INVESTIGATION OF WELDER SELECTION PARAMETERS BASED ON FUZZY ANALYTIC HIERARCHY PROCESS IN SHIPBUILDING

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SUMMARY

Today, it is very significant to select appropriate welders in shipbuilding industry. The fact that there is a really tough competition between shipyards triggers the increasing of welder quality. Higher welder quality means higher quality welding workmanship. If a shipyard has a high quality workmanship, it has bigger competitive power than its rivals. Therefore, shipyard management must take welder selection into more consideration. In this study, the weights of welder selection parameters of shipyards were determined by utilizing Chang's extent analysis method. In this way, it is aimed to understand the point of view of shipyards in selecting welder. In addition, taking into account the important parameters in welder selection, the welders can improve their weak sides. Consequently, the results obtained from this study are believed to be a guide for the people who want to work as a welder in shipyards.

1. INTRODUCTION

Worker selection is an important issue for many industries such as shipbuilding. Qualified work force provides not only productivity enhancement but also well work environment for companies. On the other hand, the fact that there is a lack of well work force influences the quality of the product and production time in negative way. That causes competitive power decline. In highly competitive markets, a company's personnel play a crucial role in the future development of the company [1]. So, shipyards give importance to the selection of personnel.

Welding operation is one of the most crucial processes in shipbuilding industry. Therefore, the selection of workers performing welding operation is a significant question for shipyards. The shipyards are liable for poor workmanship. If this is the case, the shipyards fall into a difficult situation against ship owners. So, a good welder is needed for a good welding. In welder selection, each shipyard may consider different parameters. These parameters must contain the whole features of the workers in order to find the best personnel. Because, personnel selection process is aimed at choosing the best candidate to fill the defined vacancy in a company [2]. While the parameters of wage level and experience come forward for a shipyard, the criterion of location may be taken into consideration for another shipyard. Therefore, different criteria may appear. The success of a selection system is gauged by against criteria [3]. So, the process of determination of the criteria was given a great importance and it was taken as comprehensive as possible. In this study, welder selection parameters were defined in terms of shipyards and these criteria were weighted by using Chang's fuzzy method. In this way, the factors that the shipyards take into consideration in welder selection were determined. So, this study is believed to be a guide for the worker who wants to work in shipyards as a welder. Güngör et al [4] defined seventeen sub worker selection criteria in order to select the best adequate person for a job by using Fuzzy Analytic Hierarchy Process (FAHP). Kelemenis and Askounis [5] used a new TOPSIS-based multi-criteria approach in order to select appropriate personnel for an IT firm and numbers of 11 performance parameters such as interpersonal skill, leadership, experience are presented. Dursun and Karsak [6] developed a fuzzy multi criteria decision making (MCDM) algorithm in selecting the most appropriate personnel and defined eight selection criteria such as self-confidence, personality, emotional steadiness etc. Lin [7] used an integrated analytic network process (ANP) and fuzzy data envelopment analysis (DEA) approach to effectively select the personnel for an electric and machinery company under some criteria consisting of professional knowledge and expertise, previous professional career and so on. Zhang and Liu [8] utilized an intuitionistic fuzzy multi-criteria group decision making method with grey relational analysis (GRA) to select a convenient system analysis engineer for a software company by considering five performance criteria. Chien and Chen [9] presented a data mining framework based on decision tree in selection of suitable personnel for high technology industry. Capaldo and Zollo [10] performed the personnel assessment for FIAT Research Center according to various main and sub criteria determined and utilized fuzzy logic method for assessment. Mammadova and Jabrayilova [11] applied a technique of order preference by similarity to ideal solution (TOPSIS) for selecting personnel for vacancy. Rouyendegh and Erkan [12] utilized Fuzzy Electre method on academic staff selection with the help of defined criteria. Liao and Chang [13] applied analytic network process (ANP) to hospital personnel selection by considering twelve performance criteria.

As can be seen, fuzzy AHP technique is utilized for many purposes such as supplier selection [14], software [15], mining [16], ware house selection [17], maritime [18]. In this work, fuzzy AHP technique was applied to welder selection for shipyard industry. There are not many works about the application of Chang's AHP for shipyards and shipyard's welder selection in the literature. That's why, this subject was chosen for the study.

In the study, firstly, Chang's extent analysis method was expounded. Then, the performance parameters of the welder selection for shipyards were determined. These parameters were evaluated by the experts and the linguistic statements were converted to fuzzy numbers. After these evaluations were combined, the weights of the welder selection parameters were calculated.

2. METHODOLOGY

The person assessment can be stated with fuzzy logic. When it is necessary to take a decision, people can mention their assessments with linguistic definitions. Fuzzy AHP method developed by Thomas Saaty [19] helps defining the linguistic expressions with fuzzy numbers. Fuzzy AHP is a multiphase decision making method based on gathering expert opinions by means of pair wise comparison matrices. In this study, the approach of extent analysis method presented by Chang [20] was utilized. Zadeh [21] defined fuzzy set numbers in order to model the complicated systems which people face in the daily life. These fuzzy set numbers facilitates to solve the complex problems.

