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Compatibility as an Additional Criterion for Life Saving Performance of Life Jacket

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ABSTRACT

This paper proposescompatibility as an additionalvariable or factor that contributes to lifesaving performance of life jackets. In order to support the proposal, a model and seven hypotheses were developed based on previous literatures and accidents reports. The hypotheses are compatibility of life jackets with CPV contributes to the lifesaving performance of a life jacket (H_1); Inherently buoyant life jackets are not compatible to don inside the fully enclosed spaces of CPV (H_2); Inherently buoyant life jackets are compatible to don in open spaces of CPV (H_3), Inherently buoyant life jackets are compatible to don inside the partially enclosed spaces of CPV (H_4), Inflatable life jackets are compatible to don inside the fully enclosed space of CPV (H_5),: Inflatable life jackets are compatible to don in open space of CPV (H_6); and Inflatable life jackets are compatible to don inside the partially enclosed spaces of CPV (H_7). Verification of the hypotheses and model was based on opinion fromthree groups of maritime professional. The opinionswere gathered by a survey questionnaire, and the response was using a five-point Likert Scale. The development of the survey questionnaires were according to standards of IMO. The performed analyses were descriptive analysis, variance analysis, exploratory factor analysis and correlation analysis. Based on the result, the proposed model and hypotheses were supported.

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Background:

Life jacket is a lifesaving appliancesthat provides buoyancy and preventwearerfrom drown when properly don. The specific performance of life jacket isthe ability to turn the wearerfrom any position in the water onto the person back,supported the head and protect the airway by keeping the mouth out of water (Groff & Ghadiali, 2003).The carriage of life jacketsis compulsory onboard passenger and commercial vessels by the relevant national regulations and international convention such as SOLAS 1974 (IMO, 2009). Standards for life jackets also have been established by relevant national and international institution such as the IMO and ISO based in researches.

Despite of the establishment of standards and enforcement of carriage, accidents associated with the usage of life jackets on board passenger vessels and passenger aircraft persists, although the numbers is not significant.The examples are shown in Table 1 and Table 2.

This study believed that the accidents had been caused by incompatibility between the life jacketsand passenger vessels. With respect to this issue, no safety assessmenthas been conducted relating to compatibility between life jackets and passenger vessels.Instead, the safety assessment has been conducted separately on life jackets and passenger vessels(Ayub & Nejaim, 2003; Doll *et al.*, 1978a, 1978b, 1978c; Pask & Christie, 1962; Gabb*et al.*, 1965; Groff & Ghadiali, 2003; Hart, 1988; IMO, 1998; Lois, Wang, Wall, & Ruxton, 2004; Lu & Tseng, 2012; MacDonald*et al.*, 2011; Macesker & White, 1992; Macintosh & Pask, 1957; Pask, 1961; Wang & Foinikis, 2001). Therefore, the main purpose of this study is to qualify compatibility as one of the factors that contributes to lifesaving performance of life jackets when use on board coastal passenger vessel.

2.0Conceptual Model and Research Hypotheses:

The conceptual model of the study is depicted in Figure 1. The conceptual model started with the lifesaving performance of lifejacket that is determined by effectiveness of life jacket and compatibility of life jacket with Coastal Passenger Vessel (CPV).

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Table 1: Accident Related to Usage of Life jacket on board Open Boat in UK (Source: MAIB, 2001, 2007, 2008).

	Year	Type	Casualty	Summary
1	1999	Capsized	1 person drowned	A dory capsized while carrying nine pupils and a teacher near a pontoon of Sailing Centre at HMS Excellent of Portsmouth. A nearby boat managed to rescue eight pupils and the teacher. Later, they noticed one pupil was missing. The pupil was found trapped underneath the capsized boat and was given first-aid after recovered. The pupil later died in a hospital. All pupils and the teacher were wearing life jacket at the time. The trapped pupil was unable to escape from the capsized boat due to buoyancy force of the life jacket that she used. Situation worsened by the further submerged of the up-turned boat was by some pupils that sat on top while others clung to the side of the boat.
2	2006	Collision	3 persons drowned	The yacht Ouzo sailed to Dartmouth from Bembridge, Isle of Wight (IOW) on the evening of 20 August 2006. The Ouzo had collided with the Ro-Ro Passenger Ferry Pride of Bilbao in the morning of 21 August. The sea condition of the time was moderate with sea temperature about 18°C. Three bodies of the crews were recovered within two days. All of them were found wearing the inflated life jackets that not fitted with lights. The crews were also wearing good-quality yachting clothing, which provided them good protection.
3	2007	Capsized	1 person drowned	A rigid raiding craft carrying twelve persons capsized due to accumulation of water on its deck. After capsized, four of the twelve persons on board managed to surface under the upturned hull, however, only three managed to swim clear. The fourth, a 14-year-old female cadet remained under the hull. Later, she was found trapped underneath the boat with her inflatable life jacket inflated, which possibly prevented her escape. She was afterward flown to hospital and pronounced dead-on arrival.

