Analysis of performance influence factors on shipboard drills to improve ship emergency preparedness at sea

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Abstract: Emergency preparedness is a critical aspect of ship management. It is required to establish strict procedures including drill and exercise programs to response emergency situations at any time. This study develops an approach to identify and quantify the influence factors to ship emergency preparedness demonstrated in drills on-board. A fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method is considered as a suitable method for the problem. As a case study, the affecting factors to predefined steps of an operational firefighting drill organisation are analysed in oil/product tanker at Sarkoy anchorage area. Five homogeneous experts were asked to evaluate relationship among the generic factors affecting firefighting drills on-board ship with respect to the linguistic scale. While the factors insufficient firefighting practice and training, missing crew and missing supervisor, incorrect placement of portable tools, equipment or material in firefighting system are found as cause factors; lack of safety culture and discipline about the use of personnel protective/firefighting equipment and firefighting, crew reliability and fatigues of crews on board are found as effect factors. The study is expected to contribute to the forthcoming studies on prediction of ship emergency preparedness level on-board ships.

Keywords: ship emergency preparedness; firefighting drill; ship operation management.

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1 Introduction

The environmental conditions of the sea ranks the highest of all hazards with respect to assessment of risks to cases of vessel, cargo loss and damage, injuries and fatalities (Lu and Tsai, 2008). Since emergency situations can be encountered in every industry, emergency preparedness has an importance for most of industries however it has a crucial importance in maritime industry due to the reasons such as the remoteness, the need to be fully self-sufficient and harsh weather conditions which prevent external help (Vinnem, 2011). The goal of emergency preparedness is to be prepared to take the most appropriate action in the event that a hazard becomes a reality so as to minimise its effects and, if necessary, to transfer personnel from a location with a higher risk level to one with a lower risk level (Wang, 2002). Specifically, the recent maritime cases have addressed the loss of life and property occurred due to weakness at emergency situations (abandon ship, fire, collision, grounding, and other critical situations) at international waters. Therefore, academic and industrial organisations have focused on improving ship safety management at emergency situations. The evaluation of emergency, disaster and crisis management exercises supports both individual and organisational learning, facilitates the development of response capabilities, and helps to determine whether the current level of preparedness is good enough (Beerens and Tehler, 2016). Wu et al. (2014) highlighted that; as an important part of ship management, effectiveness evaluation of drills should be carried on board in order to determine current level of emergency preparedness.

In the light of interviews with shipping companies, it is clearly seen that; companies determine their fleet vessels emergency preparedness level through inspection/audit results, incident, accident, near miss analyses and drill performances (Tac et al., 2018). And a large and growing body of literature regarding emergency preparedness in maritime industry has investigated oil spill and prevention, supply chain, personnel transfer from offshore facilities and hazard identification. There is still need for an approach which is practical to implement on board in order to evaluate emergency preparedness. Considering the literature and industrial gaps and expectations it is aimed to evaluate critical factors influencing the ship emergency preparedness level at sea.

This paper presents fuzzy DEMATEL technique to identify and quantify the influence factors in shipboard drills which affects emergency preparedness. This section gives motivation behind the study, significance of emergency preparedness on board ships and the importance of evaluation of drills. Section 2 provides a literature reviewing on emergency preparedness in maritime industry. Section 3 introduces methodologies utilised in the paper. A case study regarding the firefighting drill on-board ship is illustrated in Section 4. The final section gives conclusion and contribution of the study.

2 Literature review on emergency preparedness

Maritime transportation plays a significant role in the integrated transportation system, particularly in international trade system (Zhang et al., 2014). According to Wang (2006), common accidents in the shipping industry include: contact/collision, explosion, external hazards, fire, and flooding, grounding/stranding, hazardous substance related failure, loss of hull integrity, machinery failure and handling equipment failure. He mentioned that; emergency preparedness is a fluid, dynamic concept that keeps changing over time, dependent on a particular event and the specific hazards encountered. Kristiansen (2013) declared key aspects related to emergency preparedness as; emergency and lifesaving regulations (i.e., SOLAS, the ISM code and STCW), human behaviour, evacuation risk and pollution emergency planning. As noted by Kwesi-Buor et al. (2016), the application of numerical risk assessment approach such as the IMO's formal safety assessment (FSA) framework may not be appropriate due to input uncertainties and possible data insufficiency. Although emergency preparedness has a vital importance, there are relatively few studies in the area of maritime transportation. Much of the current literature on emergency preparedness in maritime industry pays particular attention to oil spill and prevention. With the focus on increasing petroleum activities, there is a growing concern about the effectiveness of the systems for oil spill emergency preparedness (The Pew Charitable Trusts, 2013). Several researchers such as Lin et al. (2013), Santos et al. (2013), Knol and Arbo (2014), Huntington et al. (2015) and Aguilera et al. (2006) have conducted analysis on oil spill preparedness and prevention. On the other hand, a considerable amount of literature has been published on emergency preparedness in supply chain. Markmann et al. (2013) performed a Delphi-based risk analysis to identify and assess global, man-made risks for the long-term future of supply chain security. Kwesi-Buor et al. (2016) used a hybrid modelling technique to investigate the impacts of policy interventions on industry actors' preparedness to mitigate risks and to recover from disruptions along the maritime logistics and supply chain network. Asgari et al. (2015) provided a general framework, a set of criteria and sub-criteria to study the port sustainability performance considering five major ports in the UK via multi-criteria decision-making (MCDM) and analytical hierarchy process (AHP) methods. According to Alyami et al. (2019), it is possible to reduce and eliminate the effects of accidents and/or disasters in terminal operations by effective risk forecasting mechanism. Authors proposed a novel method to facilitate the application of failure mode and effects analysis (FMEA) in assessing the safety performance of a container terminal operational system by incorporating a fuzzy rule-based Bayesian network (FRBN) with evidential reasoning (ER) which enables to measure and predict system safety performance. Pristrom et al. (2016) investigated various maritime piracy and robbery issues and then presented a novel model in order to predict the likelihood of a piracy attack by analysing the characteristics of the ship, environment conditions and the maritime security measures via Bayesian network (BN) approach.

There is a relatively small body of literature that is concerned with emergency preparedness in offshore platforms. Brachner and Hvattum (2016) proposed a mathematical model to personnel transfer between onshore bases and offshore facilities, which is usually conducted by helicopters in order to answer unsolved emergency preparedness system in the High North region due to long distance, adverse environmental conditions. In 2017, authors proposed a mathematical combined routing and covering problem (CRCP) to plan the offshore personnel transportation system and the offshore preparedness system in Arctic region. Also Wang (2002) highlighted the need to transfer personnel from offshore facilities in case of emergency.

