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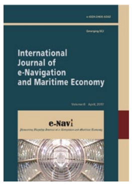

Original article

Health and Safety: Fatigue among Seafarers in Malaysia☆

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Abstract

Fatigue is not a trivial issue and needs much attention. On the other hand, fatigue among seafarers could lead to accidents at sea due to their inability and ineffectiveness in carrying out their work. Some were caused by sleepiness and lack of vigour, which, could not only affect their safety but compromising on other seafarers as well. In this study, factors that cause fatigue among seafarers were examined analytically and their quantitative priorities were determined using Analytic Hierarchy Process (AHP) method. Additionally, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used to identify the best alternatives in minimizing fatigue among seafarers. For this, data is collected through interview involving those working in academic and maritime industry with more than 5 years of experiences in dealing with seafarers. The AHP result shows that fitness is the main cause that could affect fatigue on seafarers' reliability. Besides, TOPSIS result shows that a well-maintained shipboard is the best way in sustaining seafarers' energy. In sum, fatigue among seafarers could influence on safety and may lead towards precarious health issue over a long-term.

Keywords: *Health and Safety; Fatigue on Seafarers; Reliability; Cause and Effect Analysis; Analytic Hierarchy Process (AHP); Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).*

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1. Introduction

International organizations such as World Health Organization (WHO), International Maritime Organization (IMO), and International Labor Organization (ILO) has enacted numbers of laws relating to health and safety guidelines for a safe ship operation. It is the responsibilities of shipowners and seafarers to implement the guidelines to provide quality of health, safety and accident-free environment. Currently, WHO has provided International Medical Guide for ships and the International Health Regulations (2005) whereas ISM Code has prepared specific guidelines for a safe working standard as well as ILO for health liabilities for shipowners and seafarers.

According to Yates (2010), the safety profession has been greatly transformed since the days of Hammurabi who was the sixth king of Babylon. Hammurabi is best known for his codification of laws, which included some set of worker's compensation regulation. Over the past decades, safety has become very important because of numerous maritime accidents involving human lives and the environment (Pazara, 2014). Thus, a standard safety framework is designed by IMO in order to avoid from recurrence.

In transporting goods by sea, the seafarer plays a major role in ensuring that the goods are safely delivered to the destination. The seafaring covers several professions and ranks. Seafarers depend on each other so that the operation carries out in good condition. According to Ministry of Transportation Malaysia (2016), seafaring jobs are comprising of deck and engineering crew which responsible for handling and maintenance of vessel as a whole. Seafarers need to have technical expertise and extensive knowledge of ship operations. Therefore, every seafarer must have high level of competence to ensure a safe operation of ship at all times. In this context, relevant certificates such as the Certificate of Efficiency and Certificate of Recognition are issued by the Marine Department of Malaysia to seafarers as recognition of their level of competence that enable them to serve on ships.

Maritime accident is common and happens every year in sea transportation. A study conducted by Wadsworth et al. (2008) involving 1855 professional seafarers has shown that a quarter of respondents admit of feeling fatigue or sleepy while on watch, while nearly half of them concur that fatigue could impact on their attention span while on-board.

Also, a study done by National Transportation Safety Board (NTSB) from 1 January 2001 until 31 December 2012 found that 20% of accidents are caused by fatigue (Marcus, J. H., & Rosekind, M. R., 2017).

Therefore, the primary aim of this paper is to develop decision making model for identifying, prioritizing, assessing, and proposing the best solution in minimizing fatigue among the seafarer. The Analytic Hierarchy Process (AHP) is being performed for factors pairwise comparison based on expert consideration to get most influence factors (Saaty, 2008). Furthermore, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is being employed to proposing the best alternatives in minimizing fatigue among seafarers. As a result, this model can assist ship operator to identify which alternatives are suitable based on their situation in minimizing fatigue among the seafarer.

2. Literature Review

The success of any shipping operations depends on the seafarers' performance. Normally, the shipping company will ensure that proper equipment and adequately trained seafarers are provided, as it will enable the crew to conduct their shipping operation in a safe and efficient manner. Nonetheless, the quality of seafarers' performance is not only depending on education, equipment and training provided but also healthy state of mind, body and spirit.

Fatigue is one of the health problems that causes the body to become weak and unable to work properly. Fatigue can be categorized into two aspects: (i) physical fatigue and (ii) mental fatigue. According to Jepsen, Zhao, and Van Leeuwen (2015), fatigue is a progressive loss of mental and physical alertness.

