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New approach to determine the maximum number of passengers of coastal passenger vessel

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ABSTRACT

This article proposes a new approach to determine the maximum number of passengers for coastal passenger vessels based on the donning area for life jackets. Currently, the maximum number of passenger is determined by using one of the three methods, namely length of rail, fixed seating and deck area. This study proposes the application of the life jacket donning area as a basis to determine the number of passengers. The donning area of 0.86 m2 was determined by using anthropometry data of Malaysia citizen. The new approach was tested to Duta Pangkor 3, a coastal passenger vessel (CPV) operated between Lumut and Pangkor Island Malaysia. Based on the donning area, the maximum number of passengers was 75 that was far less than 126, which was based on number of seats. The advantage of the reduced number of passengers is the sufficient area for all passenger to don the fixed buoyant life jacket at the open space of the vessel and reduce the evacuation time during emergency. This new approach can be considered by maritime authorities to determine the maximum number of passengers and approval of General Arrangement plan of coastal passenger vessels.

1. Background.

The current method to determine of the maximum number of passengers for coastal passenger vessels depends on the compliance of these three criteria: namely length of rail, fixed seating and deck area (USCG 2012). The requirement for each person for length of rail is 30 inches (0.76 meter), seat width is 18 inches (0.46 meter), and the deck area is 10 square feet (0.93 square meter). These aforementioned standards are not safety based. Although these criteria are used, the maximum number of passengers is limited further by the vessel's load and stability. The CPV operators can manipulate these three criteria to load as many passengers as possible as long as it does not exceed the limit of vessel's load in order to maximise the economy of scale of the operation. Therefore, to address this problem, this study would propose a new method based on safety to determine the maximum number of passengers of CPV, which is based on the requirement to operate personal safety equipment.

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2. Methodology.

There are three main steps involved in this research: determining the area required for a person to don a life jacket; determining the compatible area to don life jacket on board coastal passenger vessels; calculate the maximum number of passengers based on available area to don life jacket on board coastal passenger vessels.

Step 1: Determine the Area Required For a Person to Don Life Jacket The area required for a person to don life jacket was determined in two steps. The first step was to determine the movement of the relevant body parts to don life jackets by conducting observations of five persons donning a different brand of life jackets. The second step was to determine the minimum area needed for the relevant body parts to don life jacket by referring to the anthropometric data of Malaysian citizen.

Step 2: Determine the Compatible Area to Don Life Jacket on board Coastal Passenger Vessel.

Type of coastal passenger vessel chosen for the data collection was a closed-deck coastal passenger vessel engaged in

Table 1: Mean Score of Respondent's Perception on Compatibility.

Item	Meaning	Mean	Likert Scale	Support	Symbol	Compatibility Matrix
C5	Inherently Buoyant Life Jacket in Fully Enclosed Space = Not Compatible	4.00	Agree	H_2	LJ_{bfe}	0
C6	Inherently Buoyant Life Jacket in Open Space = Compatible	4.16	Agree	H_3	LJ_{bo}	1
C7	Inflatable Life Jacket in Fully Enclosed Space = Compatible	3.87	Agree	H_4	LJ_{ife}	1
C11	Inflatable Life Jacket in Open Space = Compatible	4.28	Agree	H_5	LJ_{io}	1
C12	Inherently Buoyant Life Jacket in Partially Enclosed Space = Not Compatible	3.73	Agree	H_6	LJ_{bpe}	0
C13	Inflatable Life Jacket in Partially Enclosed Space = Compatible	4.07	Agree	H_7	LJ_{ipe}	0

Source: Authors.

single-leg journey (Tzannatos 2005). In order to measure the area of each deck of the vessel, the General Average (GA) Plan was used. The image of GA plan on board the vessel was recorded by using a digital camera with 5 mega pixel resolution, which considered detailed enough for the reconstruction of the vessel's plan by using Microsoft Visio Technical Software. The image of life jacket used on board the vessel was also recorded. After reconstructed the vessel's GA plan, the area on each deck and compartment of the vessel's plan was measured by using the "shape area and perimeter" function in the Visio Technical Software.

The compatibility to don lifejacket according to type of life jacket and type of space to develop the compatibility matrix was determined by literature review and verified survey. The type of life jacket are inflatable and fixed buoyant, while the type of space are fully enclosed, partially enclosed and open.