The existing literature on fire is not extensive and focuses particularly on hazard identification and root cause analysis. Schröder-Hinrichs et al. (2011) investigated accident investigation reports related to machinery space fires and explosions in order to find out what safety problems were addressed and whether organisational factors are identified during maritime accident investigations. Author used HFACS-MSS method in their study and significant data gaps with regard to organisational factors were identified. Soner et al. (2015) proposed HFACS and FCM model to analyse the fire related deficiency database in order to identify and prioritise the consistent root causes of fire on board. According to Ikeagwuani and John (2013); failures and uncertainties that can lead to machinery fires can be tackled using hazard identification and risk techniques and also proposing control options for reducing their likelihood. Authors found that leakages on hot surfaces were the major causes of fire hazards in seafaring vessels and other hazardous factors of fire in machinery spaces that require further investigation. Baalisampang et al. (2018) reviewed fire and explosion accidents that occurred in maritime transportation between 1990 and 2015 and tried to identify causal and underlying causes of these accidents. According to authors, causal factors of fire and explosion accidents are identified and categorised as human error, thermal reaction, electrical fault, mechanical failures and unknown. Authors also discussed potential preventative measures to prevent such accidents.

There are few studies attempted to evaluate the impact of emergency preparedness in other disciplines of maritime industry. Zhang et al. (2016) proposed combined fuzzy rule base technique and an ER algorithm in order to determine risk estimation of an inland waterway transportation system by analysing significant influencing factors which are mostly major causes of marine accidents. Mileski et al. (2014) investigated cruise ship mishaps and failures. According to authors, knowing the factors that contribute to mishaps and failures can provide a foundation of preparedness that may prevent future disasters in the cruise industry. Cwilewicz and Tomczak (2004) mentioned that computer-based training (CBT) simulation possibilities play a very important role in case of auxiliary machinery interactive programs, where perfect knowledge of different operational modes is required for achieving a high level of emergency preparedness.

In the light of above literature research it is obviously seen that; there have been limited studies undertaken through emergency preparedness in maritime transportation, current emergency preparedness evaluation methods do not provide a consistent approach and impractical to implement on board ships.

3 Methodological background

This study utilises fuzzy DEMATEL approach to assess critical factors affecting ship emergency preparedness level at sea. A fuzzy DEMATEL method is beneficial in finding out the relationships among the factors and ordering the criteria based on the type of relationships and severity of their effects on each other factors (Akyuz and Celik, 2015; Wu and Lee, 2007). The main advantage of fuzzy sets integrated DEMATEL is to consider the condition of the fuzziness and handle with flexibly with fuzziness situation (Wu, 2012). The next section presents theoretical background of both methodologies and integration of them.

3.1 Fuzzy sets

Fuzzy logic is a practical approach to tackle with the vagueness, ambiguity and uncertainty of judgment and assessment in decision-making (Akyuz et al., 2016; Akyuz, 2016). Conceptually, decision-making problems involve imprecision since goals, constraints, and possible actions are not known precisely (Zadeh, 1965). In the fuzzy logic, linguistic statements of experts' are converted in to fuzzy numbers. A triangular fuzzy numbers, in this context, can be described as a triplet $\tilde{A} = (l, m, u)$ where l, m and u denote lower, medium and upper numbers of the fuzzy sets ($x \le y \le z$). The membership function of a triangular fuzzy number can be defined as follows (Zadeh, 1965).

$$\mu_{\tilde{A}} = \begin{cases} 0, & x < l \\ (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0, & x \ge u \end{cases} \tag{1}$$

Accordingly, Figure 1 illustrates a triangular fuzzy numbers. The relationship among the linguistic terms and triangular fuzzy numbers are determined with respect to the Table 1. Figure 2 shows fuzzy rating and their membership function respectively.

Figure 1 Triangular fuzzy number

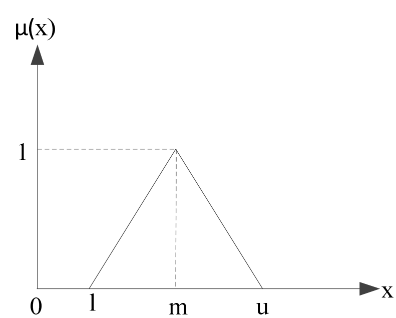
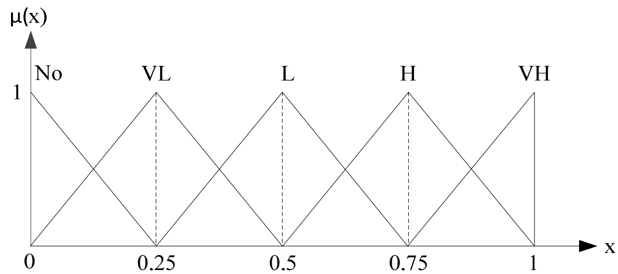


Table 1 The relationship among the linguistic terms and triangular fuzzy numbers

Linguistic terms	*Triangular fuzzy numbers*
No influence (no)	(0, 0, 0.25)
Very low influence (VL)	(0, 0.25, 0.5)
Low influence (L)	(0.25, 0.5, 0.75)
High influence (H)	(0.5, 0.75, 1)
Very high influence (VH)	(0.75, 1, 1)

Figure 2 Fuzzy rating and their membership function



For any of two triangular fuzzy numbers $\tilde{A}_1 = (l_1, m_1, u_1)$ and $\tilde{A}_2 = (l_2, m_2, u_2)$, the mathematical calculation of them are summarised as follows:

The aggregation between the triangular fuzzy numbers:

$$\tilde{A}_1 + \tilde{A}_2 = \left(l_1 + l_2, m_1 + m_2, u_1 + u_2\right) \tag{2}$$

The subtraction between the triangular fuzzy numbers:

$$\tilde{A}_1 - \tilde{A}_2 = \left(l_1 - u_2, m_1 - m_2, u_1 - l_2\right) \tag{3}$$

The multiplication between the triangular fuzzy numbers:

$$\tilde{A}_1 \times \tilde{A}_2 = \left(l_1 \times l_2, m_1 \times m_2, u_1 \times u_2\right) \tag{4}$$

The arithmetic means of the triangular fuzzy numbers:

$$k \times \tilde{A}_1 = \left(k \times l_1, k \times m_1, k \times u_1\right), (k > 0) \tag{5}$$

$$\frac{\tilde{A}_1}{k} = \left(\frac{l_1}{k}, \frac{m_1}{k}, \frac{u_1}{k}\right), (k > 0) \tag{6}$$

3.2 DEMATEL technique

The DEMATEL is one of the useful MCDM model frequently used to discuss complex and comprehensive decision-making problems (Gabus and Fontela, 1972). The aim of the method is to find out cause and effect relationship among the criteria (Lin and Tzeng, 2009). Conceptually, the technique is based on the graph theory which allows examining and explaining problems by visualisation (Lin et al., 2013). It provides the interdependence relationship among the factors as well as values of influential effect (Akyuz and Celik, 2015). This method is superior to conventional techniques due to exposing the relationships between criteria, ranking the criteria relating to the type of relationships and revealing intensity of their effects on each criterion (Seker and Zavadskas, 2017). The main steps of the DEMATEL are defined as follows (Celik and Akyuz, 2017).