In order to develop a decision making model, nine factors have been identified from the review of several literatures, which are: rest hours, fitness, psychology and emotional, crew reduction, long working hours, workload, automation, ship design and stability, and noise and vibration. According to Dawson and McCulloch (2005), sleeping duration of less than 5 hour within the 24 hour before work, or less than 12 hour within the 48 hour before starting to work may cause risks of fatigue and impaired performance. Sleep quality may include several aspects such as the number of hours and sleep latency, as well as more subjective assessments such as sleep depth (Ohayon et al., 2018). On top of that, fitness is one of the identified factors that influencing fatigue among seafarers. Fitness is then divided into three categories which is health, age and nutrition (Carotenuto, Molino, Fasanaro, & Amenta, 2012). Furthermore, seafarers' emotion will be disturbed once they are forced to work overtime, having problems with colleagues, homesickness because the seafarers sailed on board for a long time (Rengamani & Murugan, 2012). In the twenty-first century, the size reduction of the crew had a significant impact on the life and working conditions of seafarer (Exarchopoulos, Zhang, Pryce-Roberts, & Zhao, 2018). According to Exarchopoulos et al., (2018), in the early 1970s, a bulk carrier which carries 10,000 gross tonnages, usually would have about 40 crew members. However, in early 2000s, a regular cargo was at least three times larger, but the workers consisted of only 18-25 crew members and the crew size pattern was used for merchant ship of all types. In the meantime, according to Hystad and Eid (2016), prolonged exposure to the seafaring environment will lead to greater stress. In addition, seafarers live and work in the same quarters for a prolonged period of time will lead sailors to face more obstacles that will affect their resistance in dealing with barriers (Hystad and Eid, 2016). Instead, excessive workload is one of the elements that could refrain seafarers from reaching the perfect sleep stages. Besides, stress can cause seafarers to losing vitality and impacted on alertness. Typically, pressure will occur when seafarers unable to cope with risky environment or the threats during duty (Xhelilaj & Lapa, 2010). High levels of automation on board can help seafarers minimizing their duties on board. However, enhanced technology and automation have been seen as a tool in reducing the number of crews. According to Arslan and Er (2008), reducing the number of crews will cause existing seafarers to work hard to handle all available equipment and automation. In the event of emergency which requires a large numbers of sailors, the sailors will experience fatigue. Another significant factor that causes or affects seafarers' fatigue levels is the design of the ship that they work on. According to Bal et al. (2015) it is better that the ship is designed ergonomically because the design of ship itself will determine the living conditions and the level of satisfaction of the crews. The ergonomic bridge design allows secure checks and reduces the workload of master and sailors. Adding to cause of fatigue is the psychosocial work situation (Main & Chambers, 2015) and some important environmental pressures, such as noise in the ship, engine-induced vibrations, temperature and motion variations caused by weather conditions (Oldenburg, Jensen, Latza, & Baur, 2009). For example, a working environment survey on Norwegian shipbuilders conducted by Omdal (2005) identifies that exposure to noise and internal climates are the most common problems identified by the crew. Indeed, 44% of respondents reported that noise was a big problem and most of the noise stimuli takes place from several sources on board such as main engines, generators, pumps and ventilation systems (Rolland et al., 2012).

3. Methodology

In this study, the phase of methodology is consisting of eight stages starting from the first stage of the issue's identification until the completion of the study (Figure 1). By referring to fatigue on seafarer's performance through literature review, the identification and confirmation of some basic knowledge pertaining to the research is conducted.

By using quantitative approach, research problems and key variables are identified which then will be used to resolve the arised issue (Bryman, A., 2006). After that, the objective will be set up as a direction to achieve the aim of research. There are three objectives for this study.