$M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are considered as two fuzzy numbers and simple calculations in fuzzy numbers are as below:

$$M_1 \oplus M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (1)$$

$$M_1 \otimes M_2 = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \quad (2)$$

$$\lambda \otimes M_1 = (\lambda \times l_1, \lambda \times m_1, \lambda \times u_1), \lambda > 0, \lambda \in \mathbb{R} \quad (3)$$

$$M_1^{-1} = (1/u_1, 1/m_1, 1/l_1) \quad (4)$$

$X = \{x_1, x_2, ..., x_n\}$ is an object set, $U = \{u_1, u_2, ..., u_m\}$ is an objective set. Extent analysis is applied to each object for each objective and m values of extent analysis are achieved for each object at the end of this process. If M_{gi}^j $(i = 1,2,...,n; j = 1,2,...,m)$ are triangular fuzzy numbers, value of extent analysis for each object is following:

$$M_{gi}^1, M_{gi}^2, ..., M_{gi}^m \quad (5)$$

Values of extent analysis for m objectives of *i th* object are $M_{gi}^1, M_{gi}^2, ..., M_{gi}^m$ and synthetic extent value for *i th* object can be defined as below:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \quad (6)$$

These calculated synthetic extent analysis values are triangular fuzzy numbers and the weights are obtained with comparison of these numbers. The superiority degrees of M_1 and M_2 fuzzy numbers are defined in Equation 7:

$$V(M_1 \geq M_2) = \sup_{x \geq y} \left[\min \left(\mu_{M_1}(x), \mu_{M_2}(y) \right) \right] \quad (7)$$

Possibility degree of $M_1 \geq M_2$ inequality is defined as below:

$$V(M_1 \geq M_2) = \begin{cases} \text{if } m_1 \geq m_2 & 1 \\ \text{if } l_2 \geq u_1 & 0 \\ \text{otherwise} & \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} \end{cases} \quad (8)$$

In order to compare M_1 and M_2, both $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ values are needed. Value $V(M_2 \geq M_1)$ is determined like $V(M_1 \geq M_2)$ calculation. In convex triangular fuzzy numbers, seniority of a fuzzy number from *k* fuzzy numbers is defined in Equation 9:

$$\begin{aligned} & V(M \geq M_1, M_2, ..., M_k) \\ & = V[M \geq M_1 \text{ and } M \geq M_2 \text{ and ... and } M \geq M_k] \\ & = \min V(M \geq M_i), \quad i = 1,2,...,k \end{aligned} \quad (9)$$

If the calculated synthetic extent analysis values for each object of a comparison matrix are as following:

$$\begin{aligned} & d'(A_i) = \min V(S_i \geq S_k); \ k \neq i; \\ & k = 1,2,...,n; \ i = 1,2,...,n \end{aligned} \quad (10)$$

Then, weight vector for this matrix is found:

$$W' = \left(d'(A_1), d'(A_2), ..., d'(A_n) \right)^T \quad (11)$$

After that, normalization process is applied and normalized weight vector is achieved as shown in Equation 12:

$$W = \left(d(A_1), d(A_2), ..., d(A_n) \right)^T \quad (12)$$

In this study, firstly, comparison matrices were prepared and submitted to the experts to be evaluated. Then, the comparison matrices were gathered and the linguistic terms are transformed to fuzzy triangular numbers. After that, all the evaluation matrices were combined by using geometric mean and extent analysis value is calculated for each parameter. By using extent values, total extent analysis value and its inverse value are found. Then, each performance parameter is multiplied by the inverse value of total extent analysis and synthetic extent analysis values are achieved. Later, these synthetic extent values of the performance parameters are compared with each other and superiority values are found in this way. Superiority values constitute weight vector. Finally, this weight vector is exposed to normalization process and the weights of the performance parameters are determined.

Table 1. Performance parameters

Performance parameters	Abbre-viation	Definition of parameters
Age	A	How old is the welder?
Experience	E	How long has the welder been working and how many companies has the welder worked at ever before?
Welder certification	WCE	Does he have a welder certification?
Educational status	ES	What is the educational status of welder? Is he graduated from university?
Marital status	MS	Is he married?
Physical structure	PS	Does he have a strong body structure?
Wage	W	How much does he demand from shipyard?
Location	L	Where does he live? The place he lives is far away from the shipyard?
Adaption to flexible working hours	AFW	Can he work extra shift?
Multi-purpose usage of welder	MPW	Can the welder be utilized at the other works in shipyard if needed?
Loyalty to company	LC	Does he work at the shipyard for long period?
Relations with workfellows	RW	Does he get along with the work fellows?
Tendency to teamwork	TT	Is he appropriate for teamwork?
Capability of welding per hour	CWH	How many meters can he weld per hour?
Compatibility to work rules	CW	Does he obey the work rules at the shipyard?
Ability of solving troubles	AST	Can he quickly find a solution to the troubles at the work place?
Knowledge share with work fellows	KWF	Does he teach the welding operation to other workers and share the knowledge that he knows?
Compatibility to job security	CJS	Does he give importance to security at work place?

Table 2. Fuzzy number transformation scale.

Linguistic scale	Triangular fuzzy scale
Equally important	(1,1,3)
Weakly more important	(1,3,5)
Essentially more important	(3,5,7)
Very strongly more important	(5,7,9)
Absolutely more important	(7,9,9)

3. CALCULATION OF WELDER SELECTION PARAMETERS' WEIGHTS

3.1 DESCRIPTION OF PERFORMANCE PARAMETERS (STAGE 1)

In this phase, the selection parameters of welder selection will be defined. Table 1 shows the selection parameters of the welder who wants to work at shipyards. There are number of 18 selection parameters including age, experience, welder certification, educational status, marital status, physical structure, wage, location, ability of adapting flexible work hours, multi-purpose usage, loyalty, harmony to workfellows, tendency to teamwork, capability of welding per hour, compatibility to work rules, ability of solving troubles, knowledge share with work fellows and compatibility to job security. Welders will be selected by shipyard management according to these parameters.