Table 2: Data of Accident Related to Usage of Life jacket on Board Passenger Airlines (Source: Chang & Liao (2009) and FAA (1996)).

No.	Year	Type	Casualty	Summary
1	1996	Crash	123 died of 175 passengers and crews	Passengers of Ethiopian Airlines Flight 961 in 1996 had disobeyed directive from their captain by inflating their inflatable life jacket in the aircraft prior to emergency landing on water (FAA, 1996). The landing had caused the aircraft broke into three major sections. Some of the passengers died immediately due to impact while some survived. The survivors who located inside the broken fuselage were trying to escape but prevented by their inflating life jacket. The passengers were floated by their life jacket as the water level rise and push further inside by the forces of water ingress. They were eventually trapped and drowned.
2	2000	Crash	1 death and 8 minor injuries	A Hawaii BIA airline PA-31-350 ditched into sea due to engine failure. The cause of the passenger death was early inflation of the life jacket before escape through the exit point.
3	2003	Crash	2 deaths and 5 minor injuries	An Air Sun Shine Cessna 402 ditched into Treasure Cay, Bahamas, causing two deaths and five minor injuries. The two death person was a child that was wearing three life jackets and a person that inflated life jacket inside the aircraft before exiting.

According to Doll *et al*.(1978b), lifesaving performance of life jacket is comprised offour variables, namely effectiveness, reliability, wearability and accessibility.

The main purpose of this study is to qualify compatibility as one of the factors that contributes to lifesaving performance of life jacket. Instead of testing the correlation of compatibility to all four variables, the lifesaving performance of life jacket is represented only by variable effectivenessbecause it has the most important feature of life jacket which is floatation and the righting ability.

Therefore, the first hypothesis is compatibility betweenlife jacket and CPV contributes to the lifesaving performance of life jacket (H_1).The compatibility for donning life jacket on board coastal passenger vessel is determined by converge between two elements, namely type of life jacket and type of space on board CPV.Thus, the rest of the hypotheses specifically test the compatibility between type of life jacket and type of space of CPV as follows:H_2: Inherently buoyant life jackets are not compatible to don inside the fully enclosed spaces of CPV; H_3: Inherently buoyant life jackets are compatible to don in open spaces of CPV; H_4: Inherently buoyant life jackets are compatible to don inside the partially enclosed spaces of CPV; H_5: Inflatable life jackets are compatible to don inside the fully enclosed space of CPV; H_6: Inflatable life jackets are compatible to don inopen space of CPV; and H_7: Inflatable life jackets are compatible to don inside the partially enclosed spaces of CPV.

H_2, H_3,and $H_4$are developed based on the three accidents in Table 2. Although the type of life jacket that were used in the three accidents was inflatable type and not the inherently buoyant type that mostly used in the coastal passenger vessel (Ahmad Fuad *et al*., 2012), the inflatable type is considered similar with inherently buoyant type after inflated.

This is due to the changes of the physical properties of the uncharged inflatable life jacket that is compact and not buoyant andto the inflated inflatable life jacket that isbulkyandbuoyant,which similarto the physical properties of the inherently buoyant life jackets.

In the three accidents, the inflatable life jackets were inflated inside the enclosed space of the aircraft cabin which prevented the escape of the passengers after the emergency landing on water and had caused their deaths. The development of hypotheses H_2, H_3,and $H_4$are also associated with the first and third accidents of Table 1 that was donning inherently buoyant life jacket in a confine space (space inside the up-turned open boat) may cause injury or death during an accident. H_5, H_6 and H_7 are developed based on the standard practice of commercial passenger aircraft which is donning inflatable life jacket inside the enclosed cabin of aircraft without inflating it when the aircraft has to perform emergency landing on water (Air Asia, 2009).