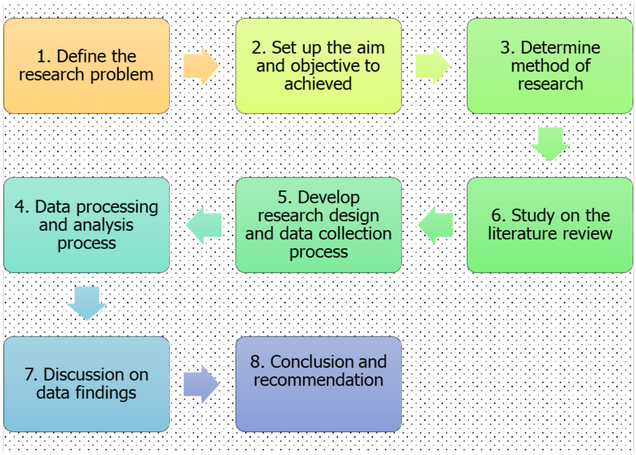

Figure 1: Flow Chart of Research Methodology

The process of discovering information will be conducted by exploratory research technique such as brainstorming sessions with experts from industry and academia, as well as from literature survey.

To achieve the second objective in this study, the Analytical Hierarchy Process (AHP) was applied to identify the most influence factor (ranking) that impact of fatigue on seafarer's performance. TOPSIS finding is then incorporated as a tool to provide solution for fatigue issue influencing seafarers.

3.1: Factors' identification and Filtration

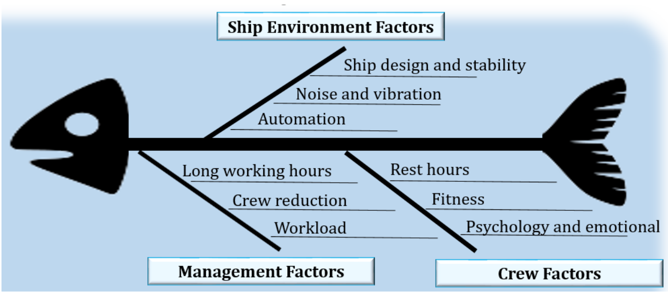

Figure 2: Ishikawa Diagram of Fatigue Factors that Influence Seafarers Reliability

For achieving the first objective, the cause and effect analysis method is used. The cause and effect diagram which also known as Ishikawa diagram or fishbone diagram is shown in Figure 2. It consists of multiple of causes. The head of the fishbone represents the problem, and the body of the fishbone represents multiple causes that contributed to the overall effects or problems (EdrawSoft, 2014). Fishbone diagrams are often used in project planning to identify all components in order to determine the workflow process. When these components are identified, it is easier to recognize each problem or inefficiency gaps into the process (EdrawSoft, 2014).

3.2: AHP Weight Assessment

To achieve the second objective, the Analytical Hierarchy Process (AHP) is applied to identify the most influenced factor (ranking) that impact of fatigue on seafarer's reliability.

Generally, the method uses following structure: problem modelling, weights valuation, weights aggregation and sensitivity analysis. AHP has the advantage of allowing hierarchical structure of the criteria, which provides a better focus on specific criteria and sub-criteria when allocating the weights of fatigue. This step is essential, because any dissimilar structure could lead to a different final ranking. When setting up AHP hierarchy with big number of elements, the decision maker should test these elements in clusters to prevent it from any major discrepancy. According to Saaty (1990), AHP consists of four major steps. All steps are described as following:

Step 1: Define the unstructured problem

Step 2: Decompose the unstructured problem into a systematic hierarchical structure (see Figure 3)

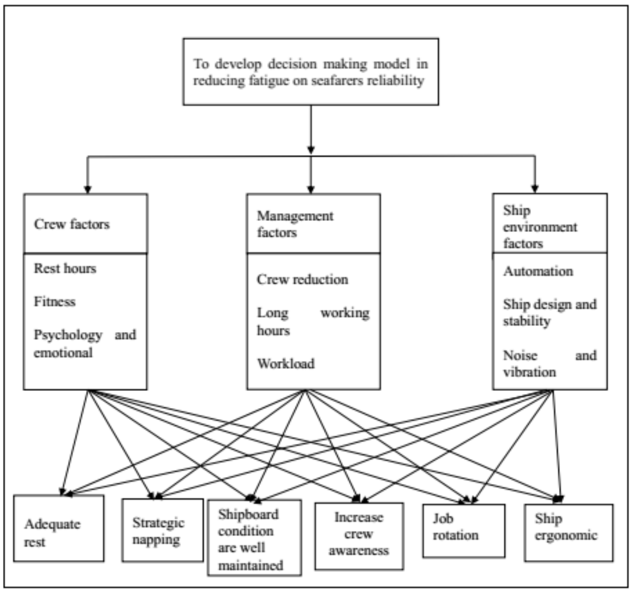

Figure 3: Hierarchical Structure of the Fatigue on Seafarers Reliability

Step 3: Establish the pairwise comparison of the criteria

In order to perform weight assignment, the comparison scale as in Table 1 is applied.