Step 1 In the first step, an initial direct-relation matrix is built for pair wise comparison. A group of experts who have knowledge and experience about is problem is determined. Then experts are asked to assess affect among each factor pairs. After linguistic assessment of experts is converted to real values, the direct-relation matrix is established. Accordingly, $A = [a_{ij}]$, where A is a $n \times n$ non-negative matrix, a_{ij} states the direct impact of factor i on factor j; and when $i = j$, the diagonal elements $a_{ij} = 0$.

Step 2 In order to compare the factors, the initial direct-relation matrix is normalised. A normalised direct-relation matrix, $D = [d_{ij}]$, is calculated by using equations (7) and (8). All elements in matrix D are complying with $0 \le d_{ij} \le 1$.

$$s = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \quad i, j = 1, 2, \dots, n \tag{7}$$

$$D = s.A \tag{8}$$

Step 3 In the third step, a total-relation matrix (T) is determined by using the equation (9) where I gives $n \times n$ identity matrix. The element t_{ij} represents the indirect effects that criterion i have on criterion j, so that the matrix T gives the total relationship among the each pair of factors.

$$T = D(I - D)^{-1} \tag{9}$$

Step 4 The sum of rows and columns of matrix T are determined in this step. r_i and c_j are determined according to the equations (10) and (11) respectively. In the equation, while r_i states all direct and indirect influence given by criterion i to all other factors, c_j gives the degree of influenced impact.

$$r_i = \sum_{1 \le j \le n} t_{ij} \tag{10}$$

$$c_j = \sum_{1 \le i \le n} t_{ij} \tag{11}$$

When $i = j$, $r_i + c_j$ presents all effects that are given and received by criterion i. That is, $r_i + c_j$ indicates both criterion i's impact on the entire system and other system factors impact upon factor i. Thus, the indicator $r_i + c_j$ implies the degree of importance that criterion i in the total system. On the other hands, the difference of the two, $r_i - c_j$, denotes the net effect that criterion i has on the system. Particularly, if the value of $r_i - c_j$ is positive, the factor i will be a net cause. When $r_i - c_j$ is negative, the factor will be a net result clustered into effect group (Akyuz and Celik, 2015; Yang et al., 2008).

Step 5 In the last step, a cause and effect relationship diagram is figured with respect to the $r_i + c_j$ and $r_i - c_j$. Hence, the complex interrelationship among factors is visualised easily.

3.3 Proposed approach: fuzzy DEMATEL

In this section, fuzzy sets and DEMATEL method are combined in order to identify and quantify the influence factors in firefighting drill which affects emergency preparedness. Integration of fuzzy sets and DEMATEL methods are expressed step by step (Akyuz and Celik, 2015). A conceptual framework of the proposed approach is depicted in Figure 3.

Step 1 *A group of experts:* expert judgements can be a solution in decision-making problem since data scarcity is a common problem in maritime industry. Particularly, the linguistic assessment of experts is practical when dealing with conditions that are defined in quantitative (Akyuz et al., 2018). The linguistic judgements of marine experts are used to transform idea of decision makers into valuable information. At this point, the fuzzy logic tackles with the vagueness, ambiguity and uncertainty of judgment and assessment in decision-making (Soner et al., 2015). In this step, it is consulted to the experts who have enough knowledge and experience about the problem in order to obtain judgments (Eglin et al., 2004). Homogeneous expert group, whose opinions are considered with the same intensity, has been selected for this study. They were asked to evaluate relationship among the generic factors affecting firefighting drills on-board ship with respect to the linguistic scale. Twenty questions, addressing to determine cause and effect relationship among the factors, were asked to marine experts. The survey was sent to the experts in excel format via e-mail and arithmetic means of their judgements are obtained.

Step 2 *Determine factors and construct fuzzy scale:* important factors are determined in order to perform evaluation. Then, linguistic variable is used in accordance with five fuzzy scales (no influence, very low influence, low influence, high influence, and very high influence). Thereafter, corresponding triangular fuzzy members are determined.

Step 3 *Obtain evaluation of the group decision-makers:* the pair wise comparison is constructed in terms of linguistics variables. Then, the fuzzy assessments are transformed into defuzzified and aggregated as a crisp value. As a result, initial direct-relation fuzzy matrix $\tilde{E}$ is established. Following equations are used respectively.

$$\tilde{E} = \begin{bmatrix} 0 & \cdots & \tilde{E}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{E}_{n1} & \cdots & 0 \end{bmatrix} \tag{12}$$

$$\tilde{e}_{ij} = \left(l_{ij}, m_{ij}, u_{ij} \right) \tag{13}$$

Step 4 *Constructed normalised direct-relation fuzzy matrix:* in the presence of the initial direct-relation matrix, a normalised direct-relation fuzzy matrix is constructed. To achieve this purpose, the following equations are adopted. In the equations, $\tilde{\beta}_i$ and γ denote triangular fuzzy numbers.

$$\tilde{\beta}_i = \sum \tilde{e}_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij} \right) \tag{14}$$

$$\gamma = \max \left(\sum_{j=1}^{n} u_{ij} \right) \tag{15}$$

The linear scale transformation, then, is applied to convert the factors into comparable scales. The normalised direct-relation fuzzy matrix $\tilde{F}$ of experts is calculated as follows.

$$\tilde{F} = \begin{bmatrix} \tilde{F}_{11} & \cdots & \tilde{F}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{F}_{n1} & \cdots & \tilde{F}_{nn} \end{bmatrix} \tag{16}$$

where $\tilde{f}_{ij} = \dfrac{\tilde{e}_{ij}}{\gamma} = \left(\dfrac{\tilde{e}_{ij}}{\gamma}, \dfrac{\tilde{e}_{ij}}{\gamma}, \dfrac{\tilde{e}_{ij}}{\gamma} \right).$

Step 5 *Calculate total-relation fuzzy matrix:* after established normalised direct-relation fuzzy matrix, a total-relation fuzzy matrix is calculated by ensuring of $\lim_{\omega \to \infty} F^{\omega} = 0.$ The crisp case of the total-relation fuzzy matrix is expressed as follows.

$$\tilde{T} = \lim_{\omega \to \infty} \left(\tilde{F} + \tilde{F}^2 + \cdots + \tilde{F}^{\omega} \right) \tag{17}$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \cdots & \tilde{t}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \cdots & \tilde{t}_{nn} \end{bmatrix} \tag{18}$$

where $\tilde{t}_{ij} = (l''_{ij}, , m''_{ij}, u''_{ij}).$

$$Matrix\left[l''_{ij} \right] = F_l \times \left(I - F_l \right)^{-1} \tag{19}$$

$$Matrix\left[m''_{ij} \right] = F_m \times \left(I - F_m \right)^{-1} \tag{20}$$

$$Matrix\left[u''_{ij} \right] = F_u \times \left(I - F_u \right)^{-1} \tag{21}$$

Step 6 *Analyse the structural model:* after calculated matrix $\tilde{T}, \tilde{r}_i + \tilde{c}_j$ and $\tilde{r}_i - \tilde{c}_j$ are determined. In the formula, $\tilde{r}_i$ and $\tilde{c}_j$ gives the sum of the rows and columns of matrix $\tilde{T}$. Since the $\tilde{r}_i + \tilde{c}_j$ presents the importance of factor *i*, $\tilde{r}_i - \tilde{c}_j$ states the net effect of factor *i*.

