, and $K = 6$ (less than the average demand) 96.00, 95.62, 94.47, 83.63, and 77.68 % for the stations from 1 to 5, respectively. If these stations belong to the same assembly line, the utilization of this assembly line is based on the lowest one which is 77.68 %. So it will be better if these stations have the same average utilization to increase the utilization of the assembly line. In the previous example, utilization probabilities for the five stations in time-adjusted electronic kanban were around 90 % which is the same result found from Eq. (6). Theoretically, regular kanban can achieve the same results if we use parts plus full bins in initial inventory and if we set initial inventory levels to the right values, but this is not easy in the practice because in this case kanban must be put in kanban post when a certain part in the bin is consumed.

Conclusion

In this study, we differentiate between push and pull systems for material flow using milk run trains. In pull system, we investigate using regular kanban, electronic kanban, and AEK. Push system was found to be effective if the variance of parts consumption is not high. On the other hand, regular kanban was found to be effective if there is sufficient train capacity. Based on its line-side inventory performance, electronic kanban is the best choice even if there is sufficient train capacity. In the case of problems in train capacity, AEK is the best choice. These results were obtained analytically and based on simulation. This study presents for the first time such comparison between these material flow control systems. Future research can investigate analytically the difference between regular kanban and electronic kanban based on their line-side inventory performance.

References

Alnahhal M, Noche B (2013) Efficient material flow in mixed model assembly lines. SpringerPlus 2(1):1–12

Álvarez R, Calvo R, Peña MM, Domingo R (2009) Redesigning an assembly line through lean manufacturing tools. Int J Adv Manuf Technol 43:949–958

Baudin M (2004) Lean logistics: the nuts and bolts of delivering materials and goods. Productivity Press, New York

Bozer Y, Ciemnoczolowski D (2013) Performance evaluation of small-batch container delivery systems used in lean manufacturing—Part 1: system stability and distribution of container starts. Int J Prod Res 51(2):555–567

Ciemnoczolowski D, Bozer Y (2013) Performance evaluation of small-batch container delivery systems used in lean manufacturing—Part 2: number of Kanban and workstation starvation. Int J Prod Res 51(2):568–581

Domingo R, Alvarez R, Peña MM, Calvo R (2007) Materials flow improvement in a lean assembly line: a case study. Assembly Autom 27:141–147

Droste M, Deuse J (2011) A planning approach for in-plant milk run processes to optimize material provision in assembly systems. In: Proceedings of the 4th International conference on changeable, agile, reconfigurable and virtual production (CARV2011), Montreal

Emde S, Boysen N (2012) Optimally routing and scheduling tow trains for JIT supply of mixed-model assembly lines. Eur J Oper Res 217:287–299

Emde S, Fliedner M, Boysen N (2012) Optimally loading tow trains for JIT-supply of mixed-model assembly lines. IIE Trans 44:121–135

Faccio M, Gamberi M, Persona A (2013a) Kanban number optimization in a supermarket warehouse feeding a mixed-model assembly system. Int J Prod Res 51(10):2997–3017

Faccio M, Gamberi M, Persona A, Regattieri A, Sgarbossa F (2013b) Design and simulation of assembly line feeding systems in the automotive sector using supermarket, kanbans and tow trains: a general framework. J Manag Control 24(2):187–208

Golz J, Gujjula R, Günther H-O, Rinderer S, Ziegler M (2011) Part feeding at high-variant mixed-model assembly lines. Flex Serv Manuf J 24:119–141

Satoglu SI, Sahin IE (2012) Design of a just-in-time periodic material supply system for the assembly lines and an application in electronics industry. Int J Adv Manuf Technol. doi:10.1007/s00170-012-4171-7

Resource of Genius Loci in Tourism

Galina Sergeevna Sologubova

Abstract The subject of the report is substantiation of the definition "Destination" in terms of pseudo-touristic space and the use of the coordinate model, the equilibrium model of the center of mass, the method of the optimization of the objective function, and the method of relative preference to define the expected (cost-effective) geographical location of the tourist center with distinctive meanings of "heritage."

Keywords Destination · Pseudo-touristic space · The equilibrium model of the center of mass · Coordinate's model · The method of relative preference

The Author's Idea

The choice of location is a strategically important task—to ensure an efficient life activity, including effectiveness of economic management. The obvious multicriteriality of the choice of a place (costs, risks, demand satisfaction, profit, environmental damage), however, is reduced to the priority of such condition, as is the speed of response. The number of investments in major projects of territories development indicates a trend of business dependence on the breadth of the territorial coverage, ensuring the timely and quick delivery of any proposal. The increase in the number of infrastructure of distributed centers exponentially reduces the response time. That means the creation of new centers is advisable; therefore, necessary to ensure the economic efficiency of this process.