Table 1: Scale of Important

Intensity of Important	Linguistic Meaning
1	Equally Important (EQ)
3	Weekly Important (WE)
5	Strongly Important (ST)
7	Very Strongly Important (VS)
9	Extremely Important (EX)
2,4,6,8	Intermediate values between two adjacent judgments

Table 1 shows preferable scale of from number 1 until 9. Scale number 1 shows the equivalent between two factors while a preferable scale number 9 shows that one criterion is very important compared to other criterions (Saaty, 2008).

The next step is to derive accurate ratio scale priorities by employing the pair-wise comparison technique. Referring to Saaty (1997), pair-wise comparison is used to facilitate experts in choosing between two indicators which is more appropriate in making decisions. This decision is made based on expert knowledge and expertise in any of its fields, while multiple of the less dominant ones are still taken as the unit of measurement. 15 experts from Malaysia are approached to perform the pair-wise comparison for each factor.

The use of MCDM methods in practical situations with multiple number of experts or a group of experts who are involve in decision-making process could result to a great deal of complexity (Raju et al., 2000). Under AHP approach, these 15 experts are relevant for further evaluations since there are studies found that incorporate a small number of group decision making, as low as three experts' evaluations/ judgements (Emovon et al., 2015; Wan et al., 2017; Azimifard et al. 2018). In other words, AHP can be applied by using small number of experts when concentrating on the problem-solving issues (Cheng and Li, 2002).

The selection of domain experts for their judgements for this study was based on the position and experiences as shown in Table 2. In this study, the experts must have more than five years' experience.

Table 2: Experts Knowledge and Experience

Experts	Position	Experience
1	Lecturer	10-15 years
2	Marine Officer	More than 20 years
3	Associate Professor	More than 20 years
4	Vessel Manager	15-20 years
5	Marine Superintendent	10-15 years
6	QHSSE Superintendent	15-20 years
7	Vessel Manager	More than 20 years
8	Vessel Manager	More than 20 years
9	Manning Advisor	More than 20 years
10	Assistant Officer	Less than 10 years
11	Operator and Traffic Manager	10-15 years
12	Operator and Traffic Manager	10-15 years
13	Operator and Traffic Manager	15-20 years
14	Operator and Traffic Manager	More than 20 years
15	Advisor Commercial	More than 20 years

Next, in order to determine the weight vector for each criterion or alternative, Equation 1 was applied:

$$wk = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{akj}{\sum_{j=1}^{n} a_{ij}}\right) k = 1,2,3, \ldots, n \qquad (1)$$

where a_{ij} stands for the entry of row i and column j in a comparison matrix of order n.

Step 4: Carry out the consistency measurement

In making decisions, humans have inconsistent properties, especially in making comparisons. Therefore, equations (2)-(4) are used to see consistency of experts in making comparisons.

$$CR = \frac{CI}{RI} \quad (2)$$

Besides, Saaty (1977), defines the Consistency Index (CI),

$$CI = \frac{\lambda\,max - n}{n-1} \ldots \quad (3)$$

$$\lambda\,\text{max} = \frac{\sum_{j=1}^{n}\left(\frac{\sum_{k=1}^{n} wk\ ajk}{wj}\right)}{n} \ldots \quad (4)$$

where λ_{max} is the largest eigenvalue and n represents the number of the attributes.

Saaty (2008) stated that if the CR value is under 0.10, the weight vector computation can be continued. However, if the CR value is above 0.10, the following three actions have to be taken (Saaty, 2013):

i. Find the most inconsistent experts in the matrix.

ii. Determine the range of values to which judgement can be altered, corresponding to the inconsistency that could be improved.

iii. Request expert to consider changing their judgement to a plausible one in that range.

3.3: TOPSIS Method

Referring to Othman, Fadzil and Abdul Rahman (2015), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) has developed by Hwang and Yoon in 1981. This method used to solve the multi-criteria decision making (MCDM) problems (Jiang, Chen, Chen, & Yang, 2011). The basic principle of the method is that the selected alternative should have the farthest distance from Negative Idea Solution (NIS) and the shortest distance from Positive Ideal Solution (PIS). The decision matrix is represented as $[X_{ij}]_{m\times n}$. While MCDM problem present m as alternative and n as criteria. The procedure of TOPSIS consists of the following steps:

i. Calculate the normalized decision matrix.