3.2 DEFINITION OF FUZZY EXPRESSIONS (STAGE 2)

At this stage of the study, definition of the linguistic statements will be carried out. Table 2 demonstrates the fuzzy number transformation scale [22]. For instance, the linguistic term "equally important" means the fuzzy number of (1, 1, 3). In the same way, the statement "weakly more important" implies (1, 3, 5) as triangular fuzzy number. The whole linguistic statements obtained from experts who evaluate the selection parameters will be converted to the triangular fuzzy numbers. Therefore, all linguistic terms will be represented by fuzzy number set.

3.3 BUILDING UP THE EVALUATION MATRIX, EXPERT RAITING AND AGGREGATION OF ASSESSMENTS (STAGE 3)

After the definition of linguistic statements, evaluation matrix will be created in order for the experts to commentate the selection parameters. These evaluation matrices will be submitted to the experts. Then, experts' assessments are gathered and these evaluations are converted to triangular fuzzy number sets. The assessments achieved from the experts are linguistic expressions and they are needed to transform fuzzy numbers. These conversion processes are performed for each expert evaluation. Table 3 shows the evaluation result of Expert 1. Here, due to lack of space, only the Expert 1's assessment result was given. Then, the whole expert assessments are aggregated and a single evaluation matrix is obtained after this aggregation process. Table 4 illustrates the aggregated evaluation result of whole experts as a single matrix.

Table 3. Evaluation of Expert 1.

	A	E	WCE	ES	MS	PS	W
A	(1, 1, 1)	(0.11, 0.14, 0.20)	(0.11, 0.14, 0.20)	(0.11, 0.11, 0.14)	(1, 1, 3)	(1, 1, 3)	(0.14, 0.2, 0.33)
E	(5, 7, 9)	(1, 1, 1)	(1, 1, 3)	(1, 3, 5)	(5, 7, 9)	(3, 5, 7)	(0.11, 0.11, 0.14)
WCE	(5, 7, 9)	(0.33, 1, 1)	(1, 1, 1)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(0.2, 0.33, 1)
ES	(7, 9, 9)	(0.2, 0.33, 1)	(0.11, 0.14, 0.20)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(1, 1, 3)
MS	(0.33, 1, 1)	(0.11, 0.14, 0.20)	(0.11, 0.14, 0.20)	(0.14, 0.2, 0.33)	(1, 1, 1)	(0.2, 0.33, 1)	(0.2, 0.33, 1)
PS	(0.33, 1, 1)	(0.14, 0.2, 0.33)	(0.11, 0.14, 0.20)	(0.14, 0.2, 0.33)	(1, 3, 5)	(1, 1, 1)	(0.2, 0.33, 1)
W	(3, 5, 7)	(7, 9, 9)	(1, 3, 5)	(0.33, 1, 1)	(1, 3, 5)	(1, 3, 5)	(1, 1, 1)
L	(7, 9, 9)	(0.11, 0.14, 0.20)	(0.14, 0.2, 0.33)	(0.33, 1, 1)	(3, 5, 7)	(7, 9, 9)	(0.11, 0.11, 0.14)
AFW	(3, 5, 7)	(0.11, 0.11, 0.14)	(0.14, 0.2, 0.33)	(0.14, 0.2, 0.33)	(5, 7, 9)	(3, 5, 7)	(0.11, 0.11, 0.14)
MPW	(1, 3, 5)	(0.2, 0.33, 1)	(0.33, 1, 1)	(0.11, 0.14, 0.20)	(0.33, 1, 1)	(0.33, 1, 1)	(0.11, 0.11, 0.14)
LC	(3, 5, 7)	(0.2, 0.33, 1)	(0.33, 1, 1)	(0.33, 1, 1)	(1, 3, 5)	(1, 3, 5)	(0.11, 0.11, 0.14)
RW	(7, 9, 9)	(1, 3, 5)	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(1, 3, 5)	(0.33, 1, 1)	(0.11, 0.11, 0.14)
TT	(7, 9, 9)	(0.14, 0.2, 0.33)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(1, 3, 5)	(1, 3, 5)	(0.11, 0.11, 0.14)
CWH	(3, 5, 7)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(7, 9, 9)	(7, 9, 9)	(0.11, 0.11, 0.14)
CW	(7, 9, 9)	(1, 3, 5)	(0.33, 1, 1)	(0.33, 1, 1)	(7, 9, 9)	(3, 5, 7)	(0.11, 0.11, 0.14)
AST	(0.2, 0.33, 1)	(0.11, 0.14, 0.20)	(0.14, 0.2, 0.33)	(0.11, 0.11, 0.14)	(7, 9, 9)	(0.33, 1, 1)	(0.11, 0.11, 0.14)
KWF	(1, 3, 5)	(0.11, 0.14, 0.20)	(0.14, 0.2, 0.33)	(0.11, 0.11, 0.14)	(7, 9, 9)	(7, 9, 9)	(0.11, 0.11, 0.14)
CJS	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)

Table 3. Evaluation of Expert 1 (continue).