The idea of the author is to offer the development of tourist destinations adulterated meanings in the territories which not necessarily have to have valuable recreational resources or are historically established routes of people and ideas

G.S. Sologubova (✉)
Economy and Management in Tourism, St. Petersburg State University of Economics, Saint Petersburg, Russia
e-mail: en-consalt@mail.ru

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movement, but belongs to the new intersection of these flows or, on the contrary, neglected, abandoned, littered with garbage, uninhabited, remote, and deaf towns. There is a need to choose the place and determine the number of potential centers of tourist interest and to compare and select the best option of dislocation. The solution must meet the limitations and requirements of the law of demand and supply, economic efficiency, balance of power recreational resource, infrastructure in the host destination, and potential demand.

For substantiation of economic efficiency of choice dislocation of a new tourist destination, econometrics offer the coordinate model, equilibrium model of the center of mass, the method of the optimization of the objective function, and the method of relative preferences. Calculation algorithm is simple and intuitive. The reliability of mathematical results is confirmed by the historicity of the choice of place of the genius loci, a famous ancient good spirit, linking the intellectual, spiritual, and emotional phenomena with their material environment.

Approaches to the Choice of Location

Administrative maps demonstrate fields' influence of cities on the surrounding territories. The boundaries of identified areas subject landscape heterogeneity, the beds of the rivers and the coastal lines of the seas, the historically established relations and trade routes.

Ideal distribution of fields of influence (Voronoi diagrams, 1850) to bind to geographically dispersed customers to service centers can be achieved, if the road network does not play a large value, such as mobile cellular operators. In the case of a dense road network, its heterogeneity can be neglected, constituting private algorithms Voronoi diagrams. The actual distribution of the field of influence of cities depends on the resistance of the environmental movement of flows (material, informational, financial, flows of people, services, knowledge).

The idea of the field of influence found an interesting continuation with respect to the problem of search of the optimal position of the objects in the supply chain. According to the physical analogy, each of the cities is the center of attraction and has a certain weight (consumer potential). In the models of commercial attraction based on the gravitational analogy, the tasks use zoning consumers and their subsequent fixing of the trading point.

Model Reilly (1929) used two points of attraction for the problem of zoning the market. The Reilly's model laid the assumption that the demand for goods and services is directly proportional to the number of population in the city and is inversely proportional to the square of the distance from the consumer to the city.

In the Christaller model (1933), the role of the city is interpreted as a place of centralized supply of goods and services of the surrounding countryside (villages and other towns). The scale of the city—the center of effectively organized trade, according to Christaller is determined by four factors: (1) the level of economic development, (2) the number of working-age population, (3) the economic distance, determined by transport availability and cost, and (4) the frequency of shopping, determined by the importance and closeness.

The Huff model (Huff retail, 1963) defines the search of the perfect position through many pre-set locations, taking into account the costs in time and money of the consumer on the road to trading points, proportional to the distance and speed of the delivery. To solve this optimization problem, two methods of calculating distances are used: (1) along the shortest path between two points on the plane (Euclidean distance); and (2) the streets of the city with rectangular quarters (Manhattan distance).

An alternative gravity model is the approach, in which the optimal location for center of gravity corresponds to the point that minimizes the value of multiplication of the mass of the transported cargoes on distance of transportation (task Weber, 1903). Based on this approach, the Chopra' model (Chopra, 2000) as a criterion for decision, uses the criterion of minimizing the total costs in the supply chain. Chopra distributed total costs by categories: vehicles, real estate, stocks, and personnel.