The basis of the compatibility between type of life jacket and type of space was highlighted in a report issued by FAA 1996, which stated that the user of the solid foam life jacket was trapped inside the water ingressed enclosed space due to buoyancy of the life jacket that prevented their escape (FAA 1996). This report suggest the practice of not using solid foam lifejacket inside the enclosed space. In a different practice, the flight safety briefing demonstrated that during an emergency, passengers are instructed to don their inflatable life jacket inside the cabin with one of the chambers inflated (Air Asia 2009). This shows that the inflatable lifejacket can be used inside the enclosed space. These practices show the compatibility to use the lifejacket is according to type of lifejacket and type of space. This practice is further supported by survey conducted to marine officers of Marine Department Malaysia to develop the compatibility matrix with"0" indicating not compatible and "1" indicating compatible (Singhal & Singhal 1996; Hohenegger et al. 2007). The Marine Department Malaysia were chosen for the survey because it is the leading maritime safety agency in Malaysia.

The survey questionnaire developed for this research comprised of 14 questions. The response received from 79 respondents from a population of 96 persons ranged from 3.71 to 4.63, which corresponds from 'Agree' to 'Strongly Agree' in the Likert scale. However, only six questions were selected to represent the compatibility matrix as shown in Table 1.

The formula to calculate the available area compatible to don life jacket on the vessel is shown in Equation 1 and Equation 2.

$$S_A = \sum A_s \times C_s \tag{1}$$

where:
S_A= Total area available to don
A_s= Area available to don for each compartment
C_s= Compatibility to don life jackets according to type of compartment and the type of life jacket

$$C_s = \begin{cases} 0, \ if \ J_{b_{fe}} \ or \ J_{b_{pe}} \\ N_i/N_i + N_b, \ if \ J_{c_{fe}} \ or \ J_{c_{pe}} \\ 1, \ if \ J_{b_o} \ or \ J_{i_{fe}} \ or \ J_{i_{pe}} \ or \ J_{i_o} \ or \ J_{c_o} \end{cases} \tag{2}$$

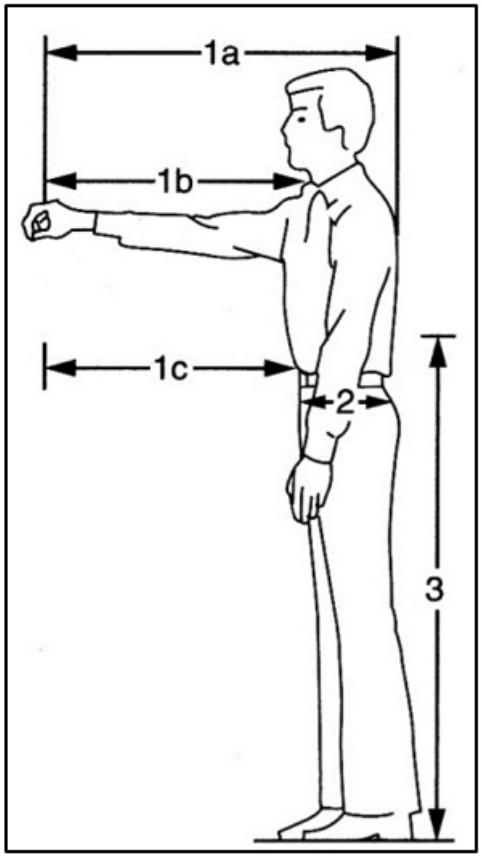
where:
$J_{b_{fe}}$= Inherently buoyant type life jacket not compatible to don in fully enclosed compartment
$J_{b_{pe}}$= Inherently buoyant type life jacket not compatible to don in partially-enclosed compartment
J_{b_o}= Inherently buoyant type life jacket compatible to don in open compartment
$J_{i_{fe}}$= Inflatable type life jacket compatible to don in an enclosed compartment

$J_{i_{pe}}$ = Inflatable type life jacket compatible to don in partially-enclosed compartment
J_{i_o} = Inflatable type life jacket compatible to don in open compartment
$J_{c_{fe}}$ = Combination of Inflatable and Inherently Buoyant life jacket in fully enclosed compartment
$J_{c_{pe}}$ = Combination of Inflatable and Inherently Buoyant life jacket in partially enclosed compartment
J_{c_o} = Combination of Inflatable and Inherently Buoyant life jacket in open compartment
N_i = Number of inflatable life jacket
N_b = Number of inherently buoyant life jacket

Step 3: Calculation of Maximum Number of Passengers

The maximum of number of passengers was calculated by the division between total area available to don life jacket with area required for a person to don a life jacket.

