Journal of Shipping and Ocean Engineering 5 (2015) 26-43
doi: 10.17265/2159-5879/2015.01.004

A Ship Officer Performance Evaluation Model Using Fuzzy-AHP

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Abstract: A ship's crew plays an important role in the maritime transportation sector and their performance is paramont in the shipping industry. On this account, an impartial evaluation of the crew's performance is an important issue. In this paper, the ship officer's performance evaluation problem is studied. The performance evaluation criteria that shipping companies take into account are determined and a performance evaluation process is modelled by using the FAHP (Fuzzy Analytic Hierarchy Process) based on Chang's Algorithm. Linguistic variables and fuzzy numbers are used in the assessment process. The results of the proposed model demonstrate that the FAHP method is effective and helps managers make better and more reliable decisions under fuzzy circumstances.

Key words: Multiple criteria evaluation, Fuzzy-AHP, performance evaluation, ship crew.

1. Introduction

Human resources are a major determinant in a company's success or failure. Personnel selection is a critical issue of companies in human resource management. Therefore, the company managers recruit qualified and efficient personnel who will help to accomplish the company's objectives.

The hierarchical structure of a ship's crew on commercial ships resembles the hierarchical structure of small companies in that there are top level managers and lower ranking employees and all operations are carried out in this hierarchical structure in the form of teamwork. In order to work at sea, all seafarers must have specific competencies as defined by the international convention on STCW (Standards of Training Certification and Watchkeeping). Having these qualifications is necessary, but not sufficient for ensuring the safety of crew, cargo and the ship. Losses caused by non-qualified crew affect both the shipping company and the maritime industry. More than 70% of marine accidents occur as a result of human errors [1]. Situations arising from such accidents as the sinking of the ship or severe damage to the ship and cargo cause significant financial losses for the shipping companies. Furthermore, accidents result in marine and environmental pollution as well as the loss of human life. From the perspective of the global maritime industry, PSCO (port state control) is important for owners and flag states. Failure to comply with the standards defined in SOLAS (Safety of Life at Sea), held by the IMO (International Maritime Organization), or detention of a ship with deficiencies may harm the reputation of the shipping company and flag state as well. Consequently, the quality of crew employed on a ship is of great importance for the shipping company in terms of being able to accomplish its objectives. In order to reduce human error, improve crew performance and ensure safety on board, ship crew performance is evaluated regularly by using an assessment report that exists in the ship's safety management manual. The

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assessment reports completed by the chief officer for the deck crew and by the chief engineer for the engine crew are taken into consideration during the overall performance evaluation by the human resource manager. Based on this evaluation, training of the crew members is tailored to the crew's training needs.

Guideline-based performance evaluations are carried out by using crisp values. However, in many practical situations, the human preference model is ambiguous and decision makers might be reluctant or unable to assign exact numerical values to the comparison judgements [2]. Performance evaluations carried out by crisp numbers do not present the interval performance values between two exact numerical values. Therefore, this type of evaluation methods is incapable of dealing with uncertain and fuzzy situations. The fuzzy theory can overcome this difficulty. One example for this situation can be given by using "leadership" criterion stated in ship officer performance evaluation procedure. The illustration of the example is given in Fig. 1. A "5 point" for leadership criterion in guideline-based performance evaluation method might be implying a performance rate which belongs to "5 point set" and "6 point set" with different membership degrees in a fuzzy based evaluation method. Similarly, the same score might be denoting a performance value which belongs to "4 point set" and "5 point set" with different membership degrees as well. It is quite clear that a performance score closer to 6 points is better than a score closer to 4 points. It is not possible to see such differences in classic evaluation methods, thus fuzzy-based models are used to tackle this issue.

Meanwhile, personnel performance evaluation is a multi-criteria decision making problem in which the performance indicators used for assessment do not have the same impact on results. Therefore, it is more suitable to assign weights for each criterion taken into consideration in the complex multi criteria decision making problems. As a decision method, AHP (analytic hierarchy process) is one of the most popular measurement theory that meets this requirement. The method permits using numerical values in judgements. Despite its popularity, AHP is ineffective when applied to ambiguous problems [2]. In order to cope with that problem fuzzy theory is combined with AHP by some scholars. As the performance evaluation process for ship officers involves uncertainties and ambiguity, this method is found suitable for the present study.

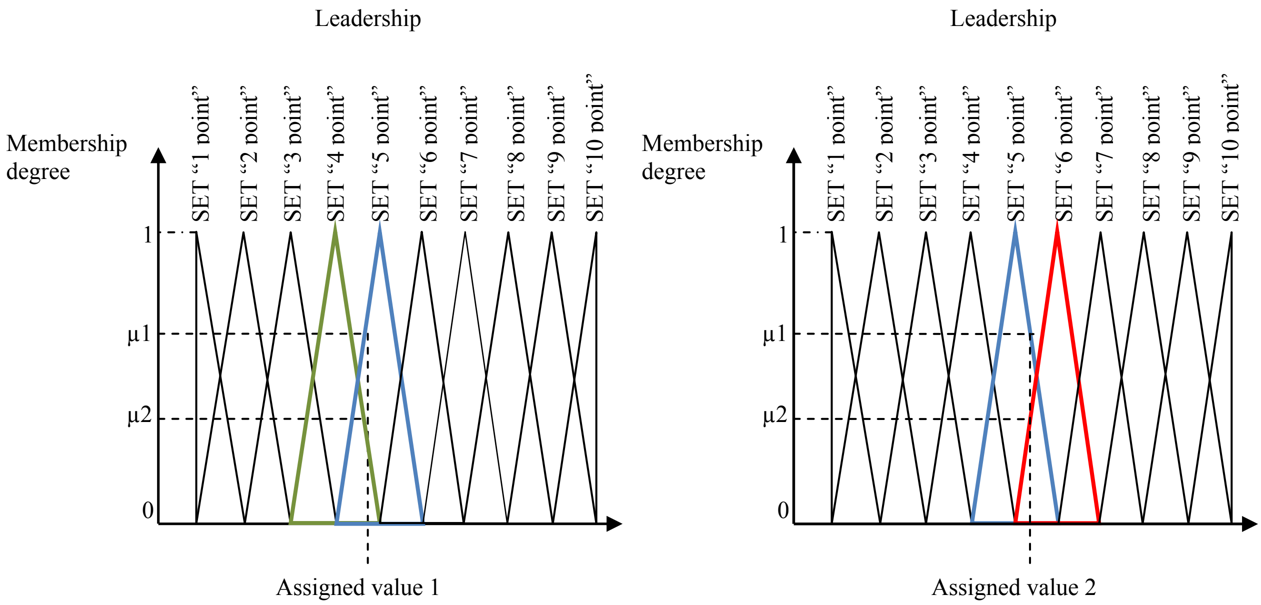

Fig. 1 Evaluation with fuzzy numbers.

Furthermore, owing to the distinct division of labor for a ship's crew, it is not possible to evaluate each person's performance with a standard evaluation procedure. According to expert opinions and the literature [3, 4], evaluation measures must be different for different members of the ship's crew. In the literature, some performance evaluation studies exist for different ranks of the ship's crew. One of the originalities of the present study is to propose a decision support system which has not yet been studied for a ship officer performance evaluation. The main contribution of the study is that it offers performance evaluation criteria that shipping companies may take into account. The evaluation criteria have been determined with respect to a detailed literature review [3-5] and the input of area expertise. Another superiority of this study is that while there are few performance evaluation studies focus on specific ship types, this model is valid for all type of ships. Besides, since the redundancy of the criteria used in evaluation causes difficulty in getting consistent results, all the evaluation measures are grouped into descriptive categories and a different approach is used for weighting of evaluation criteria. A questionnaire is sent to experts and results are used to find the weights of nine criteria. For each criterion, modes of points given to each variable in this category are calculated one by one. Calculated modes of points are converted into a fuzzy number. Weights of each main criterion are found based on the average of all mode values that form the related category. These weights used in pair-wise comparison of the main criteria.