The method of balance of costs (1) correlated with the method of balance of moments (2).

$$L_1 \cdot C_L + \frac{L_1 \cdot C_t}{v_1} = L_2 \cdot C_L + \frac{L_2 \cdot C_t}{v_2} \tag{1}$$

Table 1 The designations that identify criteria of efficiency of a tourist's destination dislocation

The name of the criterion	Designation, identifier of Z
Number of planned arrivals	p (pers.)
The population of the regions suppliers	N (thous. pers.)
Attractiveness (expert preference)	U (score)
The distance to the point of destination	L (km)
Loading thoroughfares//transport support	$G = pL$ (pers. km)
The duration of the journey//speed of transportation	$t = L/v$ (h)
The costs of the tourist transport services	$S = C_L L + C_t L/v$ (rub.)
The costs of transportation	$S_1 = C_L L$ (rub.)
The costs of the work of transport vehicles	$S_2 = C_g G$ (rub.)
The costs associated with time in the way	$S_3 = C_t t$ (rub.)
The income for one person of the population in the location of suppliers or specific solvent demand	q (rub./pers.)
Turnover of goods in the places of dislocation of tourist destinations	$Q = q N_i$, (rub.)
The capacity of the tourism infrastructure of the settlement	A (number of beds in the collective accommodation)
The throughput of the railway stations and ports (passenger traffic)	R (people per hour)

Where C_L unit transport costs—tariff for transportation (rub./km), C_g specific costs for operation and maintenance of vehicles (rub./h); C_t unit value of time in transit (rub./h)

$$\frac{N_1 \cdot q_1}{S_1^2} = \frac{N_2 \cdot q_2}{S_2^2} \quad (2)$$

Thus, using economic metrics (Table 1) in the gravitational analogy, it is possible to make up the equations of the balance at the point of "indifference" and calculate an equilibrium coefficient, which characterizes the business situation, to model scenarios of optimizing space (Zaitsev 2011).

The methods mentioned above can visualize an approach, oriented on a system of restrictions, which is exclusively economic in nature. In reality, there is objective landscape, social, environmental, and other restrictions that reduce the number of iterations—for n possible points determined, there are 2^{n-1} geographic configurations (Malyarenko 2010).

Approaches to the Definition of Tourist Space—Destination

Tourist space is considered as a part of the geographical environment in the aggregate of natural and anthropogenic elements and their interconnections, which formed the real solvent demand and a system offering a variety of services for tourist consumption.

Structuring of the tourist area includes a selection of not only individual tourist-recreational areas, but also of individual subjects of the tourist market as centers of demand. The territorial-spatial division is carried out not on the basis of geographical zoning, but on the basis of a concentration and specialization of tourist services (Dergachoff 2003).

The territorial-spatial boundaries are formed under the influence of the economic laws of supply and demand, as a result of the number of partial geographic overlay markets of recreational territories, the coincidence of the centers of donor investments, regions of the labor-supplying. The cores of such geoeconomic systems become a destination (Fig. 1).

Tourist-recreation centers and destinations are (1) the places of residence of the population, which is engaged in various sectors of the economy and (2) economic

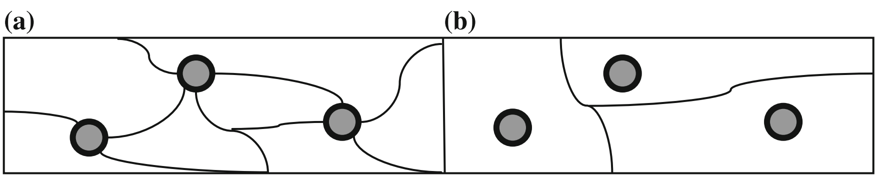

Fig. 1 **a** The administrative approach—the core of the geoeconomics system is a recreational area, forming around the tourist-recreational system. **b** The approach on the basis of scientific criteria of recreational geography and economic mechanisms of the formation of supply and demand—the core of the geoeconomics system is the destination

centers or regions, around spaces that depend on them economically and administratively.

Their spatial system that was formed historically, on the map is displayed as the network of industry centers, corresponding transport communications. The subordinated spaces represent economic areas as a result of the zoning allocated recreational zones, which form the tourist-recreational system around economic centers. The recipient regions and their cores turn into tourist destinations.

The axiological nature of constant "destination" is disclosed in the heritage (Zorin 2000). Exactly, the heritage is a semantic side of tourism. Meanings are formed in space and time, i.e., they possess the properties of historicity and location: the future, the present, and the past through the stratums of the ability of a person to the perception of the environment—consciousness, knowledge, memory, opinions, wishes, hopes. Subjectivity of perception determines the scope and content of space: the pseudo-illusory; quasi-imaginary; personal-comfortable, secluded; virtual–unreal reality. Man's perception gives the destination false ideas —inventions. Fiction becomes subject to demand, substituting the traditional meanings of natural-climatic and cultural and historical heritages. The heritage of the fictional space focuses the attention of the traveler to: (1) landscape (the appearance of the country, the object—the memorial of nature, man-made monument) and (2) the game (simulation of processes with replacement of elements on the axis of time); (3) the theme (functional objectivity).