Step 7 *Defuzzified $\tilde{r}_i + \tilde{c}_j$ and $\tilde{r}_i - \tilde{c}_j$:* the $\tilde{r}_i + \tilde{c}_j$ + and $\tilde{r}_i - \tilde{c}_j$ are defuzzified by adopting centre of area (COA) defuzzification method presented by Ross (1995) to determine best non-fuzzy performance (BNP) values. For a convex fuzzy number $\tilde{\delta}$ a real number z^* corresponding to its COA, can be estimated with following equation (Akyuz and Celik, 2015; Gumus et al., 2013).

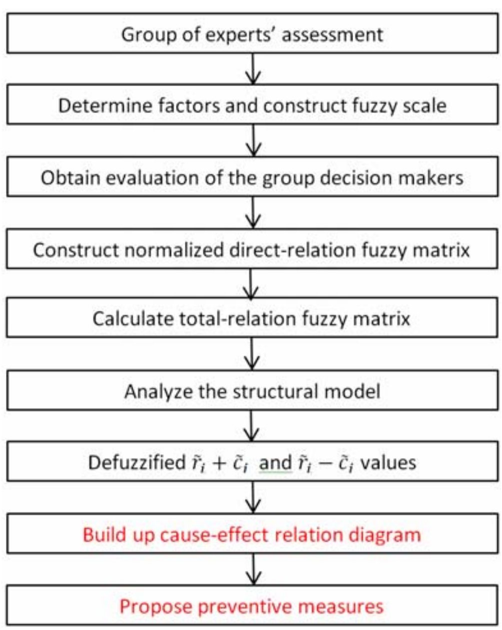
$$z^* = \frac{\int \mu_{\tilde{\delta}}(z) z dz}{\int \mu_{\tilde{\delta}}(z) dz} \tag{22}$$

The BNP value of a fuzzy number $\tilde{G} = (l_{ij}, m_{ij}, u_{ij})$ is calculated according to following equation.

$$BNP_{ij} = \frac{u_{ij} - l_{ij} + m_{ij} - l_{ij}}{3} + l_{ij} \tag{23}$$

Step 8 *Build up cause-effect relation diagram:* in the last step, the cause and effect relation diagram is depicted by mapping the dataset of $\tilde{r}_i + \tilde{c}_j$ and $\tilde{r}_i - \tilde{c}_j$. The calculation can be done according to the step 6.

Figure 3 Conceptual framework (see online version for colours)



4 Case study

In this section, the affecting factors to predefined steps of an operational firefighting drill organisation are analysed as a case study.

4.1 Problem statement

Fire on-board ship is one of the most challenging and fatal events at sea (Soner et al., 2015) since it can lead to loss of cargo and the ship, environment pollution, injuries and death (Soner et al., 2017; Akyuz, 2015). PSC survey results clearly demonstrate the vulnerability of the fire safety measures on board ships. It has been noted that fire safety measures, safety of navigation and life-saving appliances continue to be the top three categories of deficiencies discovered on ships according to the Tokyo MOU (2017) PSC annual report. Paris MOU (2017) statistics about fire safety related deficiencies illustrate approximately 13.1%, and Black Sea MOU (2017) statistics illustrate approximately 12.5% of total deficiencies constituted by fire safety. Also fire safety issues as the most common area for detainable deficiencies. In order to prevent fire risk on board ships, the ship managers and professionals should ensure effective implementation of a safety management system in accordance with the international safety management (ISM) code (Soner et al., 2015; Akyuz and Celik, 2014).The fire drill, in this context, provides the opportunity to plan and exercise command and control techniques, and to allow fire team members the opportunity to see, feel, and use equipment they need to extinguish a real fire (Veenstra and Projectgroup, 2015). In this study, the affecting factors to predefined steps of an operational firefighting drill organisation are analysed to predict of ship emergency preparedness level on-board ships.

4.2 A real case study through firefighting drill application on-board ship

A real shipboard firefighting drill is applied as illustrative example since each ship must carry out fire-fighting drill at least once a month on-board ship as per SOLAS regulation. The fire drill was conducted on 7th September 2017 at 3.00 PM in crude carrier ship which is capable of carrying 115 thousand tons of crude oil cargo. It was performed at Sarkoy anchorage area while the ship was waiting at anchorage. The weather was calm and sea was smooth. Wind speed was around ten knots. All ship crew was participated to fire-fighting drill except watch keepers. During the firefighting drill, pre and post activities were recorded by hand camera. A fire alarm was sounded along with the location and type of the fire by master. Then, each crew member mustered at muster station. Each fire team was gathered to respond to fire. Then, firefighting drill commenced to respond to the fire in the chemical store. Fireman's outfits' donned, portable extinguishers are brought to scene, hoses were laid, and fire pump started, both deck and engine teams responded to fire. At the end of drill, pre and post activities of firefighting drill were determined. The factors affecting the predefined steps of an operational firefighting drill organisation is analysed for entire procedures to predict of ship emergency preparedness level on-board ships. Table 2 shows generic factors affecting fire-fighting drills on-board ship.