	L	AFW	MPW	LC	RW	TT
A	(0.11, 0.11, 0.14)	(0.14, 0.2, 0.33)	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)
E	(5, 7, 9)	(7, 9, 9)	(1, 3, 5)	(1, 3, 5)	(0.2, 0.33, 1)	(3, 5, 7)
WCE	(3, 5, 7)	(3, 5, 7)	(1, 1, 3)	(1, 1, 3)	(1, 3, 5)	(1, 3, 5)
ES	(1, 1, 3)	(3, 5, 7)	(5, 7, 9)	(1, 1, 3)	(3, 5, 7)	(1, 3, 5)
MS	(0.14, 0.2, 0.33)	(0.11, 0.14, 0.20)	(1, 1, 3)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.2, 0.33, 1)
PS	(0.11, 0.11, 0.14)	(0.14, 0.2, 0.33)	(1, 1, 3)	(0.2, 0.33, 1)	(1, 1, 3)	(0.2, 0.33, 1)
W	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)
L	(1, 1, 1)	(0.14, 0.2, 0.33)	(1, 1, 3)	(1, 1, 3)	(0.2, 0.33, 1)	(0.2, 0.33, 1)
AFW	(3, 5, 7)	(1, 1, 1)	(1, 1, 3)	(0.2, 0.33, 1)	(0.11, 0.11, 0.14)	(0.11, 0.14, 0.20)
MPW	(0.33, 1, 1)	(0.33, 1, 1)	(1, 1, 1)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)
LC	(0.33, 1, 1)	(1, 3, 5)	(1, 3, 5)	(1, 1, 1)	(1, 3, 5)	(1, 3, 5)
RW	(1, 3, 5)	(7, 9, 9)	(1, 3, 5)	(0.2, 0.33, 1)	(1, 1, 1)	(1, 1, 3)
TT	(1, 3, 5)	(5, 7, 9)	(3, 5, 7)	(0.2, 0.33, 1)	(0.33, 1, 1)	(1, 1, 1)
CWH	(7, 9, 9)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(0.33, 1, 1)
CW	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)	(3, 5, 7)	(1, 3, 5)	(7, 9, 9)
AST	(7, 9, 9)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(0.33, 1, 1)	(0.33, 1, 1)
KWF	(7, 9, 9)	(1, 3, 5)	(1, 3, 5)	(0.33, 1, 1)	(0.33, 1, 1)	(0.33, 1, 1)
CJS	(5, 7, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)

Table 3. Evaluation of Expert 1 (continue).

	CWH	CW	AST	KWF	CJS
A	(0.14, 0.2, 0.33)	(0.11, 0.11, 0.14)	(1, 3, 5)	(0.2, 0.33, 1)	(0.11, 0.11, 0.14)
E	(1, 3, 5)	(0.2, 0.33, 1)	(5, 7, 9)	(5, 7, 9)	(0.11, 0.11, 0.14)
WCE	(1, 3, 5)	(1, 1, 3)	(3, 5, 7)	(3, 5, 7)	(0.11, 0.11, 0.14)
ES	(3, 5, 7)	(1, 1, 3)	(7, 9, 9)	(7, 9, 9)	(0.11, 0.11, 0.14)
MS	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)
PS	(0.11, 0.11, 0.14)	(0.14, 0.2, 0.33)	(1, 1, 3)	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)
W	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(0.11, 0.11, 0.14)
L	(0.11, 0.11, 0.14)	(0.14, 0.2, 0.33)	(0.11, 0.11, 0.14)	(0.11, 0.11, 0.14)	(0.11, 0.14, 0.20)
AFW	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.11, 0.11, 0.14)
MPW	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(0.11, 0.11, 0.14)
LC	(0.2, 0.33, 1)	(0.14, 0.2, 0.33)	(0.2, 0.33, 1)	(1, 1, 3)	(0.11, 0.11, 0.14)
RW	(0.2, 0.33, 1)	(0.2, 0.33, 1)	(1, 1, 3)	(1, 1, 3)	(0.11, 0.11, 0.14)
TT	(1, 1, 3)	(0.11, 0.11, 0.14)	(1, 1, 3)	(1, 1, 3)	(0.11, 0.11, 0.14)
CWH	(1, 1, 1)	(0.11, 0.11, 0.14)	(7, 9, 9)	(3, 5, 7)	(0.11, 0.11, 0.14)
CW	(7, 9, 9)	(1, 1, 1)	(5, 7, 9)	(5, 7, 9)	(0.11, 0.11, 0.14)
AST	(0.11, 0.11, 0.14)	(0.11, 0.14, 0.20)	(1, 1, 1)	(5, 7, 9)	(0.11, 0.11, 0.14)
KWF	(0.14, 0.2, 0.33)	(0.11, 0.14, 0.20)	(0.11, 0.14, 0.20)	(1, 1, 1)	(0.11, 0.11, 0.14)
CJS	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(1, 1, 1)

Table 4. Aggregated matrix of expert evaluations.