The active development of thematic tourism, which specializes in the materialization of adulterated meanings and the events, is the tendency of the last years.

Not a historical city or natural and geographical attractions determine the spatial selectivity of the tourist flows, although they are often used as territorial anchors, and the newly created objects, to meet the demands of the modern consumer— planetariums, water parks, Lego City, the country of Santa Claus, shopping and entertainment venues become the centers of tourism demand—destinations.

Good Relations with Genius Loci

Planning and design of new destinations is carried out on the basis of an assessment of a complex of factors: the tourist potential of the region, the level of competition in it, the investment climate, administrative support, socio-demographic characteristics, etc.

Initiation of destination with the adulterated meanings imply, above other things, the selection of the best locations from the point of view of tourists and the investors' and minor advantageous positions in the real geographical space.

Good relations with the genius loci—the genius of the place are a combination of common sense, observation, intuition, and mathematical standard perception of space. That is why, when choosing the location of the thematic (false sense) destinations, the greatest attention is paid to the issues of transport accessibility, including price, and distance from regional centers—potential donors of tourist flow.

The lower the total costs, the higher the economic result of tourist business. And therefore, the option of choice will be effective.

In practice, the design of tourist destinations is dominated by decisions and tasks from the marketing point of view (surveys, financial-economic and comparative analyses). The verbal and heuristic character of the models is in a high degree subjective and focused on statistical reports—information of the past periods. Application of simulation of coordinate models, based on GIS technologies, allows substantiating the multicriteria, the different measures (Table 1) selecting the location of the point of destination on the map and providing a greater objectivity of the project solution.

Modern econometrics offers several ways for a solution of such tasks: (1) coordinate model—positioning; (2) the model of choice for the costs; and (3) multicriteria model, taking into account factors of preference.

The diversity of conditions of economic activities in tourism and objectives of the niche optimization allow us to use the entire arsenal of modern science to substantiate and make the best possible decisions.

For example, a coordinate model can be used to define not only the optimal location of the object of tourism demand, but also a number of attractive facilities and their capacity. The model of choice for the costs is applicable to the problems of alternatives evaluating. In conditions of uncertainty and the multifactor nature of its decision-making, it is simple enough and effective, to use the method of relative preferences.

An Example of Task Solving Selection

The task: substantiate the location of Kamyshin city, Volgograd region as optimal for organization of tourist destination on the territory of the Russian Federation, including Saratov, Voronezh, Volgograd, and Astrakhan region. Prospective concepts of destination are: (1) environmental, ecological space; (2) adulterated meanings; (3) recreation; and (4) yacht tourism.

The solution of the problem involves three stages. The first stage includes analysis of the tourism potential of the selected region and the city of Kamyshin, the methods used are positioning on the plane, center of mass, and optimization effectiveness.

As a result of zoning of the territory and identification of the settlements with the assessment of the number (**N**) and the solvency of the population (**q**) in each of **n** possible points. Terms of selection of settlements are: (1) the presence of the route, (2) the journey time is not more than 8 h, (3) the population over 100,000 people. The population in Kamyshin city is 128,000 people. The share of income of the population by 2012 amounted to 18,000 rubles.

Location of the settlements on the plane is determined by the method of combining maps with grid coordinates.

The coordinates of the settlements (X_i, Y_i), the income and population (q_i, N_i), respectively, are the source data for compiling the balance equation by the method of the center of mass, the economic meaning to determine the equilibrium of the system of costs of tourists from different cities, which are the suppliers of solvent demand for tourist products of Kamyshin city.

From the balance equations of optimal coordinates of the destination can be calculated by the formulas (3).

$$X_D = \frac{\sum_i^n Z_i \cdot X_i}{\sum_i^n Z_i}, Y_D = \frac{\sum_i^n Z_i \cdot Y_i}{\sum_i^n Z_i} \quad (3)$$

where Z_i is a criterion of efficiency of the decisions, connected with the distance from the destination to the ith settlement (L_i), time in a way (t_i) and costs to travel (S_i). The demand for tourism services is directly proportional to the population size and its solvency and it is inversely proportional to the square of the distance that tourists need to overcome and the costs associated with transportation and time in the way of (4).

$$Z_i = \frac{\sum N_i \cdot q_i}{L_i^2 \cdot S_i} \quad (4)$$

where N_i—is the number of the population of the city—the supplier of tourist flow;

q_i—average per capita income of the city supplier of tourist flow;

$L_i = \sqrt{(X_D - X_i)^2 + (Y_D - Y_i)^2}$—it is the distance from the destination to the ith of the settlement;

$S_i = C_{\text{tariff}} \cdot L_i + t_{\text{inway}} \cdot C_{\text{tourist}}$—tourist cost related to the payment of the transport services and costs in a way.