Due to the ambiguous environment of the evaluation process, proposed decision support system for ship officer performance evaluation is modeled by using the FAHP (Fuzzy Analytic Hierarchy Process) based on Chang's Algorithm and the schematic diagram of the proposed model is presented in Fig. 2.

Furthermore, in order to explain the advantages of using fuzzy-AHP, the results of the proposed Fuzzy-AHP model are compared to the ones obtained by other techniques.

2. Literature Review

Performance evaluation is a process in which valuators assess the performance of the subjects in their work in respect to such factors as their behavior, work results, competence and capacity [6]. Performance evaluation is used as an important tool for managers in making decisions relating to improving personnel performance, assigning or terminating personnel, identifying employees' training needs and granting pay. The absence of such a system usually results in staff members being uncertain about the expectations of their manager in achieving company objectives. This leads to a decrease in the company's performance. A fair evaluation of personnel performance provides a strong human resource management tool that results in a company's success.

In maritime transportation, the accomplishment of the company's objectives depends mostly on the quality and the performance of the crew. A ship's crew generally works under difficult conditions within the complex structure of shipping. In order to ensure the safety of the vessel, cargo and crew, qualified personnel who are sensitive to environmental and occupational safety are needed. Therefore, identifying the factors that affect the performance of the crew and analyzing them on a regular basis is of great importance. Due to this importance, a scientific method must be employed for the evaluation of performance. However, since human resource performance has very different characteristics, use of a scientific and effective evaluation of human resource using qualitative methods is difficult [7].

Different methods are used for performance analysis in the maritime industry. In this study, a decision support system is proposed to evaluate ship officer performance by using the FAHP method. In the literature, there are a number of studies using fuzzy

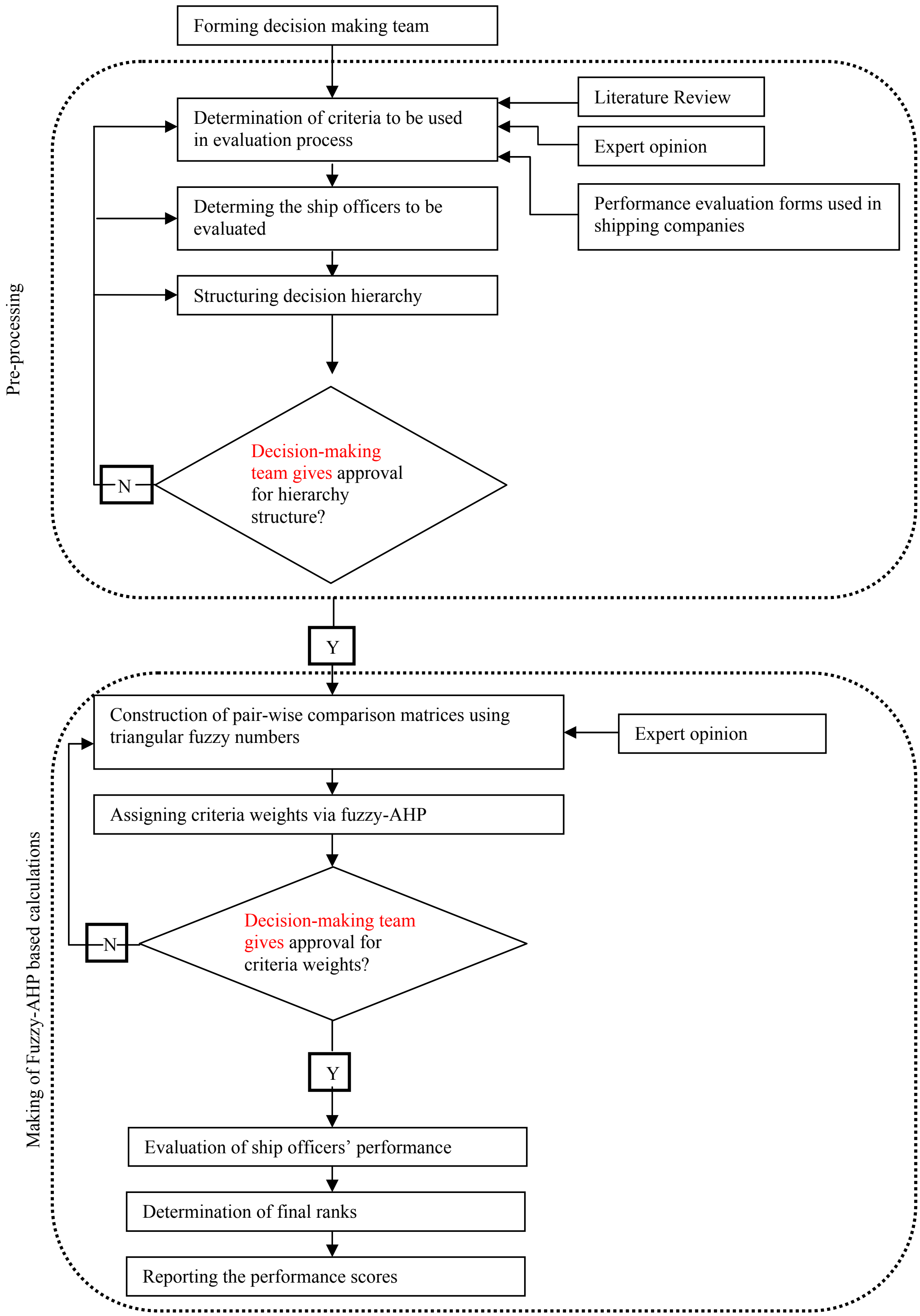

Fig. 2 Schematic diagram of the proposed model for ship officer performance evaluation.

logic in the process of performance evaluation in different areas. Shaout and Al-shammari [8] proposed an application of the fuzzy set theory to a personnel performance evaluation process. An application of the performance evaluation in a higher educational setting is proposed on the basis of education, departmental services, course load, student assessment, research and scientific activities. Dagdeviren [9] offered a model for performance evaluation with the FAHP method and the proposed method is applied to an organization that uses absenteeism of employees in its performance evaluation. In the study, the factors affecting the performance are gathered under the headings of “technical”, “behavioural” and “other”. Chou and Liang [10] proposed a fuzzy multiple criteria decision-making model for a shipping company’s performance evaluation. They characterized linguistic variables by both triangular and trapezoidal fuzzy numbers to indicate the evaluation values of the alternatives with respect to various criteria. Lee et al. [11] proposed an approach based on the FAHP and BSC (balanced scorecard) for evaluation of an IT department in the manufacturing industry in Taiwan. Li [12] established a framework of performance based on the study of R&D(research and development) personnel’s characteristics. FAHP method is used in calculation process of the weight of each index and R&D personnel’s achievements.

The studies mentioned above are only a few of the studies in which fuzzy logic is used in performance evaluation. In a survey of the literature within the scope of this research, a performance evaluation study for ship officers that would be applicable for all types of ships could not be found. However, there are some performance evaluation studies made in the field of maritime transportation.

Cicek et al. [5] used the FAHP method and proposed a modified model for the evaluation of the performance of marine engineers. Factors affecting their performance included the physical condition of working environments, job satisfaction, motivation, climate conditions, stress, competence, temporal conditions of work environment, habitability and working relationships. Arslan et al. [3] determined the factors used for evaluating a chemical tanker crew and clustered them in a hierarchical manner. The AHP method is utilized for the weighting of each factor. According to evaluation scores, training that should be given to the seafarers is determined and the SETS (Seafarer Evaluation and Training Software DEPEDES) is developed. Celik et al. [4] proposed a model on ANP (Analytic Network Process) for personnel selection. The model is applicable for only ship masters. The studies applied to maritime industry are summarized in Table 1.