	A	E	WCE	ES	MS	PS	W
A	(1, 1, 1)	(0.12, 0.15, 0.22)	(0.14, 0.19, 0.45)	(0.41, 1.07, 1.76)	(3.67, 5, 7)	(0.45, 0,51, 1.44)	(0.13, 0.17, 0.27)
E	(5,7,8.33)	(1, 1, 1)	(3.67, 5, 7)	(2.70, 4.05, 4.73)	(6.33, 8.33, 9)	(4.33, 6.33, 8.33)	(1.74, 2.41, 3.09)
WCE	(4.33, 6.33, 7.67)	(0.18, 0.43, 0.47)	(1, 1, 1)	(2.70, 4.04, 5.38)	(5, 7, 8.33)	(3.40, 4.78, 6.33)	(0.44, 0.48, 1.38)
ES	(4.73, 6.11, 6.33)	(1.77, 2.48, 3.38)	(2.42, 3.11, 3.18)	(1, 1, 1)	(3.67, 5.67, 7)	(2.71, 4.07, 5.44)	(0.41, 0.42, 1.11)
MS	(0.18, 0.43, 0.47)	(0.11, 0.12, 0.16)	(0.12, 0.15, 0.22)	(0.15, 0.21, 0.49)	(1, 1, 1)	(0.14, 0.20,0.47)	(0.15, 0.21, 0.49)
PS	(1.44, 3, 4.33)	(0.12, 0.16, 0.24)	(0.41, 1.09, 1.80)	(1.08, 1.78, 2.51)	(3.67, 5.67, 7.67)	(1, 1, 1)	(0.17, 0.26, 0.71)
W	(4.33, 6.33, 7.67)	(4.70, 6.05, 6.07)	(2.78, 4.33, 5)	(4.11, 5.67, 6.33)	(3.67, 5.67, 7)	(3, 5, 6.33)	(1, 1, 1)
L	(4.07, 5.44, 6.33)	(0.11, 0.14, 0.20)	(0.19, 0.44, 0.49)	(1.15, 2.04, 2.71)	(2.33, 4.33, 6.33)	(3.67, 5.67, 7)	(0.18, 0.41, 0.43)
AFW	(3.67, 5.67, 7.67)	(0.18, 0.42, 0.45)	(1.09, 1.80, 2.55)	(1.76, 2.47, 3.22)	(5, 7, 9)	(4.33, 6.33, 7.67)	(0.41, 1.07, 1.76)
MPW	(3, 5, 7)	(0.21, 0.49, 0.73)	(1.16, 2.07, 2.78)	(1.75, 2.45, 3.18)	(3.44, 5, 6.33)	(4.11, 5.67, 6.33)	(1.07, 1.74, 2.43)
LC	(3.67, 5.67, 7)	(0.14, 0.18, 0.43)	(0.29, 0.78, 1)	(1.82, 2.73, 3.44)	(3, 5, 6.33)	(2.73, 4.11, 5)	(0.14, 0.18, 0.43)
RW	(5.67, 7.67, 8.33)	(0.44, 1.15, 2.05)	(0.24, 0.55, 1)	(0.43, 1.13, 1.89)	(3.67, 5.67, 7)	(1.84, 2.78, 3.67)	(0.12, 0.14, 0.20)
TT	(5,7,7.67)	(0.19, 0.45, 0.51)	(0.24, 0.55, 1)	(1.78, 2.51, 3.44)	(3.67, 5.67, 7)	(3, 5, 7)	(0.15, 0.21, 0.49)
CWH	(5,7,8.33)	(0.16, 0.24, 0.55)	(1.78, 2.51, 3.44)	(2.42, 3.11, 3.18)	(5.67, 7.67, 8.33)	(5.67, 7.67, 9)	(1.74, 2.41, 3.09)
CW	(3.67, 5.67, 7)	(0.48, 1.38, 2.07)	(0.49, 1.40, 2.11)	(0.49, 1.40, 2.11)	(3.67, 5.67, 7)	(2.78, 4.33, 5.67)	(0.19, 0.44, 0.49)
AST	(2.07, 3.44, 5)	(1.74, 2.43, 3.13)	(1.08, 1.78, 2.51)	(1.75, 2.44, 3.16)	(5.67, 7.67, 9)	(2.78, 4.33, 5.67)	(1.08, 1.77, 2.49)
KWF	(1.67, 3.67, 5.67)	(1.07, 1.75, 2.45)	(0.20, 0.47, 0.55)	(1.08, 1.77, 2.49)	(5.67, 7.67, 9)	(4.33, 6.33, 7.67)	(0.14, 0.18, 0.43)
CJS	(6.33, 8.33, 9)	(5, 7, 7.67)	(6.33, 8.33, 9)	(7, 9, 9)	(6.33, 8.33, 9)	(6.33, 8.33, 9)	(6.33, 8.33, 9)

Table 4. Aggregated matrix of expert evaluations (continue).

	L	AFW	MPW	LC	RW	TT
A	(0.41, 1.08, 1.78)	(0.13, 0.18, 0.29)	(0.15, 0.22, 0.51)	(0.15, 0.21, 0.49)	(0.12, 0.14, 0.20)	(0.14, 0.18, 0.43)
E	(5, 7, 9)	(4.33, 5.67, 7)	(2.33, 3.67, 5.67)	(5, 7, 7.67)	(2.73, 4.11, 5)	(3, 4.33, 6.33)
WCE	(3.67, 5, 6.33)	(2.05, 3.40, 4.78)	(1.38, 2.07, 3.44)	(1, 1.67, 3.67)	(1, 2.33, 4.33)	(1, 2.33, 4.33)
ES	(2.71, 3.40, 4.11)	(2.04, 3.38, 4.73)	(2.70, 4.05, 5.40)	(1.37, 2.05, 3.40)	(2.07, 3.44, 5)	(1.37, 2.71, 4.07)
MS	(0.16, 0.24, 0.55)	(0.11, 0.14, 0.20)	(0.41, 0.43, 1.13)	(0.17, 0.26, 0.71)	(0.15, 0.21, 0.49)	(0.15, 0.21, 0.49)
PS	(0.15, 0.21, 0.49)	(0.13, 0.17, 0.27)	(0.41, 0.42, 1.11)	(0.44, 1.15, 2.05)	(0.70, 1.38, 2.73)	(0.15, 0.22, 0.51)
W	(5, 6.33, 7)	(4.73, 6.11, 6.33)	(4.71, 6.07, 6.11)	(5, 7, 7.67)	(5.67, 7.67, 8.33)	(3.67, 5.67, 7)
L	(1, 1, 1)	(0.13, 0.18, 0.29)	(0.41, 0.43, 1.13)	(0.70, 1.38, 2.73)	(0.44, 1.16, 2.07)	(0.44, 0.49, 1.40)
AFW	(3.67, 5.67, 7.67)	(1, 1, 1)	(0.73, 0.78, 2.33)	(1.40, 2.78, 4.33)	(1.75, 2.44, 3.16)	(0.42, 1.11, 1.84)
MPW	(3.44, 5, 6.33)	(0.55, 1.67, 2.33)	(1, 1, 1)	(2.73, 4.11, 5.67)	(1.40, 2.78, 4.33)	(1.78, 2.51, 3.44)
LC	(1.84, 2.78, 3.67)	(0.45, 1.18, 2.11)	(0.42, 1.11, 1.84)	(1, 1, 1)	(1, 3, 5)	(1.67, 3.67, 5.67)
RW	(2.07, 3.44, 5)	(3.37, 4.71, 5.40)	(0.45, 1.18, 2.11)	(0.20, 0.33, 1)	(1, 1, 1)	(0.71, 0.73, 2.11)
TT	(2.11, 3.67, 5)	(2.73, 4.11, 5.67)	(1.37, 2.71, 4.07)	(0.18, 0.29, 0.78)	(1.22, 2.33, 3)	(1, 1, 1)
CWH	(5.67, 7.67, 9)	(1.37, 2.70, 4.05)	(1.37, 2.70, 4.05)	(1.37, 2.70, 4.05)	(2.04, 3.37, 4.71)	(1.81, 2.71, 3.40)
CW	(3, 5, 7)	(1.40, 2.78, 4.33)	(1.13, 1.89, 3)	(1.18, 2.11, 3)	(0.55, 1.67, 2.33)	(2.55, 3.67, 3.69)
AST	(6.33, 8.33, 9)	(1, 3, 5)	(0.78, 2.33, 3.67)	(1.67, 3.67, 5.67)	(2.11, 3.67, 5)	(2.78, 4.33, 5.67)
KWF	(4.11, 5.67, 6.33)	(0.43, 1.13, 1.89)	(0.42, 1.11, 1.84)	(0.20, 0.47, 0.55)	(0.55, 1.67, 2.33)	(0.51, 1.44, 2.33)
CJS	(5.67, 7.67, 9)	(6.33, 8.33, 9)	(6.33, 8.33, 9)	(6.33, 8.33, 9)	(7, 9, 9)	(6.33, 8.33, 9)