According to calculations, the optimal location of the tourist destination has the following coordinates on the X-axis = 103.07; on the axis Y = 203.05. The coordinates of the city of Kamyshin in the diagram correspond to the values on the X-axis = 120; on the axis Y = 165. Deviations in the values of coordinates determine the area equal to 22 km and the travel time of 40 min. The nearest settlement, corresponding to the calculated coordinates,—Petrov Val, the population of 12,000 people, the average per capita income is 15,000 rubles a month, that does not satisfy the system limitation of decision-making.

The introduced restrictions system requires the balance of potential consumer demand and capacity of the local infrastructure for tourists' reception. Calculating result of the potential tourism demand in 11 cities of the selected regions of the Russian Federation outlined the probable number of arrivals to 1,410,732 people a year, which will draw 23,927,140 rubles into the economy of the city. Analysis of recreational resources and infrastructure potential of the city of Kamyshin showed compliance to demand for tourist services. According to the economic meaning of the balance equations of moments, the location of Kamyshin is best for the development of tourist destination, receiving tourist's flow from the territories of Voronezh, Saratov, Volgograd, and Astrakhan regions.

The second stage considers alternative solutions dislocation of a tourist destination in the indicated region: the placement of not one, but **m** tourist destinations, formation of optimal distribution of the demand for tourist products or designing tourist routes with the transit destinations (2 or more intermediate center of tourist interest). The task was solved in the framework of the coordinate model of objects disposition and optimization of the objective function—minimization of expenditures of a tourist (5).

$$S_{\Sigma} = S_1 + S_2 + S_3 \rightarrow \min \tag{5}$$

The tourist' costs represent the sum of costs: S_1—to travel from the town to the transit destination (6), S_2—the travel from the transit destination to the target one (7) and S_3—to stay in transit destination (8).

$$S_1 = \sum_{1}^{n} L_{ij} \cdot C_{\text{tariff}(i)} + C_{\text{touristcostinway}} \cdot t_{ij} \tag{6}$$

$$S_2 = \sum_{1}^{m} L_{DjDj+1} \cdot C_{\text{tariff}(Dj)} + C_{\text{touristcostinway}} \cdot t_{DjDj+1} \tag{7}$$

$$S_3 = \sum\nolimits_1^n C_{tourist\ cost\ per\ day(j)} \cdot Д \tag{8}$$

where *Д* - the number of days of stay.

The second stage determines the number, capacity and location of centers of tourist demand. Coordinate tags correlate with the location of the cities Saratov, Kamyshin and Volgograd, which can be considered as objects of tourist demand in the real-time mode, i.e., they already possess attractors and infrastructure.

Resulting from the analysis and calculation of the objective function information on the geoeconomic condition of the territory can be used for its development. For example, design of the infrastructure system of service of tourists: camping, motels, gas and motor-car repair stations, mobile points of food and beverages, trade centers, fairs, etc.

Taking into account the experience of geomarketing technologies and using the values of the real coordinates of the existing cities, we can continue problem solution of the demand's distribution and the routes' design.

At the third stage, applying the method of relative preferences, choose a specific place for the organization of a new tourist destination: from **m** possible variants of the decision on the basis of **n** factors influencing the choice (Tables 2, 3).

Comparing pairs of variants of decisions on each of the factors and recording these comparisons in the form of preference relations we obtain **n** matrices (B_1, B_2, B_3) of order **m** (number of factors) and **n** weight vectors $G_k = \{g_{ki}\}$ that forms the aggregate weight matrix of solutions $U = (G_1, G_2, G_3)$ (Table 4).