On account of being the masters of the future, ship officers are as responsible as the ship masters for environmental and occupational safety. Their performance is of great importance in the shipping industry. Shipping companies use a comprehensive list found in the ship’s safety management manual for ship officers’ performance evaluation. There are a few performance evaluation studies for ship masters in the literature, but in the scope of this study a decision support system for ship officers’ performance evaluation has not been met. For this reason, a personnel performance evaluation system for ship officers of all type of ships is suggested in this paper. Since the redundancy of the criteria in this list causes difficulty in getting consistent results, all the evaluation measures are grouped into descriptive categories and a performance evaluation system is proposed by using the FAHP method.

3. Methodology

A good decision-making model needs to tolerate vagueness or ambiguity since fuzziness and vagueness are common characteristics in many decision-making problems [13]. To deal with vagueness of human thought, Zadeh [14] first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to vagueness [15]. As the decision-making

Table 1 Performance Evaluation Studies on Ship Crew.

Reference	Application area	Techniques used	Major evaluation criteria
Cicek, Cebi and Celik (2009)	Marine engineer's performance evaluation	Fuzzy-AHP	Physical conditions of working environment Job satisfaction Motivation Climate conditions Stress Competence Temporal conditions of work environments Habitability Working relationships
Arslan, Gurel and Kadioglu (2009)	Chemical tanker crew evaluation	AHP	Professional knowledge & skill and adaptation to safety rules Professional behavior Leadership and social behavior Adaptation to sea/ship life
Celik, Er and Topcu (2009)	Ship master selection	ANP	Occupational information Professional discipline and responsibilities Leadership and coaching Personality characteristics

process on a ship officer performance measurement involves uncertainty and fuzziness, the FAHP method is found as a proper method for this study.

The AHP has extensively used as a multiple criteria decision making tool since it was first proposed by Saaty [16, 17]. It is often criticized, due to its use of an unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pair-wise comparison process [18]. Since the conventional AHP still cannot reflect the human thinking style, a few Fuzzy-AHP methods have been developed to handle fuzzy comparison matrices [15, 19]. One of these methods is Chang's method.

The outlines of fuzzy sets and the basic steps of the extent analysis method on Fuzzy AHP are explained below.

3.1 Fuzzy Sets and Fuzzy Numbers

A fuzzy set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one [14]. If the assigned value is zero, the element does not belong to the set and if the value assigned is one, the element belongs completely to the set [20]. Lastly, if the value lies within the above mentioned interval, the element belongs partially to the fuzzy set. A TFN (triangular fuzzy number) expresses the relative strength of each pair of elements in the same hierarchy and can be denoted as $\tilde{M} = (l, m, u)$, where, the parameters *l, m, u,* respectively, indicate the smallest possible value, the most promising value, and the largest possible value [21]. A triangular membership function of $\tilde{M}$ can be described as in Eq. 1:

$$\mu_{\tilde{M}}(x) = \begin{cases} 0, & x < l \\ \dfrac{x-l}{m-l}, & l \le x \le m \\ \dfrac{u-x}{u-m}, & m \le x \le u \\ 0, & x > u \end{cases} \quad (1)$$

Consider two triangular fuzzy numbers $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$. The addition of these two numbers is $(l_1 + l_2, m_1 + m_2, u_1 + u_2)$. Besides, $(l_1 - l_2, m_1 - m_2, u_1 - u_2)$ is the substraction of them. Moroever, the multiplication of them is $(l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$. Inverse of a triangular fuzzy number can be illustrated as in Eq. 2:

$$\tilde{M}_1^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right) \quad (2)$$

In fuzzy set theory, conversion scales are applied to transform the linguistic terms into fuzzy numbers [22]. Table 2 presents the scale used for comparisons in this paper.

Table 2 Linguistic terms and fuzzy expressions of ratings (Kahraman et. al.,2004).

Linguistic terms	Triangular fuzzy numbers
Equal	(1,1,1)
Weak	(2/3, 1, 3/2)
Fairly strong	(3/2, 2, 5/2)
Very strong	(5/2, 3, 7/2)
Absolute	(7/2, 4, 9/2)

3.2 Fuzzy-AHP

In Kahraman et al's [15] study, the steps of Chang's [19] extent analysis approach are explained as below:

Firstly, let $X = \{x_1, x_2, ..., x_n\}$ be an object set, and $U = \{u_1, u_2, ..., u_m\}$ be a goal set. Then each object is taken and extent analysis for each goal is performed, respectively. The values of extent analysis of i-*th* object for *m* goals can be derived with the following signs:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m, \; i = 1, 2, ..., n \quad (3)$$

where, g_i is the expression for corresponding goal and all the $M_{g_i}^j$ (j = 1, 2, ..., m) are triangular fuzzy numbers representing the performance of the object x_i with regard to each goal u_j [21].

Step 1: the value of fuzzy synthetic extent with respect to the i-*th* object, S_i, is determined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \quad (4)$$

In order to obtain $\sum_{j=1}^{m} M_{g_i}^j$, the fuzzy addition operation of m extent analysis values is performed for a specific matrix as below:

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \quad (5)$$

And to obtain $\left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right)^{-1}$, the fuzzy addition operation of $M_{g_i}^j$ (j = 1, 2, ..., m) values is performed as follows:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \quad (6)$$

and then the inverse of the vector in Eq. (6) is computed as below:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \quad (7)$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is expressed as

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left\lfloor \min\left(\mu_{M_1}(x), \mu_{M_2}(y) \right) \right\rfloor \quad (8)$$

It can be similarly defined as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \textit{otherwise}, \end{cases} \quad (9)$$

where, *hgt* is the height and *d* is the ordinate of the highest intersection point between μ_{M_1} and μ_{M_2} (See Fig. 3).

Both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$ are required to compare M_1 and M_2.

Step 3: the degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy numbers M_i (i = 1, 2, ..., k) can be defined by:

$$V(M \geq M_1, M_2, ..., M_k) =$$

$$V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and ... and } (M \geq M_k)] = \min V(M \geq M_i), \; i = 1,2,3, ...,k. \quad (10)$$

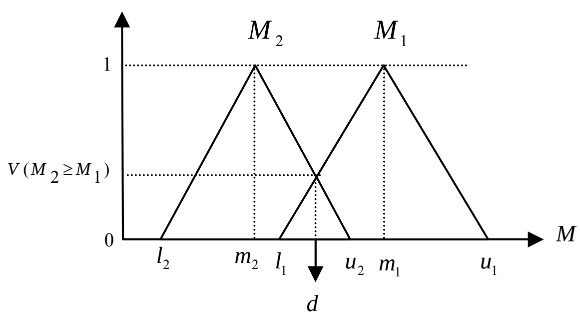

Fig. 3 The intersection between M_1 and M_2.

Suppose that:

$$d'(A_i) = \min V(S_i \geq S_k) \quad k = 1, 2, ..., n; k \neq i \quad (11)$$

Then the weight vector is defined by:

$$W' = (\mathrm{d}'(A_1), \mathrm{d}'(A_2), ..., \mathrm{d}'(A_n))^T \quad (12)$$

where, A_i (i = 1, 2, ..., n) are n elements.

Step 4: via normalization, the normalized weight vectors are:

$$W = (\mathrm{d}(A_1), \mathrm{d}(A_2), ..., \mathrm{d}(A_n))^T \quad (13)$$

where, W is a non-fuzzy number.