Table 4. Aggregated matrix of expert evaluations (continue).

	CWH	CW	AST	KWF	CJS
A	(0.12, 0.15, 0.22)	(0.15, 0.21, 0.49)	(0.43, 1.13, 1.89)	(0.18, 0.29, 0.78)	(0.11, 0.12, 0.16)
E	(2.33, 4.33, 6.33)	(2.07, 2.78, 4.33)	(3.37, 4.71, 6.07)	(4.05, 5.40, 6.11)	(0.14, 0.18, 0.43)
WCE	(1.37, 2.71, 4.07)	(1.40, 2.11, 3.67)	(2.71, 4.07, 5.44)	(2.33, 3.67, 5.67)	(0.11, 0.12, 0.16)
ES	(2.70, 4.04, 5.38)	1.40, 2.11, 3.67)	(3.37, 4.71, 5.40)	(3.38, 4.73, 5.44)	(0.11, 0.11, 0.14)
MS	(0.12, 0.14, 0.20)	(0.15, 0.21, 0.49)	(0.11, 0.13, 0.18)	(0.11, 0.13, 0.18)	(0.11, 0.12, 0.16)
PS	(0.11, 0.13, 0.18)	(0.42, 0.45, 1.18)	(0.42, 0.45, 1.18)	(0.14, 0.19, 0.45)	(0.11, 0.12, 0.16)
W	(4.70, 6.05, 6.07)	(3.67, 5, 6.33)	(3.38, 4.73, 5.44)	(5, 7, 7.67)	(0.11, 0.12, 0.16)
L	(0.11, 0.13, 0.18)	(0.15, 0.22, 0.51)	(0.11, 0.12, 0.16)	(0.41, 0.42, 1.11)	(0.11, 0.13, 0.18)
AFW	(2.45, 3.18, 3.44)	(0.45, 1.18, 2.11)	(0.20, 0.33, 1)	(2.07, 3.44, 5)	(0.11, 0.12, 0.16)
MPW	(2.45, 3.18, 3.44)	(0.71, 2.07, 3.44)	(0.47, 0.55, 1.67)	(2.73, 4.11, 5.67)	(0.11, 0.12, 0.16)
LC	(2.45, 3.18, 3.44)	(0.71, 1.40, 2.78)	(0.18, 0.29, 0.78)	(2.33, 3.67, 5.67)	(0.11, 0.12, 0.16)
RW	(2.44, 3.16, 3.40)	(0.73, 0.78, 2.33)	(0.43, 0.47, 1.22)	(0.73, 0.78, 2.33)	(0.11, 0.11, 0.14)
TT	(2.04, 2.71, 4.07)	(0.70, 0.70, 2.05)	(0.42, 0.45, 1.18)	(0.73, 1.44, 3)	(0.11, 0.12, 0.16)
CWH	(1, 1, 1)	(1.08, 1.77, 2.49)	(2.70, 4.05, 4.73)	(2.73, 4.11, 5.67)	(0.12, 0.14, 0.20)
CW	(3.38, 4.73, 5.44)	(1, 1, 1)	(1.77, 2.49, 3.40)	(3, 4.33, 6.33)	(0.11, 0.12, 0.16)
AST	(1.77, 2.48, 3.38)	(2.04, 3.38, 4.73)	(1, 1, 1)	(5, 7, 9)	(0.12, 0.14, 0.20)
KWF	(0.42, 1.11, 1.84)	(0.19, 0.45, 0.51)	(0.11, 0.14, 0.20)	(1, 1, 1)	(0.11, 0.12, 0.16)
CJS	(5.67, 7.67, 8.33)	(6.33, 8.33, 9)	(5.67, 7.67, 8.33)	(6.33, 8.33, 9)	(1, 1, 1)