The final solution of the problem of choice is a vector of weight options ***V***, defined as the product of matrices (9)

Table 2 Analysis of factors influencing on the choice of location

Factors	Designation	Dimension	Inverse value	Significance
The cost	X_1	Thous. rubles	$1/X_1$	5
State and prospects	X_2	Score	X_2	7
The tourist resource	X_3	Score	X_3	8

Table 3 Initial data for calculation by the method of relative preferences

Option selection	X_1	X_2	X_3
Jirnovsk	6078.35	2	2
Kamyshin	5820.15	3	3
Nikolaevsk	6938.1	1	3

Table 4 Aggregation matrix, the final decision

United matrix U scales options factors B_1–B_3					
Weight, g_1	Weight, g_2	Weight, g_3	Weight, g_0	City	Solution
Options	Options	Options	Factors		$V = U \times g_0$
0.34	0.33	0.25	0.25	Jirnovsk	0.30
0.36	0.5	0.38	0.35	Kamyshin	0.42
0.3	0.17	0.38	0.4	Nikolaevsk	0.29

$$V = U \times G \tag{9}$$

The greatest value of $R = \max(v_1, v_2, v_3)$ corresponds to the best variant of the decision (in the sense of preferences under uncertainty). In this example, the maximum value of preferences corresponds with Kamyshin city.

Conclusion

The genius loci = Intuition + Observation + Mathematical Standard perception of space + Common sense

Intuition: 1569 year—an attempt to combine the Volga river with the Don of the Turkish Sultan Selim; 1697 connection of 5 seas according to the plan of Peter the great; 1942—the construction of the Volga belt road to supply the troops that participated in the battle of Stalingrad.

Observation: the analysis of the landscape in Kamyshin town, as an object of heritage and recreational resource, revealed a significant number of paleobotanical, geomorphologic, geological monuments. Among them are mountain Ears, Stolbiches, Karavaies (loaves)—huge round (in diameter they reach 4–6 m) boulders, ravines and beams—beds of ancient rivers. The unique lake Elton, spring river

Ilovlya, Medveditsa, Kamyshinka, freshwater keys are unique balneological resource destination (Baranov 1952). Recreational potential of the river Volga is not restricted to water rides, a pronounced continental climate provides an always hot, dry summer, which contributes to the development of beach rest and medical tourism with the readings of the lung, skin, neurological pathologies.

Mathematical standard perception of space: the coordinates of the optimal location correspond to the locality Petrov Val (22 km North of Kamyshin); the number of tourist arrivals may be 1,410,732 people a year, that will draw 23,927,140 rubles into the economy of the city; the adequacy of resource destination Kamyshin introduced a system of restrictions (the aggregate room Fund with deficit and the total passenger traffic of all transport dominants with excess); the dislocation of Saratov and Volgograd complementarily in relation to the destination Kamyshin; the largest weighting factor (0, 42), which characterizes the multivariate analysis the different measures values, determines the maximum value of preferences to Kamyshin city.

Common sense. It is obvious that location of a tourist destination between the cities of Kamyshin and Petrov Val meets the requirements of the comprehensive efficiency: corresponds to the balance of costs, has sufficient human resources, has recreational and semantic potential, characterized by transport availability, and the potential for development of new transport communications—the possibility of building a new river passenger port and yacht port.

The contribution of the author: (1) developed the idea of the target application of GIS technologies in tourism and (2) proposed a model of use.

References

Baranov VI (1952) What they say sandstones Kamyshin and Sands Ergeni. The Regional Publishing House, Stalingrad

Calculation of distances (2012) Auto Trans info. http://ati.su/Trace/. Accessed 29 Nov 2012

Dergachoff VA (2003) The global geo-Economics (transformation of the world economic space). Monograph.: ИПРЭЭИ of national Academy of Sciences, Odessa

Malyarenko I (2010) The genius of the place of the supply chain. Management consulting. http://www.i-bakery.ru/. Accessed 21 Jan 2013

Routing and calculation of distances (2012) Toplogistic Prof. http://www.toplogistic.ru/314.html. Accessed 28 Nov 2012

The number of the population cities of Russia (2012)The Reference system, Russia. http://www.ru.all.biz/guide-population. Accessed 29 Dec 2012

Zaitsev EI (2011) Logistics and supply chain management. CBM project: advanced information technology in logistics. http://eiz.engec.ru/. Accessed 2 June 2013

Zorin IV (2000) Axiological space as the subject area of pedagogy of tourism. Theory and practice of physical culture. no. 8

The Usage of Social Media Text Data for the Demand Forecasting in the Fashion Industry

Samaneh Beheshti-Kashi and Klaus-Dieter Thoben

Abstract The fashion industry faces different challenges in the field of demand forecasting. Factors such as long delivery times in contrast to short selling periods requires precise demand figures in order to place accurate production plans. This paper presents firstly the idiosyncrasies of the fashion industry and shows current fashion forecasting approaches. Then, the idea of applying social media text data within the demand forecasting process is presented by showing works of integrating user generated content in different application fields. Following the research question on the predictive value of social media text data for the fashion industry, the research objective and the methodology are formulated in a last step.