4. A Fuzzy MCDM Model for Ship Officer Performance Evaluation

There are a number of criteria that affect ship crew performance as mentioned earlier. In this study, 34 variables are taken into consideration. As the number of criteria being compared must be small (not more than nine) to improve consistency and the corresponding accuracy of measurement [23] in AHP, the number of criteria is reduced by grouping variables into descriptive categories. At the grouping stage, information from the literature review [3-5] and human expertise are taken into consideration. Thirty four variables are grouped into nine categories and a hierarchical model which contains two levels as main criteria, sub-criteria and three alternatives respectively is constructed as shown in Fig. 4.

The criteria and the evaluation variables they contain are prepared mostly based on human expertise and demonstrated in Table 3.

In order to examine the wide range of data set, a questionnaire is sent to experts. A 5-point Likert Scale is used to evaluate thirty four criteria. For all items, participants were required to indicate their opinion about the importance of each criterion from 1 (very unimportant) to 5 (very important). The questionnaires are sent to 50 human experts and received 35 complete questionnaires. Among those participants, 8 (23%) are human resource managers in a shipping company and 18 (51%) are masters on ships and 9 (26%) are officers.

Questionnaire results are used to find the weights of nine criteria. For each criterion, modes of points given to each variable in this category are calculated one by one. Calculated modes of points are converted into fuzzy numbers. Weights of each main criterion are found based on the average of all mode values that form the related category. These weights used in pair-wise comparison of the main criteria are given in Table 4.

The present study is applied to three ship officers (A_1, A_2, A_3) working at a real shipping company. Their performance has already been evaluated by an extensive list that exists in the ship's safety management manual of the company. According to the past evaluation results, A_1 has the best score and A_3 has the worst score among those ship officers. The human resource manager of the company evaluated the

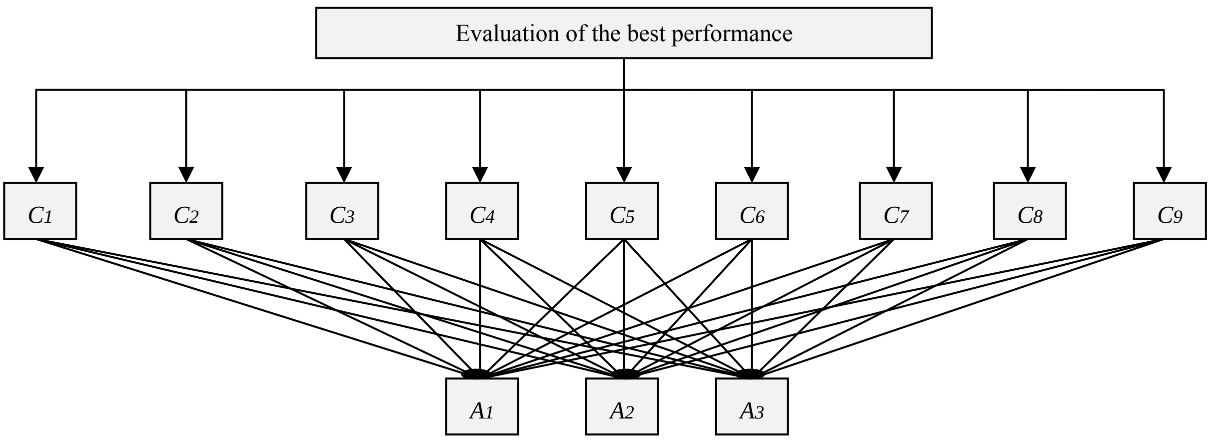

Fig. 4 Basic Structure of AHP.

Table 3 Criteria and evaluation variables.

Criterion number	Major evaluation criterion	Evaluation variables
C_1	Leadership	Motivation Decisiveness Leadership Taking responsibility Sharing responsibility Reliability Equity
C_2	Personal characteristics	Cabin/associate cleanness Personal cleanness
C_3	Adaptation to international standards	ISM knowledge, MARPOL knowledge ISPS knowledge Adaptation to ISM, Adaptation to MARPOL Adaptation to ISPS
C_4	Professional knowledge	Professional knowledge Cargo operation knowledge Knowledge of equipment English knowledge
C_5	Professional behaviour	Relations with inferiors/superiors Adaptation of marine usage and customs Sharing knowledge
C_6	Occupational discipline	Work quality Timing in work life Self-help
C_7	Adaptation to ship and sea life	Adaptation on drug policy Adaptation on alcohol policy Adaptation on sealife Psychological adaptation on sealife Physical adaptation on sealife
C_8	Ability on office tasks	Computer knowledge Ability in paper work
C_9	Safety adaptation	Having safety culture Attendance to drill

Table 4 Weights of main criteria.

C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
(2.64, 3.14, 3.64)	(1.08, 1.5, 2)	(2, 2.5, 3)	(2.5, 3, 3.5)	(2.5, 3, 3.5)	(2.5, 3, 3.5)	(2.9, 3.4, 3.9)	(2, 2.5, 3)	(2.5, 3,3.5)

three ship officers' performance by the FAHP model proposed in this study and the new evaluation results are compared with the past results.

The fuzzy comparison data of the nine criteria with respect to the goal is given in Table 5.

First of all, the fuzzy synthetic extent values of nine criteria are determined in accordance with the Chang's extent analysis method. The received synthetic extent values of nine criteria by using Eq. 4 are as follows:

S_{C1} = (7.77, 9.79, 15.09) × (1/121.35, 1/84.53, 1/61.37) = (0.064, 0.116, 0.246)

S_{C2} = (3.53, 5.12, 7.65) × (1/121.35, 1/84.53, 1/61.37) = (0.029, 0.061, 0.125)

S_{C3} = (6.01, 8.53, 12.25) × (1/121.35, 1/84.53, 1/61.37) = (0.050, 0.101, 0.200)

S_{C4} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.061, 0.121, 0.236)

S_{C5} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.061, 0.121, 0.236)

S_{C6} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.061, 0.121, 0.236)

S_{C7} = (8.49, 11.060, 16.23) × (1/121.35, 1/84.53, 1/61.37) = (0.070, 0.137, 0.264)

S_{C8} = (6.01, 8.53, 12.25) × (1/121.35, 1/84.53, 1/61.37) = (0.050, 0.101, 0.200)

Table 5 The fuzzy evaluation matrix with respect to the goal.

	1.46	0.80	1.20	1.40	1.40	1.40	1.56	1.20	1.00
C_9	1.05	0.50	0.83	1.00	1.00	1.00	1.13	0.83	1.00
	0.75	0.31	0.57	0.71	0.71	0.71	0.83	0.57	1.00
	1.82	1.00	1.50	1.75	1.75	1.75	1.95	1.00	1.75
C_8	1.26	0.60	1.00	1.20	1.20	1.20	1.36	1.00	1.20
	0.88	0.36	0.67	0.83	0.83	0.83	0.97	1.00	0.83
	1.26	0.69	1.03	1.21	1.21	1.21	1.00	1.03	1.21
C_7	0.92	0.44	0.74	0.88	0.88	0.88	1.00	0.74	0.88
	0.68	0.28	0.51	0.64	0.64	0.64	1.00	0.51	0.64
	1.46	0.80	1.20	1.40	1.40	1.00	1.56	1.20	1.40
C_6	1.05	0.50	0.83	1.00	1.00	1.00	1.13	0.83	1.00
	0.75	0.31	0.57	0.71	0.71	1.00	0.83	0.57	0.71
	1.46	0.80	1.20	1.40	1.00	1.40	1.56	1.20	1.40
C_5	1.05	0.50	0.83	1.00	1.00	1.00	1.13	0.83	1.00
	0.75	0.31	0.57	0.71	1.00	0.71	0.83	0.57	0.71
	1.46	0.80	1.20	1.00	1.40	1.40	1.56	1.20	1.40
C_4	1.05	0.50	0.83	1.00	1.00	1.00	1.13	0.83	1.00
	0.75	0.31	0.57	1.00	0.71	0.71	0.83	0.57	0.71
	1.82	1.00	1.00	1.75	1.75	1.75	1.95	1.50	1.75
C_3	1.26	0.60	1.00	1.20	1.20	1.20	1.36	1.00	1.20
	0.88	0.36	1.00	0.83	0.83	0.83	0.97	0.67	0.83
	3.37	1.00	2.78	3.24	3.24	3.24	3.61	2.78	3.24
C_2	2.09	1.00	1.67	2.00	2.00	2.00	2.27	1.67	2.00
	1.32	1.00	1.00	1.25	1.25	1.25	1.45	1.00	1.25
	1.00	0.76	1.14	1.33	1.33	1.33	1.48	1.14	1.33
C_1	1.00	0.48	0.80	0.95	0.95	0.95	1.08	0.80	0.95
	1.00	0.30	0.55	0.69	0.69	0.69	0.80	0.55	0.69
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9