3.4 CALCULATION OF EXTENT ANALYSIS VALUES FOR EACH PARAMETER (STAGE 4)

At this step, the extent analysis values of each performance criterion will be found. For the first parameter (age), extent analysis value is calculated as below:

$$\sum_{j=1}^{18} M_{g1}^{j} = ((1+0.12+0.14+0.41+3.66+0.44+$$

0.13+0.41+0.13+0.15+0.15+0.12+0.14+0.12+0.15+0.43+0.18+0.11),(1+0.15+0.19+1.07+5+0.51+0.17+1.08+0.18+0.22+0.21+0.14+0.18+0.15+0.21+1.13+0.29+0.12),(1+0.22+0.45+1.76+7+1.44+0.27+1.78+0.29+0.51+0.49+0.20+0.48+0.22+0.49+1.89+0.78+0.16))
= (7.99, 12.02, 19.37)

Similarly, extent analysis values for whole parameters are calculated and the following table (Table 5) is created. The values of extent analysis are able to be seen from Table 5.

Table 5. Extent analysis values of performance parameters

Parameters	Extent analysis values
Age	(7.99, 12.02, 19.37)
Experience	(59.13, 83.30, 105.43)
Welder certification	(35.08, 53.53, 76.45)
Educational status	(39.93, 57.59, 74.19)
Marital status	(3.60, 4.55, 8.09)
Physical structure	(11.06, 17.84, 28.57)
Wage	(69.23, 95.79, 107.51)
Location	(15.70, 24.12, 34.26)
Adaption to flexible working hours	(30.68, 46.77, 64.36)
Multi-purpose usage of welder	(32.13, 49.50, 66.27)
Loyalty to company	(23.95, 40.04, 55.70)
Relations with workfellows	(24.64, 35.77, 50.18)
Tendency to teamwork	(26.65, 40.93, 57.07)
Capability of welding per hour	(43.70, 63.53, 79.28)
Compatibility to work rules	(30.84, 50.07, 66.11)
Ability of solving troubles	(40.76, 63.19, 83.27)
Knowledge share with workfellows	(22.22, 36.15, 47.25)
Compatibility to job security	(106.67, 140.67, 151.33)

After that, total extent analysis value is calculated as following:

$$\sum_{i=1}^{18} \sum_{j=1}^{18} M_{gi}^{j} = ((7.99+59.13+35.08+39.93+3.60+$$

11.06+69.23+15.70+30.68+32.13+23.95+24.64+26.65+43.70+30.84+40.76+22.22+106.67),(12.02+83.30+53.53+57.59+4.55+17.84+95.79+24.12+46.77+49.50+40.04+35.77+40.93+63.53+50.07+63.19+36.15+140.67),(19.37+105.43+76.45+74.19+8.09+28.57+107.51+34.26+64.36+66.27+55.74+50.18+57.07+79.28+66.11+83.27+47.25+151.33)) = (623.94,915.35,1174.74)

The next step is the finding of the inverse value of total extent analysis. Its value is determined as below:

$$\left[\sum_{i=1}^{18} \sum_{j=1}^{18} M_{gi}^{j}\right]^{-1} = (0.000851,\ 0.001092,\ 0.001603)$$

3.5 DETERMINATION OF SYNTHETIC EXTENT ANALYSIS VALUES OF PARAMETERS (STAGE 5)

In this section of the study, synthetic extent analysis values will be calculated by using Equation 6. Following, calculation for the criterion of Age is shown:

$$S_1 = \sum_{j=1}^{18} M_{gi}^{j} \otimes \left[\sum_{i=1}^{18} \sum_{j=1}^{18} M_{gi}^{j}\right]^{-1} = ((7.99\text{x}0.000851),$$

(12.02x0.001092),(19.37x0.001603))=(0.0068,0.0131, 0.0310).

Table 6. Synthetic extent analysis values of parameters

Parameters	Synthetic extent analysis values
Age	(0.0068, 0.0131, 0.0310)
Experience	(0.0503, 0.0910, 0.1690)
Welder certification	(0.0299, 0.0585, 0.1225)
Educational status	(0.0340, 0.0629, 0.1189)
Marital status	(0.0031, 0.0050, 0.0130)
Physical structure	(0.0094, 0.0195, 0.0458)
Wage	(0.0589, 0.1046, 0.1723)
Location	(0.0134, 0.0263, 0.0549)
Adaption to flexible working hours	(0.0261, 0.0511, 0.1032)
Multi-purpose usage of welder	(0.0273, 0.0541, 0.1062)
Loyalty to company	(0.0204, 0.0437, 0.0893)
Relations with workfellows	(0.0210, 0.0391, 0.0804)
Tendency to teamwork	(0.0227, 0.0447, 0.0915)
Capability of welding per hour	(0.0372, 0.0694, 0.1271)
Compatibility to work rules	(0.0263, 0.0547, 0.1060)
Ability of solving troubles	(0.0347, 0.0690, 0.1335)
Knowledge share with workfellows	(0.0189, 0.0395, 0.0757)
Compatibility to job security	(0.0908, 0.1537, 0.2425)

3.6 COMPARISON OF SYNTHETIC EXTENT ANALYSIS VALUES AND DEFINITION OF WEIGHT VECTOR (STAGE 6)

Here, Equation 8 will be utilized for determining the synthetic extent analysis values of performance parameters. In this section, calculation for "Educational Status" parameter is shown.