Keywords Demand forecasting · Apparel industry · Social media · Communities

Introduction and Problem Description

The apparel industry often deals with stock out or overstocked inventories which result into high losses for companies. Especially, this industry is characterized through high impulse purchases and, most buying decisions are made at the POS. Therefore, the availability of a product is highly crucial for the companies' success (Nenni et al. 2013). While companies require accurate information about future demands, mostly this information is not present, since the demand is influenced by

S. Beheshti-Kashi (✉) · K.-D. Thoben
BIBA-Bremer Institut für Produktion und Logistik GmbH, University of Bremen, Hochschulring 20, 28359 Bremen, Germany
e-mail: bek@biba.uni-bremen.de

K.-D. Thoben
e-mail: tho@biba.uni-bremen.de

S. Beheshti-Kashi
International Graduate School for Dynamics in Logistics (IGS), University of Bremen, Hochschulring 20, 28359 Bremen, Germany

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variant factors such as changing weather conditions, competition, holidays as well as the general economic situation (Thomassey 2010). In addition, fashion trends are very short and approximately 95 % of fashion items of a collection will be replaced in the following season. Consequently, companies face a lack of historical sales data for future items (Thomassey 2014). Volatile consumer demands and high product varieties in color and sizes are additional idiosyncrasies (Christopher et al. 2004).

While most production plants are located in Asian countries such as China, Bangladesh or Taiwan, the target region for these products are european countries (Mostard et al. 2011). Due to this fact time- to- market has been compared to the short selling period of a fashion product for a long time. Therefore, production of successful products is rarely possible (Fissahn 2001). In order to be time efficient companies also fly the products to Europe, which is however, related to high costs (Hoyndorff et al. 2010). Consequently, accurate forecasts are crucial since production decisions are often due before exact demand figures are known. Due to the described factors and the lack of historical data, traditional forecasting methods are difficult to be applied and therefore, new approaches have to be considered.

Fashion Sales Forecasting and the Predictive Power of Online Chatter

For forecasting of sales data statistical techniques such as exponential smoothing, ARIMA, Box and Jenkins model, regression models or Holt Winters model are often applied. However, due to the idiosyncrasies of the fashion industry and requirement of historical data these methods can be hardly adopted by apparel companies (Thomassey 2014). Nevertheless, a large number of commercial software often applies these techniques for their predictions (Jain 2007), although most sales experts use these forecasts only as a baseline for their own estimations (Thomassey 2014). Recently, advanced forecasting methods such as extreme learning machine (ELM) algorithms have been introduced (Sun et al. 2008). Wong and Guo (2010) base their model on the ELM and propose a hybrid intelligent model for mid-term forecasts for fashion retailer. In the work of Au et al. (2008) evolutionary neural networks (ENN) show promising results especially in the case of noisy data. Other authors use further soft computing techniques such as fuzzy logic (Thomassey 2010). These works focus on the application of different techniques. In contrast, Mostard et al. (2011) show a different approach by considering pre-order demand information.

The present paper addresses the described challenges by integrating customers' opinions in the forecasting process. With the rise of the Web 2.0 and the emerging social media applications the ordinary user obtained a new role: He is an active and producing entity and not purely consuming. For this role literature introduced the term producer (Bruns 2006). Especially fashion is a widely discussed topic in the communities and many fashion blogs publish different fashion related topics. Kaplan and Haenlein (2010) define Social Media as group of Internet-based applications *that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content*. Various authors have examined the relationship from online chatter to real world outcomes and the predictive power of such user generated content. For instance, Asur and Huberman (2010) focused on movie box-office revenues and Twitter data and showed a strong correlation between the online data and the real future rank of a movie. Dhar and Chang (2009) suggest that user generated content is a good indicator for future sales of online music sales. However, they emphasize the consideration of also other influencing factors. Further research focuses on exploring sentiments from Twitter data and examining potential correlations to the value of the Dow Jones Industrial Average (Bollen et al. 2011). Likewise Twitter posts were used to investigate the platforms role in predicting the outcome of future elections (Tumasjan et al. 2010).

A further research stream is the usage of search keywords for prediction. Google Flu trends estimates influenza distributions based on search keywords related to the topic influenza (Google 2014). Goel et al. (2010) focus on entertainment goods and assume that consumers interested in a specific movie or game might also search for it. They conclude that search-based predictions are domain specific and other domains should be considered in further research. This paper intent to integrate both described research streams.