Table 2 Generic factors affecting firefighting drills on-board ship

Code	*Factor*
F1	Un pre-defined scenario and scenario realism
F2	Lack of knowledge and education level of officers/engineers
F3	Insufficient firefighting training and practice
F4	Missing crew
F5	Missing supervisor
F6	Experience of crew
F7	Insufficient supervisor experience in rank
F8	No learning objectives defined in previous drills
F9	External factors (weather, sea state, wind, etc.)
F10	Unclearly pre-defined crew's task in muster list
F11	Lack of safety culture and discipline about the use of personal protective/firefighting equipment and firefighting
F12	Fatigues of crews on board
F13	Insufficient physical capability (age, weight)
F14	Illness and health problems of crew
F15	Being under the influence of alcohol and drug
F16	Crew reliability
F17	Failure on firefighting/communication equipment
F18	Neglected items in firefighting equipment routine inspection check list
F19	Incorrect placement of portable tools, equipment or material in firefighting system
F20	Wrong IMO labelling of firefighting equipment

4.3 Analysis of respondents

A comprehensive survey was performed with five marine experts. The survey was sent to the experts in excel format along with cover letter, instructions, descriptions of dimensions and the criteria, pair-wise comparison of the criteria, demographic data and company information. The respondents were asked to evaluate the pair wise influence between criteria, such as what is the degree of influence that 'un pre-defined scenario and scenario realism' has on 'crew reliability', giving five choices in linguistic terms: no influence, very low influence, low influence, high influence, very high influence. Marine experts have been working in a reputable tanker ship management company which has six crude oil tanker ships in their fleet and reputable bulk carrier company which has 16 bulk vessels in their fleet. The profile of marine experts includes superintendents and safety manager (HSEQ) who have wide experiences on-board as a master and chief engineer. The experts have 'advanced fire fighting training certificate' as per STCW Code Reg. VI/3, Sec. A-VI/3, and Table VI/3. They meet minimum requirements for standard of competence in advanced firefighting such as; control fire-fighting operations aboard ships, organise and train fire parties, inspect and service fire-detection and fire-extinguishing systems and equipment, investigate and compile reports on incidents involving fire. Moreover, the experts participated various drills on-board ships as a supervisor and team member during their sea service. The experts whose competencies are oceangoing master had role as supervisors during fire drills conducted on deck, accommodation, bridge, paint store etc. The expert whose competency is oceangoing chief engineer had role as supervisor on fire drills conducted in engine room. Detailed characteristics of the five decision-making experts are given in Table 3. Since there were five marine experts participated to survey, the arithmetic means of their judgements are obtained.

4.4 Empirical analysis

The firefighting drill recorded on-board ship is presented to marine experts along with generic factors before empirical analysis. The marine experts assess relationship between the generic factors by using fuzzy linguistic scale presented in Table 1. Accordingly, Table 4 depicts linguistic assessments of the marine experts.

After aggregating marine experts' evaluation, an initial direct-relation fuzzy matrix, as illustrated in Table 5, is figured out. Then, a normalised direct-relation fuzzy matrix is constructed by using equations (14)–(16) respectively. Table 6 shows the normalised direct-relation fuzzy matrix. Thereafter, a total-relation fuzzy matrix can be calculated by adopting equations (17)–(21). Table 7 provides the total-relation fuzzy matrix.

The fuzzy values of $\tilde{r}_i, \tilde{c}_j, \tilde{r}_i + \tilde{c}_j, \tilde{r}_i - \tilde{c}_j,$ figured in Table 8, is calculated by using total relation matrix. Then, defuzzification process is performed to convert the fuzzy numbers into crisp values. By using equations (22) and (23), the crisp values of the r_i, c_j, $r_i + c_j$, $r_i - c_j$, provided in Table 9, is calculated to assess cause-effect relation.

4.5 Findings and discussion

In the view of outcomes presented in r_i, c_j, $r_i + c_j$, $r_i - c_j$ Table 9, Figure 4 shows the cause-effect relation diagram. According to the diagram, the factors affecting predefined steps of an operational firefighting drill can be divided into two significant groups; cause and effect factors.

Figure 4 Cause-effect relation diagram (see online version for colours)

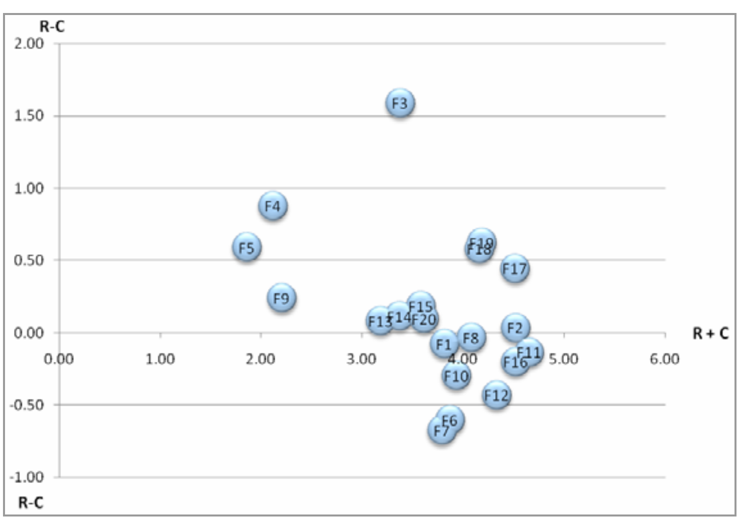


Table 3 The characteristics of the five decision-making experts

Experts	*Age*	*Education level*	*Competency*	*Sea experience (years)*	*Shore experience (years)*	*Job title*	*Job responsibility*
Expert 1	49	Bachelor in Maritime Management and Transportation Engineering	Oceangoing master	14	12	HSEQ manager	To monitor the effectiveness and compliance with HSEQ programs and initiatives; to develop policies, procedures and campaigns to enhance health, safety, environment and quality assurance on board; to track internal alcohol tests and initiate external D&A tests as necessary; to ensure that the emergency response room is updated and in readiness at all times to manage an emergency; to ensure effective closure of audit findings and incidents, and inspection deficiencies related to HSEQ, through appropriate corrective and preventive actions and to approve close out of incidents and audit corrective actions. Fire related job responsibilities: to investigate and prepare reports of fire incidents; to prepare campaigns to increase fire safety awareness; to prepare close out of deficiencies/ non-conformities related fire recorded on both internal and external audits/inspections.
Expert 2	44	Bachelor in Maritime Management and Transportation Engineering	Oceangoing master	12	9	Safety superintendent	To carry out ISM/ISPS internal audits; to schedule and organise external audits; to implement ISM procedures; GAP analyses and research the innovative ideas to improve the system to meet industrial requirements. Fire related job responsibilities: to inspect fire-detection and fire-extinguishing systems and equipment on board and train the personnel if needed; to arrange service for the certification and calibration of the fire-extinguishing systems and equipment; to decide the selection of most appropriate fire equipment purchase as per rules and regulations.
Expert 3	41	Bachelor in Marine Engineering	Oceangoing chief engineer	10	8	Marine superintendent	Responsible for the overall technical operations that include overseeing the daily operations of maintenance and repair, budgeting, survey schedules, inspections of the assigned fleet vessels. To monitor the PMS and ensure proper implementation on board the managed vessels and upgrade company's PMS to improve reliability of machinery, equipment and ensuring the application in the most efficient way while complying with the SMS. Fire related job responsibilities: to control fire-detection and fire-extinguishing systems and equipment on board such as isolation valves, fire pumps, etc., and to ensure their proper working and leak tightness; to track maintenance of fixed CO2, fixed foam and hyper mist systems; to prepare reports of fire incidents in machinery.