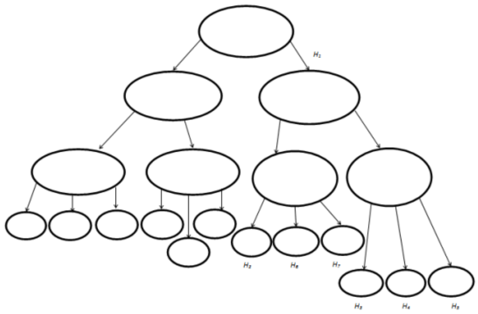

Fig. 1: The proposed conceptual model of the study.

3.0 Research Methodology:

3.1Questionnaire Design and Sampling:

The purpose of thestudy is to verifythe hypotheses developed based on previous literature and accident records.The empirical data for the study was collected by using a questionnairesurvey.

The steps taken to develop the questionnaire followed as stipulated by Piaw (2011). The items measured in the questionnaire survey were based on requirements of the International Life-Saving Appliance Code (LSA Code) and a literature review on standard of the life jacket (IMO, 1996, 1998, 2005).Two sets of questions of A and B were prepared to test the acceptance of variable effectiveness and compatibility respectively. The responseswere using a five-point Likert Scale where1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, and 5 = strongly disagree(Likert, 1932).

The pilot study was conducted prior to the full survey to marine executives of Port of Tanjung Pelepas Malaysia, to determine the reliability of the questionnaire.The result of Cronbach's Alphaof the pilot study was 0.916,which above 0.7 and considered reliable(Piaw, 2011).A full questionnaire survey was conducted to three sample groups, namely Marine Officers of Malaysia Marine Department, Lecturers of Nautical Science Department and Maritime Technology Department of Universiti Malaysia Terengganu, and Ship/Marine Surveyors of three companies based in Malaysia,namely Petronas Maritime Services,Lloyd's Register of Shipping and Ship Classification Malaysia.The population of the marine officer is 130 and sample size is 97; population of ship/marine surveyor is 34 and sample size is 32; and population of the lecturer is 21 and sample size is 19. The sample size for each group is determined by using the table to determine size sample from a given population developed by Krejcie & Morgan(1970). The questionnaire survey was conducted from September to December 2013, mostly by email and few by hand. The total number of responsesreceived was 68 which, comprises of 29marine officers,20lecturers and 19 ship/marine surveyors.

3.2 Data Analysis:

Fourresearch methods were used for data analysis.The first method was the descriptive statisticsthat produced the mean and standard deviation for eachquestion and factor.The second method was theexploratoryfactor analysis thatidentifiesthe number of underlying factors and loading factors of each factor. The third method was variance analysis (one-way ANOVA)which examinesthe difference betweenthe mean. The fourth method was the multiple regression analysis thatdetermines the strength of relationship between the factors.

4.0 Results:

4.1Results of Demographic Analysis:

The composition of the respondents according to their occupation is shown in Table 3. The biggest group of respondents is Marine Officers (42.6%), followed by Lecturer (29.4%) and Ship/Marine Surveyors (27.9%).

Table 3: Distribution of Respondent according to Occupation.

Occupation	Frequency	Percentage
Marine Officer	29	42.6
Ship/Marine Surveyor	19	27.9
Lecturer (Nautical & Maritime Technology)	20	29.4
Total	68	100.0

4.2Results of Descriptive Analysis:

The survey questionnaire comprises of 12 questions as shown in Table 4. The range of responds from the 68 respondents is from 3.73 to 4.79 which refer from 'agree' to 'strongly agree' of the Likert scale.

Table 4: The Score of Each Measuring Variable/Question.