Research Objective

The objective of the research is to examine the applicability of the integration of data, which is published online by ordinary user in the fashion demand forecasting process. At the one hand social media applications have to be focused in order to analyze their relation to fashion products and to be able to identify factors, which are identifiers for future trends. On the other hand sales data of fashion companies should be examined. In addition, the current handling of fashion companies with social media applications and content will be examined. After analyzing these different aspects and finding out effects and relationships between them, then a solution on how these data might be integrated in the demand forecasting process for fashion products will be derived.

Research Methodology

Following the research question on the predictive value of social media text data for the fashion industry several perspectives have to be considered. A corpus has to be generated from different social media applications, which will be done by the mean of web mining methods. For the preprocessing step of the text, different text mining methods have to be applied. In a following step, sentiment analysis and opinion mining methods will serve for analysis purposes. These results will be the basis for examining correlations to real sales data. A case study approach will serve as the main method for a requirement analysis based on fashion companies for an adequate integration of social media data in real life demand forecasting processes. After reviewing the literature regarding fashion forecasting as well as the existing theories on the impact of social media on real world outcomes the different cases will be selected. Expert interviews and online questionnaires will serve for the data collection and be the ground for analysis purposes.

References

Asur S, Huberman BA (2010) Predicting the future with social media. In: IEEE/WIC/ACM international conference on web intelligence and intelligent agent technology, vol 1, pp 492–499

Au KF, Choi TM, Yu Y (2008) Fashion retail forecasting by evolutionary neural networks. Int J Prod Econ 114:615–630

Bollen J, Maoa H, Zengb X (2011) Twitter mood predicts the stock market. J Comput Sci 2:2–8

Bruns A (2006) Towards produsage: futures for user-led content production. In: Sudweeks F, Hrachovec H, Ess C (eds) Cultural attitudes towards communication and technology 2006, 28 June–1 July. Tartu, Estonia

Christopher M, Lowson R, Peck H (2004) Creating agile supply chains in the fashion industry. Int J Retail Distrib Manage 32(8):367–376

Dhar V, & Chang EA (2009) Does chatter matter? The impact of user-generated content on music sales. J Interact Mark 23(4):300–307. http://linkinghub.elsevier.com/retrieve/pii/S1094996809000723

Fissahn J (2001) Marktorientierte Beschaffung in der Bekleidungsindustrie. Dissertation, Münster University

Goel S, Hofman JM, Lahaie S, Pennock DM, Watts DJ (2010) What can search predict. Working paper

Google (2014) Google Trends. http://www.google.org/flutrends/about/how.html. Accessed 10 Mar 2014

Hoyndorff K, Hülsmann S, Spee D, ten Hompel M (2010) Fashion logistics. Grundlagen über Prozesse und IT entlang der Supply Chain, Munich, Huss-Verlag GmbH

Jain CL (2007) Benchmarking forecasting software and systems. J Bus Forecast Methods Syst 26 (4):30–33

Kaplan AM, Haenlein M (2010) Users of the world, unite! the challenges and opportunities of social media. Bus Horiz 53:59–68

Mostard J, Teunter R, de Koster R (2011) Forecasting demand for single period products: a case study in the apparel industry. Eur J Oper Res 211:139–147

Nenni ME, Giustiniano L, Pirolo L (2013) Demand forecasting in the fashion industry: a review. Int J Eng Bus Manage 5(37):1–6

Sun ZL, Choi TM, Au KF, Yu Y (2008) Sales forecasting using extreme learning machine with applications in fashion retailing. Decis Support Syst 46(1):411–419

Thomassey S (2010) Sales forecasting in clothing industry: the key success factor of the supply chain management. Int J Prod Econ 128(2):470–483

Thomassey S (2014) Sales forecasting in apparel and fashion industry: a review. In: Choi TM, Hui CL, Yu Y (eds) Intelligent fashion forecasting systems. Springer, Berlin

Tumasjan A, Sprenger TO, Sandner FG, Welpe IM (2010) Predicting elections with twitter: what 140 characters reveal about political sentiment. In: Proceedings of the fourth international AAAI conference on weblogs and social media, pp 178–185

Wong W, Guo ZX (2010) A hybrid intelligent model for medium-term sales forecasting in fashion retail supply chains using extreme learning machine and harmony search algorithm. Int J Prod Econ 128(2):614–624