Table 3 The characteristics of the 5 decision-making experts (continued)

Experts	*Age*	*Education level*	*Competency*	*Sea experience (years)*	*Shore experience (years)*	*Job title*	*Job responsibility*
Expert 4	42	Bachelor in Maritime Management and Transportation Engineering	Oceangoing master	8	8	Marine superintendent	To ensure certification of vessel are valid and to avoid failure due non-compliance; to ensure vessels are meeting reporting requirements and proper documentation as per ISM, ISPS, OHSAS 18000 and ISO 14001; to ensure ISM, ISPS and ISO compliances, with properly organised audit plans and efficient preparation, to minimise NCN and OBS; to ensure compliance with applicable legal and other requirements by all vessels and raise corrective action when necessary; and a member of the shore emergency response team for the vessels they are in charge of. Fire related job responsibilities: to inspect fire-detection and fire-extinguishing systems and equipment on board, to arrange service for the certification and calibration of the fire-extinguishing systems and equipment; to request extension for the annual service from flag state if needed.
Expert 5	45	Bachelor in Maritime Management and Transportation Engineering	Oceangoing master	13	10	ISM/vetting superintendent	To promote the SMS policy and culture on board vessels; to demonstrate his commitment to safety and environmental excellence, by his behaviour; to suggest improvements/ modifications of the SMS; to carry out Investigating accidents, incidents and serious near misses; to review all reports of non-conformities, incidents or near misses received by the vessels assigned to him and to follow-up the implementation and verification of corrective/preventive actions process inclusive their effectiveness. To participate in the emergency response team, as delegated by the general manager. Fire related job responsibilities: to arrange service for the certification and calibration of the fire-extinguishing systems and equipment; to request extension for the annual service from flag state if needed; to track fire-extinguishing systems and equipment certificates updated.

Table 4 Linguistic assessments of the marine experts

	F1	*F2*	*F3*	…..	*F19*	*F20*
F1	(NO, NO, NO, NO, NO)	(H, L, H, L, L)	(L, NO, L, L, L)	……	(VL, L, VL, NO, NO)	(VL, NO, NO, VL, L)
F2	(VL, NO, VH, VL, VH)	(NO, NO, NO, NO, NO)	(H, VH, VH, H, VH)	……	(NO, VH, H, NO, H)	(H, VH, H, NO, NO)
F3	(VL, NO, VH, VL, VH)	(H, VH, VH, H, VH)	(NO, NO, NO, NO, NO)	……	(H, VH, H, H, H)	(H, H, H, H, VH)
F4	(H, NO, NO, H, NO)	(H, NO, NO, H, NO)	(L, L, NO, L, NO)	……	(NO, NO, NO, NO, NO)	(NO, NO, NO, NO, NO)
F5	(VL, NO, NO, VL, NO)	(VL, NO, VL, NO, NO)	(VL, L, NO, VL, NO)	……	(NO, NO, NO, NO, NO)	(NO, NO, NO, NO, NO)
F6	(NO, NO, VH, NO, VH)	(NO, NO, H, NO, H)	(NO, L, H, NO, H)	……	(NO, VH, NO, NO, NO)	(NO, VH, NO, NO, NO)
F7	(NO, NO, VH, NO, VH)	(NO, NO, H, NO, H)	(NO, L, VH, NO, VH)	……	(NO, VH, NO, NO, NO)	(NO, VH, NO, NO, NO)
F8	(NO, NO, VH, NO, VH)	(VL, L, H, VL, H)	(VH, L, H, VH, H)	……	(NO, H, H, NO, H)	(NO, H, H, NO, H)
F9	(NO, NO, VL, NO, VL)	(NO, NO, NO, NO, NO)	(NO, NO, VL, NO, VL)	……	(NO, NO, NO, NO, NO)	(NO, NO, NO, NO, NO)
F10	(H, NO, H, H, H)	(H, NO, H, H, H)	(VL, NO, H, VL, H)	……	(NO, L, NO, NO, NO)	(NO, L, NO, NO, NO)
F11	(L, NO, VH, L, VH)	(L, NO, H, L, H)	(VL, NO, VH, VL, VH)	……	(VL, VH, NO, VL, NO)	(VL, VH, NO, VL, NO)
F12	(H, NO, VL, H, VL)	(L, NO, VL, L, VL)	(NO, NO, VL, NO, VL)	……	(NO, H, NO, NO, NO)	(NO, H, NO, NO, NO)
F13	(NO, NO, L, NO, L)	(NO, NO, L, NO, L)	(NO, NO, L, NO, L)	……	(NO, H, NO, NO, NO)	(NO, H, NO, NO, NO)
F14	(NO, NO, VH, NO, VH)	(NO, NO, L, NO, L)	(NO, NO, VL, NO, VL)	……	(NO, H, NO, NO, NO)	(NO, H, NO, NO, NO)
F15	(NO, NO, H, NO, H)	(NO, NO, VL, NO, VL)	(NO, NO, VL, NO, VL)	……	(NO, VH, NO, NO, NO)	(NO, VH, NO, NO, NO)
F16	(NO, NO, H, NO, H)	(VL, NO, H, VL, H)	(VL, NO, H, VL, H)	……	(VL, VH, NO, VL, NO)	(VL, VH, NO, VL, NO)
F17	(VL, NO, VL, VL, VL)	(H, NO, H, H, H)	(H, NO, L, H, L)	……	(H, H, NO, H, NO)	(L, H, NO, L, NO)
F18	(NO, NO, VL, NO, VL)	(VH, NO, VL, VH, VL)	(L, NO, H, L, H)	……	(H, VH, NO, H, NO)	(H, VH, NO, H, NO)
F19	(L, NO, VL, L, VL)	(VH, NO, VL, VH, VL)	(H, NO, H, H, H)	……	(NO, NO, NO, NO, NO)	(H, VH, NO, H, NO)
F20	(NO, NO, VL, NO, VL)	(VH, NO, VL, VH, VL)	(L, NO, H, L, H)	……	(H, VH, NO, H, NO)	(NO, NO, NO, NO, NO)

Table 5 The initial direct-relation fuzzy matrix

	F1	*F2*	*F3*	...	*F19*	*F20*
F1	(0, 0, 0.25)	(0.35, 0.60, 0.85)	(0.20, 0.40, 0.655)	…	(0.05, 0.20, 0.45)	(0.05, 0.20, 0.45)
F2	(0.30, 0.50, 0.65)	(0, 0, 0.25)	(0.65, 0.90, 1)	…	(0.35, 0.50, 0.70)	(0.35, 0.50, 0.70)
F3	(0.30, 0.50, 0.65)	(0.65, 0.90, 1)	(0, 0, 0.25)	…	(0.55, 0.80, 1)	(0.55, 0.80, 1)
⋮	⋮	⋮	⋮	⋮	⋮	⋮
F19	(0.10, 0.30, 0.55)	(0.30, 0.50, 0.65)	(0.40, 0.6, 0.85)	…	(0, 0, 0.25)	(0.35, 0.50, 0.70)
F20	(0, 0.10, 0.35)	(0.30, 0.50, 0.65)	(0.30, 0.50, 0.75)	…	(0.35, 0.50, 0.70)	(0, 0, 0.25)