From Table 3, S_{C1} = (7.77, 9.79, 15.09) × (1/121.35, 1/84.53, 1/61.37) = (0.06, 0.12, 0.25), S_{C2} = (3.53, 5.12, 7.65) × (1/121.35, 1/84.53, 1/61.37) = (0.03, 0.06, 0.12), S_{C3} = (6.01, 8.53, 12.25) × (1/121.35, 1/84.53, 1/61.37) = (0.05, 0.10, 0.20), S_{C4} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.06, 0.12, 0.24), S_{C5} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.06, 0.12, 0.24), S_{C6} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.06, 0.12, 0.24), S_{C7} = (8.49, 11.060, 16.23) × (1/121.35, 1/84.53, 1/61.37) = (0.07, 0.14, 0.26), S_{C8} = (6.01, 8.53, 12.25) × (1/121.35, 1/84.53, 1/61.37) = (0.05, 0.10, 0.20), S_{C9} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.06, 0.12, 0.24) are obtained. Using these vectors, $V(S_{C1} \geq S_{C2})$ = 1.00, $V(S_{C1} \geq S_{C3})$ = 1.00, $V(S_{C1} \geq S_{C4})$ = 0.97, $V(S_{C1} \geq S_{C5})$ = 0.97, $V(S_{C1} \geq S_{C6})$ = 0.97, $V(S_{C1} \geq S_{C7})$ = 0.89, $V(S_{C1} \geq S_{C8})$ = 1.00, $V(S_{C1} \geq S_{C9})$ = 0.97, $V(S_{C2} \geq S_{C1})$ = 0.52, $V(S_{C2} \geq S_{C3})$ = 0.65, $V(S_{C2} \geq S_{C4})$ = 0.51, $V(S_{C2} \geq S_{C5})$ = 0.51, $V(S_{C2} \geq S_{C6})$ = 0.51, $V(S_{C2} \geq S_{C7})$ = 0.42, $V(S_{C2} \geq S_{C8})$ = 0.65, $V(S_{C2} \geq S_{C9})$ = 0.51, $V(S_{C3} \geq S_{C1})$ = 0.90, $V(S_{C3} \geq S_{C2})$ = 1.00, $V(S_{C3} \geq S_{C4})$ = 0.87, $V(S_{C3} \geq S_{C5})$ = 0.87, $V(S_{C3} \geq S_{C6})$ = 0.87, $V(S_{C3} \geq S_{C7})$ = 0.78, $V(S_{C3} \geq S_{C8})$ = 1.00, $V(S_{C3} \geq S_{C9})$ = 0.87, $V(S_{C4} \geq S_{C1})$ = 1.00, $V(S_{C4} \geq S_{C2})$ = 1.00, $V(S_{C4} \geq S_{C3})$ = 1.00, $V(S_{C4} \geq S_{C5})$ = 1.00, $V(S_{C4} \geq S_{C6})$ = 1.00, $V(S_{C4} \geq S_{C7})$ = 0.91, $V(S_{C4} \geq S_{C8})$ = 1.00, $V(S_{C4} \geq S_{C9})$ = 1.00, $V(S_{C5} \geq S_{C1})$ = 1.00, $V(S_{C5} \geq S_{C2})$ = 1.00, $V(S_{C5} \geq S_{C3})$ = 1.00, $V(S_{C5} \geq S_{C4})$ = 1.00, $V(S_{C5} \geq S_{C6})$ = 1.00, $V(S_{C5} \geq S_{C7})$ = 0.91, $V(S_{C5} \geq S_{C8})$ = 1.00, $V(S_{C5} \geq S_{C9})$ = 1.00, $V(S_{C6} \geq S_{C1})$ = 1.00, $V(S_{C6} \geq S_{C2})$ = 1.00, $V(S_{C6} \geq S_{C3})$ = 1.00, $V(S_{C6} \geq S_{C4})$ = 1.00, $V(S_{C6} \geq S_{C5})$ = 1.00, $V(S_{C6} \geq S_{C7})$ = 0.91, $V(S_{C6} \geq S_{C8})$ = 1.00, $V(S_{C6} \geq S_{C9})$ = 1.00, $V(S_{C7} \geq S_{C1})$ = 1.00, $V(S_{C7} \geq S_{C2})$ = 1.00, $V(S_{C7} \geq S_{C3})$ = 1.00, $V(S_{C7} \geq S_{C4})$ = 1.00, $V(S_{C7} \geq S_{C5})$ = 1.00, $V(S_{C7} \geq S_{C6})$ = 1.00, $V(S_{C7} \geq S_{C8})$ = 1.00, $V(S_{C7} \geq S_{C9})$ = 1.00, $V(S_{C8} \geq S_{C1})$ = 0.90, $V(S_{C8} \geq S_{C2})$ = 1.00, $V(S_{C8} \geq S_{C3})$ = 1.00, $V(S_{C8} \geq S_{C4})$ = 0.87, $V(S_{C8} \geq S_{C5})$ = 0.87, $V(S_{C8} \geq S_{C6})$ = 0.87, $V(S_{C8} \geq S_{C7})$ = 0.78, $V(S_{C8} \geq S_{C9})$ = 1.00, $V(S_{C9} \geq S_{C1})$ = 1.00, $V(S_{C9} \geq S_{C2})$ = 1.00, $V(S_{C9} \geq S_{C3})$ = 1.00, $V(S_{C9} \geq S_{C4})$ = 1.00, $V(S_{C9} \geq S_{C5})$ = 1.00, $V(S_{C9} \geq S_{C6})$ = 1.00, $V(S_{C9} \geq S_{C7})$ = 0.91 and $V(S_{C9} \geq S_{C8})$ = 1.00 are obtained. The normalized weight vector from Table 5 is calculated as WG = $(0.119, 0.055, 0.104, 0.121, 0.121, 0.121, 0.133, 0.104, 0.121)^T$.

S_{C9} = (7.39, 10.24, 14.47) × (1/121.35, 1/84.53, 1/61.37) = (0.061, 0.121, 0.236)

These values are compared by means of Eq. 9. Obtained results are presented in Table 6.

The priority weights for nine criteria are calculated by using Eq. 10.