Figure 1: Anthropometric measures standing.



Source: Authors.

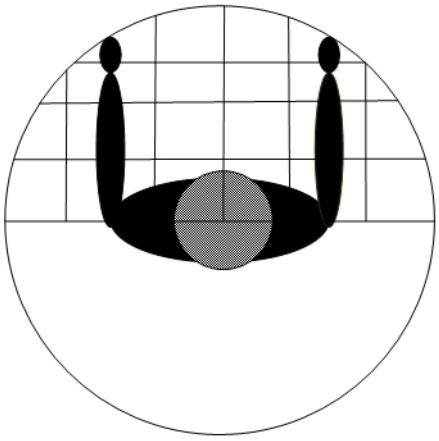
3. Results and Discussion.

3.1. Minimum Area for a Person to Don a Life Jacket.

The observation on donning test of life jacket showed that the participants performed a half forward and then full upward movement of arms to don life jacket as shown in Figures 1 to 3. This movement was also quite similar to the knockout punch movement. The anthropometry data relevant with this movement is the shoulder grip length, which is the dimension of 1a in Figure 4.

The shoulder grip length of 95^{th} percentile of Malaysian is 0.74 meter (Mohamad et al. 2010). It was used as the basis to calculate an area for a person to don a life jacket. Based on the donning test as shown in Figures 1 to 3, the area in front of the body, which was correspond to the shoulder grip length was used to don the life jacket. In order to calculate the area required for a person to don a life jacket, the formula of circle area divides by 2 ($\Pi r^2/2$) was used. The circle area was divided by two because only the area in front of the body is involve in the donning process as shown in Figure 5. The result of the calculation was 0.86 meter^2. Therefore, the minimum area required for a person to don a life jacket is 0.86 meter^2.

Figure 5: Area in front of the body involve in the donning.



Source: Authors.

3.2. Compatible Area to Don Life Jacket on the Coastal Passenger Vessel.

Data collection was conducted on "Duta Pangkor 3", which is a coastal passenger vessel operated between Lumut town and Pangkor Island in the state of Perak, Malaysia. The vessel is a closed-deck type coastal passenger vessel engaged in single-leg journey. The vessel particulars are shown in Table 2.

The drawing of the vessel's GA plan hanging on the wall of the vessel was captured by using a digital camera with resolution of five mega pixel. The data collection of the GA plan in such a way was more practical and quicker than facing the bureaucracy of getting a copy of the drawing from the vessel's operator. However, careful consideration has been taken during taking the image of the GA plan by capturing many images at the right angle (90 degrees) as possible from the front of the drawing to reduce error. The best captured image of GA plan was then selected and further improved by using Microsoft Office Picture Manager to ensure the image was as good as possible to be used for reconstruction of the vessel's GA plan drawing by using Microsoft Visio Technical Software. The reconstructed plan of Duta Pangkor 3 is shown in Figure 6. The type of life jacket used was inherently buoyant or solid foam (Groff & Ghadiali 2003; Doll et al. 1978).

Figure 2: Donning test life jacket brand A.

Source: Authors.

Figure 3: Donning test life jacket vest design brand B.

Source: Authors.

Figure 4: Donning test life jacket vest design brand C.

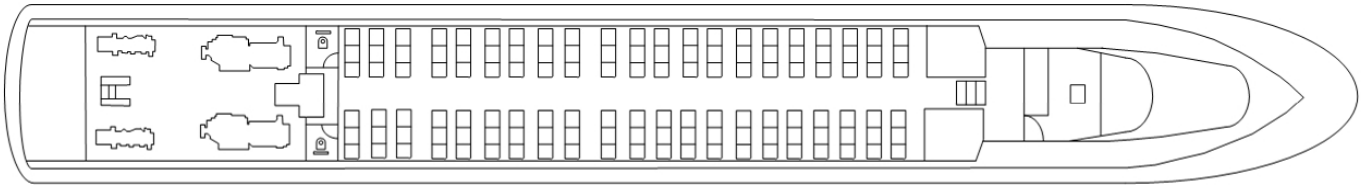
Source: Authors.