Table 6 The normalised direct-relation fuzzy matrix

	F1	*F2*	*F3*	...	*F19*	*F20*
F1	(0, 0, 0.02)	(0.03, 0.05, 0.07)	(0.02, 0.03, 0.04)	…	(0.00, 0.02, 0.03)	(0.01, 0.02, 0.03)
F2	(0.02, 0.04, 0.05)	(0, 0, 0.02)	(0.05, 0.07, 0.08)	…	(0.03, 0.04, 0.05)	(0.03, 0.04, 0.05)
F3	(0.02, 0.04, 0.05)	(0.05, 0.07, 0.08)	(0, 0, 0.02)	…	(0.04, 0.06, 0.08)	(0.04, 0.06, 0.08)
⋮	⋮	⋮	⋮	⋮	⋮	⋮
F19	(0.01, 0.02, 0.04)	(0.02, 0.04, 0.05)	(0.03, 0.05, 0.07)	…	(0, 0, 0.02)	(0.03, 0.04, 0.05)
F20	(0, 0.01, 0.03)	(0.02, 0.04, 0.05)	(0.02, 0.04, 0.06)	…	(0.03, 0.04, 0.05)	(0, 0, 0.02)

Table 7 The total-relation fuzzy matrix

	F1	*F2*	*F3*	...	*F19*	*F20*
F1	(0.01, 0.02, 0.20)	(0.03, 0.07, 0.27)	(0.02, 0.06, 0.26)	…	(0.01, 0.04, 0.21)	(0.01, 0.03, 0.20)
F2	(0.03, 0.06, 0.26)	(0.01, 0.04, 0.26)	(0.06, 0.10, 0.32)	…	(0.04, 0.07, 0.25)	(0.04, 0.07, 0.25)
F3	(0.03, 0.07, 0.28)	(0.06, 0.11, 0.34)	(0.01, 0.04, 0.28)	…	(0.05, 0.09, 0.29)	(0.05, 0.09, 0.29)
⋮	⋮	⋮	⋮	⋮	⋮	⋮
F19	(0.02, 0.05, 0.27)	(0.03, 0.07, 0.31)	(0.04, 0.08, 0.32)	…	(0.01, 0.03, 0.23)	(0.03, 0.06, 0.26)
F20	(0.01, 0.03, 0.21)	(0.03, 0.06, 0.26)	(0.03, 0.06, 0.26)	…	(0.03, 0.06, 0.22)	(0.01, 0.01, 0.19)

Table 8 Fuzzy values of $\tilde{r}_i, \tilde{c}_j, \tilde{r}_i + \tilde{c}_j, \tilde{r}_i - \tilde{c}_j$

	$\tilde{r}_i$	$\tilde{c}_j$	$\tilde{r}_i + \tilde{c}_j$	$\tilde{r}_i - \tilde{c}_j$
F1	(0.32, 0.83, 4.46)	(0.39, 0.92, 4.54)	(0.71, 1.75, 8.99)	(–4.21, –0.09, 4.07)
F2	(0.53, 1.15, 5.15)	(0.47, 1.10, 5.16)	(1.00, 2.25, 10.31)	(–4.63, 0.05, 4.68)
F3	(0.59, 1.28, 5.59)	(0.46, 0.60, 1.62)	(1.05, 1.87, 7.21)	(–1.04, 0.68, 5.12)
…	…	…	…	…
F19	(0.52, 1.19, 5.50)	(0.36, 0.78, 4.20)	(0.88, 1.97, 9.70)	(–3.69, 0.41, 5.14)
F20	(0.34, 0.83, 4.40)	(0.35, 0.77, 4.16)	(0.70, 1.59, 8.56)	(–3.81, 0.06, 4.05)

Table 9 Crisp values of the r_i, c_j, $r_i + c_j$, $r_i - c_j$

	r_i	c_j	$r_i + c_j$	$r_i - c_j$
F1	1.870	1.949	3.819	–0.079
F2	2.277	2.243	4.520	0.034
F3	2.483	0.896	3.379	1.587
F4	1.497	0.621	2.117	0.876
F5	1.225	0.634	1.859	0.591
F6	1.634	2.239	3.873	–0.604
F7	1.558	2.233	3.791	–0.675
F8	2.025	2.059	4.084	–0.034
F9	1.224	0.985	2.209	0.239
F10	1.818	2.114	3.932	–0.296
F11	2.260	2.395	4.655	–0.136
F12	1.951	2.381	4.332	–0.430
F13	1.634	1.552	3.186	0.083
F14	1.742	1.627	3.369	0.115
F15	1.883	1.698	3.581	0.184
F16	2.160	2.360	4.520	–0.200
F17	2.480	2.037	4.517	0.444
F18	2.371	2.193	4.812	0.425
F19	2.403	2.180	4.805	0.444
F20	1.858	2.160	4.305	–0.016

4.5.1 Cause factors

In order to identify and quantify the influence factors in firefighting drill which affects emergency preparedness, it is very significant to concentrate on the cause factors which require more attention. The value of $r_i - c_j$ gives significant casual factors affecting the predefined steps of an operational firefighting drill. According to the Table 9, F3 (insufficient firefighting training and practice) has the highest $r_i - c_j$ value among all the factors. It means that F3 has significant influence. Also, the F3 has quite high r_i value among all the factors from the point of influential impact degree when compared to the other factors. It shows that F3 has the considerable impacts on the other factors. The second most important causal factor is F4 (missing crew) as it has the second highest $r_i - c_j$ value. It has great influence on the entire process although the value of r_i is not quite high. Likewise, F5 (missing supervisor) is a significant causal factor influencing predefined steps of an operational firefighting drill since it ranks third on the top. The moderate r_i value of F5 could not dispute the reality that it has a considerable influence on the entire process. Sequentially, F19 (incorrect placement of portable tools, equipment or material in firefighting system) and F18 (neglected items in firefighting equipment routine inspection check list) are another significant factors affecting predefined steps of an operational firefighting drill since they have quite higher $r_i - c_j$ values as well as r_i values.