$d'(C_1)$ = min(1.00,1.00, 0.97, 0.97, 0.97, 0.89, 1.00, 0.97) = 0.89

$d'(C_2)$ = min(0.52, 0.65, 0.51, 0.51, 0.51, 0.42, 0.65, 0.51)= 0.42

$d'(C_3)$ = min(0.97, 1.00, 0.87, 0.87, 0.87, 0.78, 1.00, 0.87)= 0.78

$d'(C_4)$ = min(1.00, 1.00, 1.00, 1.00, 1.00, 0.91, 1.00, 1.00) = 0.91

$d'(C_5)$ = min(1.00, 1.00, 1.00, 1.00, 1.00, 0.91, 1.00, 1.00) = 0.91

$d'(C_6)$ = min(1.00, 1.00, 1.00, 1.00, 1.00, 0.91, 1.00, 1.00)= 0.91

$d'(C_7)$ = min(1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00) = 1.00

$d'(C_8)$ = min(0.90, 1.00, 1.00, 0.87, 0.87, 0.87, 0.78, 1.00) = 0.78

$d'(C_9)$ = min(1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 0.91, 1.00) = 0.91

Then the weight vector is defined by Eq. 12 as W'= (0.89, 0.42, 0.78, 0.91, 0.921, 0.91, 1.00, 0.78, 0.91). After normalization by Eq. 13, the normalized priority weight vector is obtained as W = (0.119, 0.055, 0.104, 0.121, 0.121, 0.121, 0.133, 0.104, 0.121)^T.

Then normalized priority weights of pairwise comparison matrices for three ship officers are calculated in the same way as above. The comparison matrices and calculations are presented in Tables 7-15.

Priority weights for each comparison matrices are as follows:

$W_{C1} = (0.66, 0.29, 0.05)^T$

$W_{C2} = (0.33, 0.33, 0.33)^T$

$W_{C3} = (1.00, 0.00, 0.00)^T$

$W_{C4} = (1.00, 0.00, 0.00)^T$

$W_{C5} = (0.45, 0.32, 0.23)^T$

$W_{C6} = (0.33, 0.33, 0.33)^T$

$W_{C7} = (0.33, 0.33, 0.33)^T$

$W_{C8} = (0.33, 0.33, 0.33)^T$

$W_{C9} = (0.45, 0.32, 0.23)^T$

The combination of priority weights for criteria and alternatives is used to determine the final scores of the

Table 6 Comparison of synthetic extent values of nine criteria.

$V(S_{C1} \geq S_{C2}) = 1.00$	$V(S_{C2} \geq S_{C1}) = 0.52$	$V(S_{C3} \geq S_{C1}) = 0.90$
$V(S_{C1} \geq S_{C3}) = 1.00$	$V(S_{C2} \geq S_{C3}) = 0.65$	$V(S_{C3} \geq S_{C2}) = 1.00$
$V(S_{C1} \geq S_{C4}) = 0.97$	$V(S_{C2} \geq S_{C4}) = 0.51$	$V(S_{C3} \geq S_{C4}) = 0.87$
$V(S_{C1} \geq S_{C5}) = 0.97$	$V(S_{C2} \geq S_{C5}) = 0.51$	$V(S_{C3} \geq S_{C5}) = 0.87$
$V(S_{C1} \geq S_{C6}) = 0.97$	$V(S_{C2} \geq S_{C6}) = 0.51$	$V(S_{C3} \geq S_{C6}) = 0.87$
$V(S_{C1} \geq S_{C7}) = 0.89$	$V(S_{C2} \geq S_{C7}) = 0.42$	$V(S_{C3} \geq S_{C7}) = 0.78$
$V(S_{C1} \geq S_{C8}) = 1.00$	$V(S_{C2} \geq S_{C8}) = 0.65$	$V(S_{C3} \geq S_{C8}) = 1.00$
$V(S_{C1} \geq S_{C9}) = 0.97$	$V(S_{C2} \geq S_{C9}) = 0.51$	$V(S_{C3} \geq S_{C9}) = 0.87$
$V(S_{C4} \geq S_{C1}) = 1.00$	$V(S_{C5} \geq S_{C1}) = 1.00$	$V(S_{C6} \geq S_{C1}) = 1.00$
$V(S_{C4} \geq S_{C2}) = 1.00$	$V(S_{C5} \geq S_{C2}) = 1.00$	$V(S_{C6} \geq S_{C2}) = 1.00$
$V(S_{C4} \geq S_{C3}) = 1.00$	$V(S_{C5} \geq S_{C3}) = 1.00$	$V(S_{C6} \geq S_{C3}) = 1.00$
$V(S_{C4} \geq S_{C5}) = 1.00$	$V(S_{C5} \geq S_{C4}) = 1.00$	$V(S_{C6} \geq S_{C4}) = 1.00$
$V(S_{C4} \geq S_{C6}) = 1.00$	$V(S_{C5} \geq S_{C6}) = 1.00$	$V(S_{C6} \geq S_{C5}) = 1.00$
$V(S_{C4} \geq S_{C7}) = 0.91$	$V(S_{C5} \geq S_{C7}) = 0.91$	$V(S_{C6} \geq S_{C7}) = 0.91$
$V(S_{C4} \geq S_{C8}) = 1.00$	$V(S_{C5} \geq S_{C8}) = 1.00,$	$V(S_{C6} \geq S_{C8}) = 1.00$
$V(S_{C4} \geq S_{C9}) = 1.00$	$V(S_{C5} \geq S_{C9}) = 1.00$	$V(S_{C6} \geq S_{C9}) = 1.00$
$V(S_{C7} \geq S_{C1}) = 1.00$	$V(S_{C8} \geq S_{C1}) = 0.90$	$V(S_{C9} \geq S_{C1}) = 1.00$
$V(S_{C7} \geq S_{C2}) = 1.00$	$V(S_{C8} \geq S_{C2}) = 1.00$	$V(S_{C9} \geq S_{C2}) = 1.00$
$V(S_{C7} \geq S_{C3}) = 1.00$	$V(S_{C8} \geq S_{C3}) = 1.00$	$V(S_{C9} \geq S_{C3}) = 1.00$
$V(S_{C7} \geq S_{C4}) = 1.00$	$V(S_{C8} \geq S_{C4}) = 0.87$	$V(S_{C9} \geq S_{C4}) = 1.00$
$V(S_{C7} \geq S_{C5}) = 1.00$	$V(S_{C8} \geq S_{C5}) = 0.87$	$V(S_{C9} \geq S_{C5}) = 1.00$
$V(S_{C7} \geq S_{C6}) = 1.00$	$V(S_{C8} \geq S_{C6}) = 0.87$	$V(S_{C9} \geq S_{C6}) = 1.00$
$V(S_{C7} \geq S_{C8}) = 1.00$	$V(S_{C8} \geq S_{C7}) = 0.78$	$V(S_{C9} \geq S_{C7}) = 0.91$
$V(S_{C7} \geq S_{C9}) = 1.00$	$V(S_{C8} \geq S_{C9}) = 1.00$	$V(S_{C9} \geq S_{C8}) = 1.00$

Table 7 Evaluation of ship officers with respect to leadership.

C_1		A_1			A_2			A_3	
A_1	(1	1	1)	(2/3	1	3/2)	(5/2	3	7/2)
A_2	(2/3	1	3/2)	(1	1	1)	(2/3	1	3/2)
A_3	(2/7	1/3	2/5)	(2/3	1	3/2)	(1	1	1)

The normalized weight vector from Table 7 is calculated as $W_{C1} = (0.66, 0.29, 0.05)^T$.
From Table 7, $S_{A1} = (4.17, 5, 6) \times (1/12.9, 1/10.3, 1/8.45) = (0.32, 0.48, 0.71)$, $S_{A2} = (2.33, 3, 4) \times (1/12.9, 1/10.3, 1/8.45) = (0.18, 0.29, 0.47)$, $S_{A3} = (1.95, 2.33, 2.90) \times (1/12.9, 1/10.3, 1/8.45) = (0.15,0.23, 0.34)$ are obtained. Using these vectors, $V(S_{A1} \geq S_{A2}) = 1.00$, $V(S_{A1} \geq S_{A3}) = 1.00$, $V(S_{A2} \geq S_{A1}) = 0.44$, $V(S_{A2} \geq S_{A3}) = 1.00$, $V(S_{A3} \geq S_{A1}) = 0.072$ and $V(S_{A3} \geq S_{A2}) = 0.715$ are obtained.