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2 ij}}, i = 1,2, \ldots\ldots, m;\ j = 1,2, \ldots\ldots, n \ldots \quad (5)$$

ii. Calculate the weighted normalized decision matrix.

$$V_{ij} = w_j \times R_{ij},\ i = 1,2, \ldots\ldots, m; j = 1,2, \ldots\ldots, n \ldots \quad (6)$$

iii. Determine the positive and negative ideal solution by looking 'cost' and 'benefit'

$$V^{+} = \{V^{+}{}_1, V^{+}{}_2, V^{+}{}_3, \ldots\ldots V^{+}{}_n\} = \{(maxj\ V_{ij} | j \epsilon J)\}, \{(minj\ \ V_{ij}\ | j \epsilon J')\} \ldots \quad (7)$$

$$V^{-} = \{V^{-}{}_1, V^{-}{}_2, V^{-}{}_3, \ldots\ldots V^{-}{}_n\} = \{(maxj\ V_{ij} | j \epsilon J)\}, \{(minj\ \ V_{ij}\ | j \epsilon J')\} \ldots \quad (8)$$

iv. Calculate the distance separation measure for PIS (D+) and NIS (D-)

$$D^{+}i = \sqrt{\sum_{i=1}^{n}\left(V_{ij} - V^{+}{}_2\right)^2}\ , i = 1,2, \ldots\ldots, m \ldots \quad (9)$$

$$D^{-}i = \sqrt{\sum_{i=1}^{n}\left(V_{ij} - V^{-}{}_2\right)^2}\ , i = 1,2, \ldots\ldots, m \ldots \quad (10)$$

v. Calculate the relative closeness to the ideal solution, RC_i^{+}

$$RC_i^{+} = \frac{D^{-}i}{D^{+}i + D^{-}i}, i = 1,2, \ldots\ldots, m \ldots \quad (11)$$

4. Case Study

For the assessment process of the Fatigue Risk Factor Model, a decision maker has to deal with quantitative data. However, to deal with quantitative data, 15 experts in the Malaysia are approached to perform the pair-wise comparison for every risk factor. The selection of domain experts for their judgements was based on the position and experiences. In this study, the experts have more than five years experience.

After the experts answering the questionnaire, researcher need to calculate the geometric mean.

$$GM_{IJ} = [e_{ij}^{1}, e_{ij}^{2}, e_{ij}^{3} \ldots e_{ij}^{k}]\frac{1}{k} \ldots (Eq.\ 12)$$

The equation is represents as follows:

- k is the number of expert
- e_{ij}^{k} is the expert opinion for relative importance of the i criterion to the criterion.
- From the result, the calculation to determine the importance for each criterion is:

GM value between crew factor and management factor:

GM_{IJ}=[(1)×(0.2000)×(1)×(1)×(8)×(8)×(1)×(1)×(1)×(0.5000)×(0.1111)×(3)×(1)×(9)×(1)]1/15

=1.2177

GM value between crew factor and ship environment factor:

GM_{IJ}=[(4)×(0.3333)×(6)×(8)×(8)×(8)×(1)×(1)×(0.2000)×(1)×(1)×(4)×(9)×(9)×(6)]1/15

= 2.5910

GM value between crew factor and ship environment factor:

GM_{IJ}=[(7)×(3)×(9)×(8)×(0.5000)×(2)×(1)×(1)×(0.3333)×(5)×(9)×(2)×(9)×(2)×(7)]1/15

= 2.8214

Pair-wise comparison is based on the evaluation model that has been identified. Same technique and calculation process will be applied to all paired-wise comparison for aggregation process. Matrix D in this test case is the main criteria of fatigue factors (i.e. crew factor, management factor, ship environment factor and the calculation as shown below:

$$Matrix\ D = \begin{pmatrix} 1 & 1.2177 & 2.5910 \\ 0.8212 & 1 & 2.8214 \\ 0.3859 & 0.3544 & 1 \end{pmatrix}$$