Ref.	Measuring Variables/Questions	Mean	Std. Deviation	Likert Scale
EV1	Lifejackets should be able to float its user both in calm and rough waters (float)	4.79	0.534	Strongly Agree
EV5	Lifejackets should not restrain movement of user to swim (swim)	4.41	0.738	Agree
EV6	Lifejacket should be able to float its user of any weight as long as he can fits in (float)	4.32	0.953	Agree
EV10	Lifejackets should allow user to swim during face-up position (swim)	4.46	0.818	Agree
EV11	Lifejackets should be able to float its user without any assistance (float)	4.75	0.500	Strongly Agree
EV15	Lifejackets should have the ability to balance the user body at the water surface during swimming (swim)	4.31	0.833	Agree
CV5	Passengers who don inherently buoyant type life jacket in the fully enclosed cabin will likely be trapped inside sinking passenger vessel.	4.00	0.905	Agree
CV6	Passengers who don inherently buoyant type life jacket in open passenger area will be less likely be trapped inside sinking vessel.	4.16	0.931	Agree
CV7	Passengers who don inflatable type life jacket in the fully enclosed cabin will be less likely be trapped inside sinking passenger vessel.	3.87	0.903	Agree
CV11	Passengers who don inflatable type life jacket in open passenger area will be less likely be trapped inside sinking passenger vessel.	4.28	0.794	Agree
CV12	Passengers who don inherently buoyant type life jacket in the partially enclosed cabin will likely be trapped inside sinking passenger vessel.	3.73	1.024	Agree
CV13	Passengers who don inflatable type life jacket in the partially enclosed cabin will be less likely be trapped inside sinking passenger vessel.	4.07	0.893	Agree

4.5 Results of Variance Analysis:

The results of Kolmogorov-Smirnov normality testfor each questionis significant ($p \leq 0.05$) which showthat the data is not normally distributed. The result of the Chi-Square test between variable occupation (lecturer, ship/marine surveyor and marine officer) and constructs effectiveness is not significant (X^2= 14.33, df = 22, p > 0.05). The Chi-Square test between variable occupation and construct compatibility is also not significant (X^2= 29.65, df = 26, p > 0.05). These results showed that, there are no difference of opinion on compatibility and effectiveness among the three groups of occupations.

4.3Results of Exploratory Factor Analysis:

Results of the Exploratory Factor Analysis are shown in Table 5. The value of Kaiser-Meyer-Olkin measure of sampling adequacy is 0.749, which is over than 0.5. This shows that the measuring variables are measuring the same aspect and therefore,considered acceptable for factor analysis(Lu & Tseng, 2012; Piaw, 2009).The Bartlett's Test of Sphericity was significant ($P < 0.05$)and shows that the measuring variables are correlated and acceptable for factor analysis(Piaw, 2009).

There werefour factors identified in the 11measuring variables or questions by using eigenvaluegreater than one (Table 15). The factors and measuring variables are described as below:

i. Factor 1 identified as Don Compatibility, consisted of three measuring variables, namely CV_{12}, CV_5, and CV_{13}.
ii. Factor 2 identified as Swim Capability, consisted of three items, namely EV_5, EV_{15} and EV_{10}.
iii. Factors 3 identified as Space Compatibility, consisted of three items, namely CV_{11}, CV_7 and CV_6.
iv. Factor 4 identified as Float Capability, consisted of two items, namely EV_1 and EV_{11}.

Factor loading is a simple correlation between the measuring variables and the relevant factors. The factor loading for all measuring variables is ranging from 0.459 to 0.966. According to Piaw(2009), factor loading should be at least 0.33. In addition to that,the higher the factor loading, the stronger the measuring variables correlate with the relevant factors. Therefore, all measuring variables are correlated with the relevant factors.

The correlation between all pairs of factors is shown in Table 6. The correlation is ranging from 0.30 to 0.601. According to Piaw (2009), values above 0.2 shows a good correlation between the factors. Therefore, all four factors are correlated.

Based on Table 5 and 6, the results of the factor analysis are parallel with the proposed model in Figure 1.

4.4 Verification of the Hypotheses:

The verification of the hypotheses developed in section 2.5 was using two results of analysis, namely bivariate correlationand descriptive analysis.The verification of the hypotheses is started with H_1 by using bivariate correlation analysis between construct effectiveness, which represents lifesaving performance of life jacket with construct compatibility. The results showed that there was a significant and positive relationship (r =

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0.474, $P < 0.05$) between construct effectiveness and construct compatibility. Therefore, H_1 is supported.The verification of the rest of the hypotheses (H_2 to H_7) is according to results in Table 7. The mean score is ranging from 3.74 to 4.26 and referring to respond of Agree in the Likert Scale. Therefore, H_2, H_3, H_4, H_5, H_6 and H_7 are supported.

Table 5: Pattern Matrix of Exploratory Factor Analysis.