$$V(S_4 \geq S_1) = 1 \,(\text{Because } 0.0629 \geq 0.0131)$$

$$V(S_4 \geq S_2) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} =$$

$$\frac{0.0503 - 0.1189}{(0.0629 - 0.1189) - (0.0910 - 0.0503)} = 0.709$$

$$V(S_4 \geq S_3) = 1 \,(\text{Because } 0.0629 \geq 0.0585)$$

$V(S_4 \geq S_5) = 1$ (Because $0.0629 \geq 0.0050$)
$V(S_4 \geq S_6) = 1$ (Because $0.0629 \geq 0.0195$)

$$V(S_4 \geq S_7) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} = \frac{0.0589 - 0.1189}{(0.0629 - 0.1189) - (0.1046 - 0.0589)} = 0.590$$

$V(S_4 \geq S_8) = 1$ (Because $0.0629 \geq 0.0263$)
$V(S_4 \geq S_9) = 1$ (Because $0.0629 \geq 0.0511$)
$V(S_4 \geq S_{10}) = 1$ (Because $0.0629 \geq 0.0541$)
$V(S_4 \geq S_{11}) = 1$ (Because $0.0629 \geq 0.0437$)
$V(S_4 \geq S_{12}) = 1$ (Because $0.0629 \geq 0.0391$)
$V(S_4 \geq S_{13}) = 1$ (Because $0.0629 \geq 0.0447$)

$$V(S_4 \geq S_{14}) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} = \frac{0.0372 - 0.1189}{(0.0629 - 0.1189) - (0.0694 - 0.0372)} = 0.926$$

$V(S_4 \geq S_{15}) = 1$ (Because $0.0629 \geq 0.0547$)

$$V(S_4 \geq S_{16}) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} = \frac{0.0347 - 0.1189}{(0.0629 - 0.1189) - (0.0690 - 0.0347)} = 0.932$$

$V(S_4 \geq S_{17}) = 1$ (Because $0.0629 \geq 0.0395$)

$$V(S_4 \geq S_{18}) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} = \frac{0.0908 - 0.1189}{(0.0629 - 0.1189) - (0.1537 - 0.0908)} = 0.236$$

Then, as a result of comparison of synthetic analysis value of "Educational Status" with the others, the value of (in other words, superiority degree) becomes 0.236.

$$d'(A_i) = \min V(S_i \geq S_k);\ k \neq i;\ k = 1,2,...,n;\ i = 1,2,...,n$$
$$d'(A_4) = \min V(S_4 \geq S_1, S_2, S_3, S_5, S_6, ..., S_{17}, S_{18})$$
$$d'(A_4) = 0.236$$

Superiority degrees of the other parameters are calculated in the same way with the criterion "Educational Status" and finally weight vector is obtained by using Equation 11.

$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T =$ (0, 0.555, 0.249, 0.236, 0, **0**, 0.624, 0, 0.108, 0.134, 0, 0, 0.0064, 0.300, 0.133, 0.335, 0, 1)

Finally, normalized weight vector is determined by using Equation 12.

$W = (d(A_1), d(A_2), ..., d(A_n))^T =$ (0, 0.1508, 0.0676, 0.0641, 0, 0, 0.1695, 0, 0.0293, 0.0364, 0, 0, 0.0017, 0.0815, 0.0361, 0.0910, 0, 0.2717)

4. CONCLUSIONS

According to Figure 1, shipyard management considers the criterion of "compatibility to job security" the most because the weight value of this parameter is around 27%. The second most significant criterion in welder selection is "wage" and its weight is around 17%. The third most important criterion in terms of shipyard is "experience" since it has the weight of about 15%. The criteria of "age, marital status, physical structure, location, loyalty to company, relations with workfellows and knowledge share with workfellows " is least important criteria because their weights are too small. So, it can be concluded from the study that whether a welder is married, his age and physical structure, and the distance from the place he lives to the shipyard location, his desire to work for another companies, and relations with the other workers are not important in welder selection. The most significant parameter for shipyard is "compatibility to job security", "wage" and "experience", respectively.

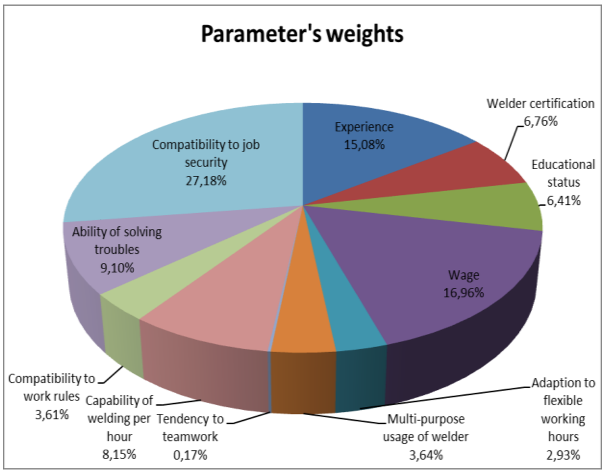

Figure 1. Weights of welder selection parameters

In this study, the weights of welder selection parameters were determined and it was aimed that the welders who want to work at shipyards know about the parameters taken into consideration by shipyards. In this way, the welders can evaluate themselves and improve their weak sides prior to applying to shipyards. In the study, numbers of 18 parameters were determined and their weights were calculated by Chang's extent analysis method. The shipyards take "compatibility to job security" into consideration the most. It shows that the job security is one of the most important things for shipyards. The fact that the work failures recently increased in Turkey caused that the shipyards give importance to job security much more ever before. So, the shipyards want the welders to comply with the security rules as security is the most important parameter for them. Besides, the wage level that the welder requests from shipyard and the duration that the welder have worked ever before are the other most important things for shipyards in selecting welders. On the other hand, the marital status of welders, his physical power, and the place where he lives have very little importance for shipyards.

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