Based on Matrix D, Equation 1 is used to calculate the weight for main criteria and it will be demonstrated as follows:

$$w_k = \frac{1}{n}\Sigma_{j=1}^{n}\left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}}\right)(k = 1,2,3, \ldots n)$$

$$w_a = \frac{1}{3}\left[\left(\frac{1}{2.2071}\right) + \left(\frac{1.2177}{2.5722}\right) + \left(\frac{2.5910}{6.4125}\right)\right] = 0.4438$$

$$w_b = \frac{1}{3}\left[\left(\frac{0.8212}{2.2071}\right) + \left(\frac{1}{2.5722}\right) + \left(\frac{2.5910}{6.4125}\right)\right] = 0.4004$$

$$w_c = \frac{1}{3}\left[\left(\frac{0.3859}{2.2071}\right) + \left(\frac{1.2177}{2.5722}\right) + \left(\frac{2.5910}{6.4125}\right)\right] = 0.1559$$

Based on the result above, the weight for crew factor (w_a) is 0.4438, for management factor (w_b) is 0.4004 and for ship environment factor (w_c) is 0.1559. After that, CR of pair-wise comparison will be calculated by using Equation 2 to 4. Based on the Equation 4, λ_{max} is applied to calculate for RI and CR.

A = (1×0.4438) + (1.2177×0.4004) + (2.5910×0.1559)

= 1.3352

B = (0.8212×0.4438) + (1×0.4004) + (2.8214×0.1559)

= 1.2046

C = (0.3859×0.4438) + (0.3544×0.4004) + (1×0.1599)

= 0.4691

$$\lambda_{max} = \frac{\left(\frac{1.3352}{0.4438}\right) + \left(\frac{1.2046}{0.4004}\right) + \left(\frac{0.4691}{0.1559}\right)}{3}$$

$$= \frac{9.0269}{3}$$

= 3.0090

CI is calculated by using Equation 3 and it will be followed by the Equation 4 for CR calculation. Based on Table 7, when the random index (RI) for two factors are 0, CI can be calculated as follows:

$$CI = \frac{3.0090 - 3}{3 - 1} = 0.0045$$

$$CR = \frac{CI}{RI} = \frac{0.0045}{0.5200}$$

= 0.0086

According to Saaty (1980), if CR value is maintained at 0.1 or less than 0.1, the judgement on the data analysis is considered acceptable. Therefore, according to the analysis, the results of CR for main criteria of factor fatigue on seafarers' reliability in Malaysia is 0.0086 which can be considered acceptable.

For the TOPSIS method, all the information represented in a table structure and all criteria as well as sub-criteria are directly linked to all alternatives. The sample model of analysis in this study is shown in Table 3. Each criteria and sub-criteria is grouped and categorized based on the expert surveys. Further, the cause and effect analysis is build up using the selected literature as discussed. The function of the goal of each sub-criterion is to determine the PIS and NIS in this analysis. There are two possible levels of goal used for each parameter which are named either "Benefit" or "Cost" goal. The goal for "Benefit" is related to a positive solution, while the goal for "Cost" is associated with the negative solution in determining the PIS and NIS. "Benefit" goal is focused on the sub-criteria that contribute to advantages in reducing fatigue, meanwhile, "Cost" goal is focusing on the sub-criteria that contributed to disadvantages that reducing fatigue.

Table 3: The Sample Model of Analysis

CRITERIA	SUB-CRITERIA	GOAL	
Crew factors (CF)	Rest hours (RH)	Benefit	ALTERNATIVE
	Fitness (F)	Benefit	
	Psychology and emotional (PE)	Benefit	
Management factors (MF)	Crew reduction (CR)	Cost	
	Long working hours (LWH)	Cost	
	Workload (W)	Cost	
Ship environment factors (SEF)	Automation (A)	Benefit	
	Ship design and stabiltiy (SDS)	Benefit	
	Noise and vibration (NV)	Cost	

5. Result and Discussion

The interview session is conducted with 15 experts involving vessel managers, academicians, marine officers, marine superintendents, operators and traffic managers. Following this, Analytical Hierarchy Process (AHP) has been used to identify the weight value of the experts' judgment for each risk factor (i.e crew factor, management factor, and ship environment factor), before being tested with Consistency Ratio (CR) to prove the validity of expert's judgment (Table 3). Once judgment is done, it is necessary to check whether there are consistent. To ensure the validity of CR data, the value should be less than or equal 0.10.