4.5.2 Effect factors

The effect factors can be defined as the factors which are easily impacted by the others. Considering the importance of cause factors, the effected factors can pose a major challenge and it is necessary to analyse effect factors which may cause unintended consequences in emergency situations on board. The value of $r_i + c_j$ gives idea about the influence of effect factors. In the view of findings, F11 (lack of safety culture and discipline about the use of personnel protective/firefighting equipment and firefighting) has the highest $r_i + c_j$ value among the all factors. In addition, it is degree of influential impact index (r_i) and influenced impact index (c_j) values are considerable high among all factors. Thus, F11 has potential effect on predefined steps of an operational firefighting drill. Likewise, F16 (crew reliability) has the second highest $r_i + c_j$ values. The c_j and r_i value of F16 seemingly are quite high when compared to other factors. Therefore, the F16 has significant effects on the on predefined steps of an operational firefighting drill. The other influential factor over the firefighting drill is F12 (fatigues of crews on board) as it ranks on the third according to the $r_i + c_j$.

4.5.3 Discussion

Insufficient firefighting practice and training found as the most causal factor affecting firefighting drill. Although international maritime regulations require that all personnel employed on board receive proper familiarisation training (IMO, 2010; ISM Code, 2014), there is a lack of standardisation of vessel design, which leads to significant amount of diversity in layouts and structure, making familiarisation a tailored process applied to each vessel (Tvedt et al., 2018).

While the training at shore is completed, on board training is mostly disregarded or postponed. Insufficient firefighting practice and training on board mostly results from work overload, time limitation or lack of safety awareness. Insufficient firefighting training and practice may cause to increase of response time when decision-making with missing knowledge and imperfect familiarisation in case of fire. In the light of findings, the missing crew and missing supervisor are the second substantial causal factors. The missing crew could pose serious impact on the consequences. Each emergency response team, appointed by the master of ship according to the SOLAS muster list, has an important role during emergency response. Therefore, missing crew could cause to disrupt the system during emergency situation such as fire on-board ship. Likewise, supervisor such as master of chief officer, is one of the most important crew members in response team since he/she manages whole process along with crew member. Incorrect placement of portable tools, equipment or material in firefighting system and neglected items in firefighting equipment routine inspection check list is another significant causal factor affecting firefighting drill. These factors mostly resulted from lack of safety awareness, discipline and lack of familiarisation.

According to Karahalios (2017), a fast reaction from a well-trained crew that will follow clearly the procedures may ensure their safety and minimise ship damage in case of fire. Lack of safety culture and discipline with respect to using of personnel protective/firefighting equipment are also found the most significant effect factor in this study. Lack of safety culture addresses to the shipping company and leads to negative attitudes towards safety awareness and increased resistance to safety initiatives. Human (ship crew) reliability is one of the other significant factor affecting operational process of the firefighting drill. Human factor is playing critical role and leads to fatal maritime accidents. The expectation of the ship crew is to complete operations or procedures such as emergency response without performing errors. Hence, crew reliability is key attribute in case of response an emergency. According to the findings, fatigue is considered as another effecting factor. Both physical and mental fatigue causes to decrease in alertness, mental concentration, and motivation (Akhtar and Utne, 2014). Therefore, the fatigue leads to prevent the effective response in emergency situation on-board ship.

Table 10 Preventive actions

Factor	*Suggested preventive actions*
F3	Combine drills with trainings, teach and demonstrate before use
F4	Determine stand ins for crew
	Change duties in muster list regularly and switch positions and duties for crew
F5	Determine stand ins for supervisor
	Change duties in muster list regularly (switch positions and duties) for supervisor
F11	Create safe behave to eliminate confusion of thinking during chaos
	Publish safety campaigns by office
	Increase safety culture awareness
	Increase team integration and discipline
F16	Increase retention rate
	Enhance personnel selection and recruitment procedures
F18–F19	Cross check of equipment's by different persons
	Controls should be done against approved fire control plan
	Increase safety culture awareness
	Increase team integration and discipline
	Increase familiarisation regarding safety equipment's
	Prevent crew fatigue

4.5.4 Preventive measures proposal

In the light of above findings, F3, F4, F5, F11, F16, F18 and F19 are found as critical generic factors which affect drill performance negative and increase drill duration.

In order to minimise and avoid the effect of generic factors, preventive measures are introduced. Considering the marine experts' wide experiences and knowledge, the preventive measures proposed by them are the most effective measures. Table 10 provides the preventive measures against the most critical generic factors affecting operational firefighting drill.

5 Conclusions

The various reports published by International Maritime Organization (IMO) have pointed that; although there have been sufficient number of rules; there are implementation deficiencies in operation level. There is still considerable concern about the ship emergency preparedness. The key challenge of emergency preparedness is to conduct procedures including drill and exercise. The purpose of this paper is to evaluate critical factors influencing the ship emergency preparedness level at sea. To achieve this purpose, the fuzzy DEMATEL technique is used. In the paper, while the DEMATEL method enables to identify and analyse the critical factors with respect to causal-effect relation, fuzzy sets tackle the uncertainty in decision-making. Utilising the fuzzy sets and the DEMATEL constitutes the unique contribution of this research by evaluating factors affecting the ship emergency preparedness level. A real shipboard firefighting drill is applied to demonstrate the model since fire is one of the tragic situation frequently encountered at sea. A set of generic factors affecting firefighting drills on-board ship are evaluated by taking into consideration of causal-effect relation. The most significant factors, affecting predefined steps of an operational firefighting drill, are revealed and evaluated. The results of the study demonstrates that insufficient firefighting practice and training, missing crew and missing supervisor and incorrect placement of portable tools, equipment or material in firefighting system should be given highest priority for effective preparedness in case of fire on board since they are cause factors. On the other hand, the factors lack of safety culture and discipline about the use of personnel protective/ firefighting equipment and firefighting, crew reliability and fatigues of crews on board should be given utmost attention since they are in effect group and may cause unintended consequences in emergency. After evaluation of most significant factors, the preventive measures are recommended in the view of marine experts in order to minimise and avoid the effect of generic factors. Determination of generic factors affecting fire drill performance and their preventive measure contribute ship owners/managers to evaluate their fleet vessel status and to improve their performance in fire drills by remedying the deficiencies and reducing the risk factors to minimum in defined factors. Moreover, a further research plan would be developing a simulation of a fire drill in order to estimate average response time via obtaining actual time data from sufficient number of vessels during drill for each steps. Using fuzzy DEMATEL along with average response time by simulation approaches will contribute to specifying current level of performance during drill which affects emergency preparedness in fire. The IMO stipulated evaluation of ship emergency preparedness level in operational level under SOLAS, chapter IX (ISM code application). This research will remedy aforementioned gap and provide practical application tool for forthcoming studies to evaluate ship emergency preparedness level. Particularly, the outcomes of the research would help in understanding the real-shipboard scenario with respect to the firefighting drill in a better way since it increases crew and shore-based personal knowledge on the unique condition of firefighting.

In conclusion, this paper shows how a comprehensive insight into the ship emergency preparedness can be gained by maritime safety managers and professionals. The study may be extended to the forthcoming researches on prediction of ship emergency preparedness level on-board ships.

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