	Factor			
	1	2	3	4
Passenger don inherently buoyant Lj in partially enclosed	0.780			
Passenger don inherently buoyant Lj in fully enclosed	0.686			
Passenger don inflatable Lj in partially enclosed	0.648			
Lj should not restrain movement		0.966		
Lj ability to balance user body water surface		0.653		
Lj should allow user to swim face-up		0.647		
Passenger don inflatable in open area			0.918	
Passenger don inflatable Lj in fully enclosed			0.616	
Passenger don inherently buoyant Lj in open			0.561	
Lj should be able to float in calm and rough water				0.938
Lj should able to float without any assistance				0.459
Extraction Method: Principal Axis Factoring. Rotation Method: Promax with Kaiser Normalization.[a]				
a. Rotation converged in 6 iterations.				

Table 6: Factor Correlation Matrix.

Factor	1 (Don Compatibility)	2 (Swim Capability)	3 (Space Compatibility)	4 (Float Capability)
1	1.000	0.299	0.601	0.309
2	0.300	1.000	0.470	0.530
3	0.601	0.470	1.000	0.470
4	0.309	0.530	0.470	1.000
Extraction Method: Principal Axis Factoring. Rotation Method: Promax with Kaiser Normalization.				

Table 7: Mean Score of Respondent's Perception on Compatibility

Hypothesis	Item	Meaning of Measuring Variables/Questions	Mean	Likert Scale
H_2	CV5	Inherently Buoyant vs. Fully Enclosed Space = Not Compatible	4.00	Agree
H_3	CV6	Inherently Buoyant vs. Open Space = Compatible	4.15	Agree
H_4	CV12	Inherently Buoyant vs. Partially Enclosed = Not Compatible	3.74	Agree
H_5	CV7	Inflatable vs. Fully Enclosed Space = Compatible	3.85	Agree
H_6	CV11	Inflatable vs. Open = Compatible	4.26	Agree
H_7	CV13	Inflatable vs. Partially Enclosed = Compatible	4.07	Agree

Discussion:

The main objective of this paper is to qualify compatibility as one of the factors that contributes to lifesaving performance of life jacket. This objective can be met by verify the developed hypotheses and conceptual model in Figure 1. The verified conceptual model is shown in Figure 2. The correlation between construct compatibility and lifesaving performance of life jackets is determined by the relationship between construct compatibility with construct effectiveness,which is one of the fourestablished constructs that contributes to lifesaving performance of life jackets (Doll *et al*., 1978a, 1978b, 1978c). The Pearson correlation analysis result showsthat there is a significant relationship (r=0.474, $p \leq 0.05$) between construct compatibility with construct effectiveness. Thus, this result supports$H_1$and the proposed model.In order to verify the proposed factors of effectiveness and compatibility in Figure 2, result of the pattern matrix in Table 5 is used. Therefore, the existence of swim capability and float capability factors for construct effectiveness and don compatibility and space compatibility factors for construct compatibility are supported. In the proposed model (Figure 1), factor float, capability is derived from three measuring variables, namely EV_1, EV_6 and EV_{11}. However, EV_6 was later removed in the verified model (Figure 2), due to value of loading factor less than 0.2. Finally, H_2, H_3, H_4, H_5, H_6 and H_7 are supported by the mean results of each measuring variable in Table 9. All resultsare referring to linguistic value of 'Agree' of the Likert scale. The results that support the application of construct compatibility as one of the criteria for lifesaving performance of life jackets would improve the safety level of passengers in the passenger vessels by suggesting the usage of suitable type of life jackets according to type of space available on board.

Conclusion:

The hypotheses and model developed in this paper were based on previous literatures and accident reports. The verification of the model and hypotheses were performed by survey the opinions of three relevant groupsof maritime professional.Analyses that were performed are descriptive analysis, variance analysis, exploratory factor analysis and correlation analysis. Based on the result of the analyses, compatibility is accepted as one of the factors that contributed to lifesaving performance of life jackets along with the proposed model and hypotheses. Construct/variable compatibility is one of the criteria that determined the performance of life jackets. The application of compatibility would improve the safety level of passengers in the passenger vessels by suggesting the usage of suitable type of life jackets according to type of space available on board.

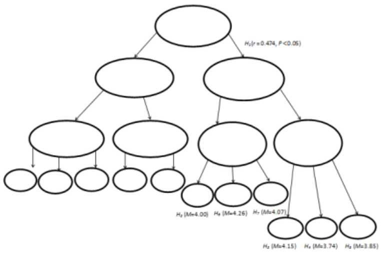

Fig. 2: The verified model of the study.

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