Table 4: Result of Weight Values and Consistency Ratios for all main and Sub-Criteria

Factors	Weight of Main Factors	Sub-factors	Local Weight of Sub-factors	Global Weight
CF	0.4438	**RH**	0.3715	0.1649
		F	0.4111	0.1824
		PE	0.2174	0.0965
			CR 0.0001	
MF	0.4004	**CR**	0.1995	0.0799
		LWH	0.4238	0.1697
		W	0.3768	0.1509
			CR 0.0000	
SEF	0.1559	**A**	0.1579	0.0246
		SDAS	0.2455	0.0383
		NV	0.5966	0.0930
	CR 0.0092		***CR 0.0069***	

In this study, the CR for main criteria is 0.0092, while the sub-criteria for crew factor is 0.0001, sub-criteria for management factor is 0.0000 and sub-criteria for ship environment factor is 0.0069. As a result, these collected data are valid.

Table 4 presents the weight value for the fatigue risk factors on seafarers' reliability. Based on the assessment, crew factor is the main risk that being highlighted as critical risks (0.4438), followed by management factor (0.4004) and ship environment factor (0.1559). Furthermore, global weights of sub-criteria is gained by multiplying main criteria weight with sub-criteria local weights.

Table 5: Ranking Orders of the Lowest-Level Criteria

Lowest-Level Criteria	Global Weight	Rank
Fitness	0.1824	1
Long Working Hours	0.1697	2
Rest Hour	0.1649	3
Workload	0.1509	4
Psychology and Emotional	0.0965	5
Noise and Vibration	0.0930	6
Crew Reduction	0.0799	7
Ship Design and Stability	0.0383	8
Automation	0.0246	9

Table 5 is organized from the highest to lowest ranking for each risk factor. As a result, (i.e. global weights for lowest level factors), the lowest level of risks is fitness (0.1824), followed by long working hours (0.1697) and rest hour (0.1649). Automation (0.0246) is the lowest level risks regarding to fatigue on seafarers reliability.

Next, best alternative to reduce fatigue among seafarers in Malaysia is shown. To obtain the result, TOPSIS method is used to obtain Relative Closeness (RC) to the ideal solution.

Table 6: The Relative Closeness to the Ideal Solution, (RC_i^+)

Alternative	$RC_i^+ = \frac{D^-}{D^+ + D^-}$
Ship Condition are Well Maintained (SCAWM)	0.7274 (1)
Ship Ergonomic (SE)	0.7258 (2)
Increase Crew Awareness (ICA)	0.5555 (3)
Job Rotation (JR)	0.3494 (4)
Strategic Napping (SN)	0.3271 (5)
Adequate Rest (AR)	0.2613 (6)

Table 6 lists the alternatives of the relative closeness to the ideal solution. It is found that SCAWM is an alternative which earns the highest place out of six other alternatives due to its ability to affect the intensity of sailors. When a ship is in good condition, (disturbance-free) without engine failure and noise, seafarers may sail safely as less job is required to ensure the capability of vessel since it has been well-inspected before cruising. Additionally, the quality of health among seafarers shall be maintained based on the factors mentioned earlier.

6. Conclusion

Fatigue is an issue that needs to be recognized, particularly in the maritime industry as it could affect human ability to make decisions in a well-balanced manner. In the case of seafarers, some are unable to conduct their jobs properly due to extreme fatigue. As a result, it leads to unwanted accidents including serious injuries and fatality. In this study, the decision-making model has been developed in order to propose the best alternative in minimizing the fatigue among seafarer. Firstly, the contributed factors are identified through literatures and brainstorming with experts. As a result, nine factors for assessing the best solutions are identified which are rest hours, fitness, psychology and emotional, crew reduction, long working hours, workload, automation, ship design and stability, as well as noise and vibration. Thirdly, a generic hierarchical structure where it can be modified and adjusted based on decision makers' preferences is developed to provide a visual structure. Fourth, the AHP method is employed, prioritizing the contributed factors of fatigue among seafarer. The most significant factors are found to be fitness, long working hours, rest hour, workload, psychology and emotional, noise and vibration, crew reduction, ship design and stability, as well as automation. Finally, all influenced factors are assessed quantitatively by using the the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in order to obtain the best alternative in alleviating fatigue among seafarer. Consequently, Condition are Well Maintained (SCAWM) is found as the best alternative. By having this model, it can assist ship operator to identify which alternative is suitable based on their situation and condition. To sum up, fatigue among seafarers could impacted on safety issue and may lead towards precarious health condition over a long-term.

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