Table 8 Evaluation of ship officers with respect to personal characteristics.

C_2		A_1			A_2			A_3	
A_1	(1	1	1)	(1	1	1)	(2/3	1	3/2)
A_2	(1	1	1)	(1	1	1)	(2/3	1	3/2)
A_3	(2/7	1/3	2/5)	(2/3	1	3/2)	(1	1	1)

The normalized weight vector from Table 8 is calculated as $W_{C2} = (0.33, 0.33, 0.33)^T$.

Table 9 Evaluation of ship officers with respect to adaptation to international standards.

C_3		A_1			A_2			A_3	
A_1	(1	1	1)	(3/2	2	5/2)	(7/2	4	9/2)
A_2	(2/5	1/2	2/3)	(1	1	1)	(2/3	1	3/2)
A_3	(2/9	1/4	2/7)	(2/3	1	3/2)	(1	1	1)

The normalized weight vector from Table 9 is calculated as $W_{C3} = (1.00, 0.00, 0.00)^T$.

Table 10 Evaluation of ship officers with respect to professional knowledge.

C_4		A_1			A_2			A_3	
A_1	(1	1	1)	(3/2	2	5/2)	(7/2	4	9/2)
A_2	(2/5	1/2	2/3)	(1	1	1)	(2/3	1	3/2)
A_3	(2/9	1/4	2/7)	(2/3	1	3/2)	(1	1	1)

The normalized weight vector from Table 10 is calculated as $W_{C4} = (1.00, 0.00, 0.00)^T$.

Table 11 Evaluation of ship officers with respect to professional behavior.

C_5		A_1			A_2			A_3	
A_1	(1	1	1)	(2/3	1	3/2)	(3/2	2	5/2)
A_2	(2/3	1	3/2)	(1	1	1)	(2/3	1	3/2)
A_3	(2/5	1/2	2/3)	(2/3	1	3/2)	(1	1	1)

The normalized weight vector from Table 11 is calculated as $W_{C5} = (0.45, 0.32, 0.23)^T$.

Table 12 Evaluation of ship officers with respect to occupational discipline.

C_6		A_1			A_2			A_3	
A_1	(1	1	1)	(1	1	1)	(1	1	1)
A_2	(1	1	1)	(1	1	1)	(1	1	1)
A_3	(1	1	1)	(1	1	1)	(1	1	1)

The normalized weight vector from Table 12 is calculated as $W_{C6} = (0.33, 0.33, 0.33)^T$.

Table 13 Evaluation of ship officers with respect to adaptation to ship and sea life.

C_7		A_1			A_2			A_3	
A_1	(1	1	1)	(1	1	1)	(1	1	1)
A_2	(1	1	1)	(1	1	1)	(1	1	1)
A_3	(1	1	1)	(1	1	1)	(1	1	1)

The normalized weight vector from Table 13 is calculated as $W_{C7} = (0.33, 0.33, 0.33)^T$.

Table 14 Evaluation of ship officers with respect to ability on office tasks.

C_8		A_1			A_2			A_3	
A_1	(1	1	1)	(2/3	1	3/2)	(2/3	1	3/2)
A_2	(2/3	1	3/2)	(1	1	1)	(1	1	1)
A_3	(2/3	1	3/2)	(1	1	1)	(1	1	1)

The normalized weight vector from Table 14 is calculated as $W_{C8} = (0.33, 0.33, 0.33)^T$.

Table 15 Evaluation of ship officers with respect to safety adaptation.

C_9		A_1			A_2			A_3	
A_1	(1	1	1)	(2/3	1	3/2)	(3/2	2	5/2)
A_2	(2/3	1	3/2)	(1	1	1)	(2/3	1	3/2)
A_3	(2/5	1/2	2/3)	(2/3	1	3/2)	(1	1	1)

The normalized weight vector from Table 15 is calculated as $W_{C9} = (0.45, 0.32, 0.23)^T$.

Table 16 Final results.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Alternative priority weight
Weight	0.119	0.055	0.104	0.121	0.121	0. 121	0.133	0.104	0.121	
A_1	0.663	0.333	0.333	1.000	0,451	0.333	0.333	0.333	0.451	0.482
A_2	0.290	0.333	0.333	0.000	0.324	0.333	0.333	0.333	0.324	0.285
A_3	0.048	0.333	0.333	0.000	0.226	0.333	0.333	0.333	0.226	0.233

A_1 has the best performance.

three ship officers. Table 16 shows the final scores. According to the results given in Table 16, ship officer A_1 has the best performance and A_3 is the worst among those three ship officers. When compared to the past evaluation results the proposed model is found reliable and constant.

As previously mentioned in this study, ship crew performance evaluation is carried out by using a report that exists in ship's safety manual. The evaluation criteria in this report used by shipping companies resembles to each other in general, however, a standardised list does not exist and each shipping company uses its own evaluation form during assessment. The contribution of this study is that it offers a standardised evaluation model for ship officers by the help of area expertise and a detailed literature review.

Moreover, a scale of 0-5 or 0-10 is used to give point to ship officer for each criterion in that list during assessment. The ship officer whose performance is assessed out of a maximum of 100 points is evaluated by using criteria that are assumed to have the same priority weight. However, all of the evaluation criteria in any kind of working. environment never have the same priority. The model proposed in this study assigns different priority weights to each evaluation criterion by using expert opinion and it helps to eliminate the problem. AHP method is used as a multicriteria decision making tool in the process of weight assignment to the determined criteria.

Guideline-based performance evaluations are carried out by using crisp values. However, ship officer performance evaluation process has an ambiguous environment and such an approach prevents to carry out a detailed evaluation. In order to cope with that problem, Fuzzy-AHP is used in the present study.

Furthermore, the results of the proposed Fuzzy-AHP model are compared to the ones obtained by other techniques and the performance of the same three ship officers (A_1, A_2, A_3) is evaluated by using non-fuzzy AHP.

In this phase, questionnaire results are used to find the weights of nine criteria. For each criterion, modes of points given to each variable in this category are calculated one by one. Each mode value is converted into a crisp number by using Saaty's 1-9 Scale given in Table 17. Weights of each main criterion are found based on the average of all standardised values that form the related category. These weights used in pair-wise comparison of the main criteria are given in Table 18.

The non-fuzzy comparison of the nine criteria with respect to the goal and the comparison matrices of three ship officers with respect to each criterion are presented in Tables 19-28.

Final results presented in Table 29 shows that final scores of the three ship officers are in the same order with the ones obtained by using Fuzzy-AHP. On the other hand, it is seen that the ratio of change in old and new performance scores is different. While the non-fuzzy AHP performance score of ship officer A2 is too close to the score obtained by Fuzzy-AHP, the rate and the direction of change are different for ship officers A1 and A3 who have the best and the worst performance scores. The reason of this difference is that non-fuzzy AHP method uses crisp values which do not present the interval performance values between two exact numerical values and the obtained results prove that it is incapable of dealing with uncertain and fuzzy situations.

Table 17 Saaty's 1-9 Scale for the pair-wise comparison (Saaty, L. T., 1980).

Linguistic term	Preference number
Equally important/preferred	1
Weakly more important/preferred	3
Strongly more important/preferred	5
Very strong important/preferred	7
Absolutely more important preferred	9
Intermediate values	2, 4, 6, 8

Table 18 Weights of main criteria (non-fuzzy AHP).