Table 2: Vessel Particulars.

Vessel name	**MV Duta Pangkor 3**
Country	Malaysia
Operating Area	Lumut to Pangkor Island
Length Overall	38.36m
Beam	4.06m
Approved Maximum Number of Passengers	126
Crew	3
Total persons on board	126

Source: Authors.

Figure 6: GA plan of MV Duta Pangkor 3.



Source: Authors.

Table 3: Calculation of the Scale of GA Plan of Duta Pangkor 3.

LOA of model	281.028 mm
LOA of vessel	37860 mm
Scale	135

Source: Authors.

The measurement of the deck area of each compartment on the vessel started with determining the scale of the GA plan. The scale was determined by the division between length overall (LOA) with LOA measured on the plan as shown in Table 3.

The Duta Pangkor 3 is a single deck coastal passenger vessel, thus the calculation was only limited to the closed-deck compartment and open-deck compartment on the single deck, which are depicted in Table 4, Table 5 and Table 6 respectively. Number of passengers shown in Table 4 is 126, whereas 0 passengers are shown in Table 5. This is because all passengers were located in the fixed seating compartment on the main deck, while no accommodation was allocated for passengers in the open-deck compartment on the same deck.

Table 4: Calculation of the Scale of GA Plan of Duta Pangkor 3.

Number of passengers	126
Model	6361.81 mm^2
Vessel	115463050.36 mm^2
Vessel	115.46 m^2

Source: Authors.

Table 5: Calculation of area of open compartment of the main deck (open compartment).

Number of passengers	0
Model	3530.2923 mm^2
Vessel	64072651.91 mm^2
Vessel	64.07 m^2

Source: Authors.

Table 6: Calculation of Total Area.

Total Area (enclosed)	115.46 m^2
Total Area (semi-enclosed)	0.00 m^2
Total Area (open)	64.07 m^2
Total Area	179.54 m^2

Source: Authors.

Table 7: Calculation of Maximum Number of Passengers according to compatible area to don life jacket.

Type of life jacket	Inherently Buoyant
Approved Maximum Number of Passengers	126
Area Available to Don	64.07 m^2
Area Required to Don a Life Jacket	0.86 m^2
Number of passengers able to don life jackets according to compatible area	74.5 ≈ 75

Source: Authors.

3.3. Calculation of Maximum Number of Passenger Based on Donning Area.

The calculation of the maximum number of passengers able to don life jackets based on the available area is shown in Table 7. As shown, the number of passengers able to don life jackets on the vessel was 75. The number was obtained by dividing Space Available to Don (64.07m^2) with Space Required to Don a Life Jacket (0.86m^2). Based on the donning area of life jacket and the available open area, this research proposed 75 passengers as the maximum number of passengers against 126 passengers, which is the approved maximum number of passengers according to number seats. This new propose number is 51 person less than the existing number. However, the reduction in number of passenger would give a sufficient area to all passengers to don their life jacket at the open area of the vessel. Another advantage of the reduce number of passengers is less time taken to evacuate all the passengers during emergency, which reduces the risk of passengers being trapped inside the enclosed area (Transportation Safety Board of Canada 1994; The Seaplane Pilots Association 2006). However, the CPV operator would strongly oppose this proposal because it will reduce the income of the operation. In order to cover the losses, the operator have to increase the price of the ticket, which may cause complaint from the user.

The determination of the number of passengers according to donning area of life jacket can be used by the maritime authorities to determine the maximum number of passengers based on safety for coastal passenger vessels. This approach can be used especially for the approval of the GA plan of coastal passenger vessels.

The new approach can be used by the maritime safety agency to determine the maximum number of passenger according to safety requirement. This approach also can be used for approval of coastal passenger vessel GA plan.

Conclusions.

This research proposes donning area of life jacket, which is developed from observation during donning test and anthropometry data as a new approach to determine the maximum number of passengers for coastal passenger vessels. The current methods are length of rail, width of fixed seating and deck area. This new approach would reduce the number of passengers on a vessel but at the same time reduce the risk of passengers being trapped inside the closed-deck compartment and reduce the evacuation time during accident. This new approach can be used by the maritime authorities to determine the maximum number of passengers and approval of coastal passenger vessel's GA plan.

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