C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
7.3	4	6	7	7	7	7.8	6	7

Table19 The non-fuzzy evaluation matrix with respect to the goal.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Priorities
C_1	1.0	1.8	1.2	1.0	1.0	1.0	0.9	1.2	1.0	0.12
C_2	0.5	1.0	0.7	0.6	0.6	0.6	0.5	0.7	0.6	0.07
C_3	0.8	1.5	1.0	0.9	0.9	0.9	0.8	1.0	0.9	0.10
C_4	1.0	1.8	1.2	1.0	1.0	1.0	0.9	1.2	1.0	0.12
C_5	1.0	1.8	1.2	1.0	1.0	1.0	0.9	1.2	1.0	0.12
C_6	1.0	1.8	1.2	1.0	1.0	1.0	1.0	1.2	1.0	0.12
C_7	1.1	2.0	1.3	1.1	1.1	1.0	1.0	1.3	1.1	0.13
C_8	0.8	1.5	1.0	0.9	0.9	0.9	0.8	1.0	0.9	0.10
C_9	1.0	1.8	1.2	1.0	1.0	1.0	0.9	1.2	1.0	0.12

Inconsistency = 0.

Table 20 The non-fuzzy pair wise comparisons and priorities of three ship officers under leadership criterion.

	A_1	A_2	A_3	Priorities
A_1	1	3	7	0.67
A_2	0.333	1	3	0.24
A_3	0.143	0.33	1	0.09

Inconsistency = 0.01.

Table 21 The non-fuzzy pair wise comparisons and priorities of three ship officers under personal characteristics criterion.

	A_1	A_2	A_3	Priorities
A_1	1	1	3	0.43
A_2	1	1	3	0.43
A_3	0.33	0.,33	1	0.14

Inconsistency = 0.

Table 22 The non-fuzzy pair wise comparisons and priorities of three ship officers under adaptation to international standards criterion.

	A_1	A_2	A_3	Priorities
A_1	1	5	9	0.71
A_2	0.2	1	3	0.17
A_3	0.11	0.33	1	0.07

Inconsistency = 0.03.

Table 23 The non-fuzzy pair wise comparisons and priorities of three ship officers under professional knowledge criterion.

	A_1	A_2	A_3	Priorities
A_1	1	5	9	0.75
A_2	0.2	1	3	0.18
A_3	0.11	0.33	1	0.07

Inconsistency = 0.03.

Table 24 The non-fuzzy pair wise comparisons and priorities of three ship officers under professional behavior criterion.

	A_1	A_2	A_3	Priorities
A_1	1	3	5	0.63
A_2	0.33	1	3	0.26
A_3	0.2	0.33	1	0.11

Inconsistency = 0.04.

Table 25 The non-fuzzy pair wise comparisons and priorities of three ship officers under occupational discipline criterion.

	A_1	A_2	A_3	Priorities
A_1	1	1	1	0.33
A_2	1	1	1	0.33
A_3	1	1	1	0.33

Inconsistency = 0.

Table 26 The non-fuzzy pair wise comparisons and priorities of three ship officers under adaptation to ship and sea life criterion.

	A_1	A_2	A_3	Priorities
A_1	1	1	1	0.,33
A_2	1	1	1	0.33
A_3	1	1	1	0.33

Inconsistency = 0.

Table 27 The non-fuzzy pair wise comparisons and priorities of three ship officers under ability on office tasks criterion.

	A_1	A_2	A_3	Priorities
A_1	1	3	3	0.60
A_2	0.33	1	1	0.20
A_3	0.33	1	1	0.20

Inconsistency = 0.

Table 28 The non-fuzzy pair wise comparisons and priorities of three ship officers under safety adaptation criterion.

	A_1	A_2	A_3	Priorities
A_1	1	3	5	0.63
A_2	0.33	1	3	0.26
A_3	0.2	0.33	1	0.11

Inconsistency = 0.04.

5. Conclusion

Decision-makers face vagueness in the decision making process. In many cases, group decision making can improve the consistency of the human decision making process and using fuzzy numbers helps to reach a more effective decision. In this paper, a ship officer performance evaluation system for all types of ships is proposed. Due to the multi-dimensional characteristic of human performance, it is of great importance to use a scientific method for performance evaluation. As the decision-making process on ship officer performance measurement involves uncertainties and fuzziness, the FAHP is found as a proper method for this study.

Owing to the distinct compilation of a ship's crew, it is more suitable to use a different evaluation process for different members of the crew according to their rank. In the literature, there are a few performance evaluation studies for different members of a ship's crew. A ship officer performance evaluation study applicable for all types of ships has not been found in the literature review. An originality of the present study is to propose a decision support system for the ship officer performance evaluation process for all types of ships.

There are a number of variables that affect ship officer performance. The evaluation of criteria has been determined with respect to a detailed literature review [3-5] and also input from area expertise. The questionnaires were sent to 50 experts and 35 completed questionnaires were returned. Among those participants, 8 (23%) are human resource managers in a shipping company, 18 (51%) are masters on ships,

Table 29 Final results for non-fuzzy AHP evaluation.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Final score
	0.12	0.07	0.10	0.12	0.12	0.12	0.13	0.10	0.12	
A_1	0.67	0.43	0.71	0.75	0.63	0.33	0.33	0.60	0.63	0.567
A_2	0.24	0.43	0.17	0.18	0.26	0.33	0.33	0.20	0.26	0.263
A_3	0.09	0.14	0.07	0.07	0.11	0.33	0.33	0.20	0.11	0.165

and 9 (26%) are officers.

Another originality of the present study is to use a different method for the weighting of evaluation criteria. Since the redundancy of the criteria used in evaluation causes difficulty in getting consistent results, all the evaluation variables are grouped into descriptive categories and a different approach is used for weighting of criteria. A questionnaire is sent to experts and results are used to find the weights of nine criteria. For each criterion, modes of points given to each variable in this category are calculated one by one and calculated modes of points are converted into fuzzy numbers. Weights of each main criterion are found based on the average of all mode values that form the related category. These weights used in pair-wise comparison of the main criteria. Remaining part of the performance evaluation process is modelled by using the FAHP based on Chang's Algorithm.

In order to validate the practicality of the proposed system, it is applied to three ship officers (A_1, A_2, A_3) working in a real shipping company. Their performance has already been evaluated by a comprehensive list that exists in the ship's safety management manual of the company. According to the past results, A_1 has the best performance score and A_3 has the worst score. The human resource manager of the shipping company evaluated the three ship officers' performances by the FAHP model proposed in this study. When the two methods were compared, the ship officers' priority weights are found in the same order and the new evaluation results demonstrated that the system is reliable.

Furthermore, the results of the proposed Fuzzy-AHP model are compared to the ones obtained by other techniques and the performance of the same three ship officers (A_1, A_2, A_3) is evaluated by using non-fuzzy AHP. The obtained results prove that non-fuzzy AHP is incapable of dealing with uncertain and fuzzy situations.

Because of the varieties of constraints on human resources in maritime industry, human resource management is more complex when compared with the other business disciplines [4]. Therefore, critical decisions should be performed in a professional manner. Personnel evaluation process is the most critical issue in the activities of human resources management department in a shipping company. In order to accomplish the establishment of professional manner in maritime industry, a systematic evaluation approach must be adopted. As a decision support system, the proposed study helps the manager give a general and fast decision in the personnel evaluation process. In future studies, the proposed performance evaluation system can be restructured for other members of the ship's crew.

There are many other multi-attribute evaluation methods that can be combined with fuzzy logic such as TOPSIS and ELECTRE as presented in the literature [25-29]. The application of these methods to ship officer performance evaluation problem with more evaluation criteria might be suggested for further research. Moreover, the proposed evaluation model is applied only to Turkish officers who are employed in a Turkish shipping company. Another further research can be performed on applying the proposed model to officers from different nationalities.

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