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IMPLEMENTING FAHP-BSC INTEGRATED APPROACH FOR EVALUATING THE PERFORMANCE OF MAINTENANCE AND REPAIRS SYSTEM IN NINA PLANT OIL COMPANY

MARJAN MOHAMMADJAFARI[a1] AND BEHROOZ BAYEGAN[b]

[ab]Department of Engineering, Salience and Research Branch, Islamic Azad University, Kerman, Iran

ABSTRACT

Nowadays, designing and evaluation of maintenance systems and repairs is one of the critical issues in industry. Evaluation methods that exclusively rely on financial measures are not suitable for these systems. The aim of this research is to apply an integrated approach of fuzzy analytical hierarchy process (FAHP) and balanced score card (BSC) for evaluating the maintenance and repairs systems in Nina company in Sirjan. The concept of BSC is defined in the hierarchy based on 4 aspects of financial aspect, customers' aspect, internal processes aspect, and growth and learning aspect and indexes under each aspect are selected. Then, FAHP is used for weighing and prioritization of indexes/indicators. Results show that among all these aspects of balanced score card of maintenance and repairs systems, growth and learning has the least priority over other aspects. In addition, among all indexes, the indexes of equipment's overall effectiveness, the percentage of employees' participation in professional and technical net courses, and the percentage of employees' satisfaction play an important role in the performance of the maintenance and repairs systems. The results of this research can be beneficial and useful for industrial managers and experts and assists them in making correct decisions and appropriate strategies in future.

KEYWORDS : Performance evaluation, Maintenance systems, Balanced score card (BSC), Fuzzy analytic hierarchy process (FAHP)

Maintenance and repairs systems (MRS) refer to a set of factors including staff, equipment, facilities, and constructions with defined and specific goals in such a way that they can gather together and meet the regular preventive and repair needs of devices and machinery systems effectively. The results of researches show that many factories unfortunately pay little attention to maintenance and repairs section due to their hidden and potential imposed expenses. Recently, managers are preoccupied with questions like “Is investment in maintenance and repairs section worthy?”, “Have the works and operations done in these section been successful and are these operations efficient?” As a result, measuring and evaluating the performance of maintenance and repairs systems have become progressively more significant for managers.

Several methods and techniques have been proposed for evaluating investment in maintenance and repairs section recently. However, known financial measurement methods such as return of investment (ROI), internal rate return (IRR), and net present value (NPV) and the retrieve period have been inadequate and unsatisfactory (Abran. A and Buglione. L, 2003) . It is reasonable to figure out how maintenance and repairs system contributes to the strategic and organizational aims in evaluating investment in this section and that evaluation methods dependent on the financial measurements are not exclusively appropriate on their own for maintenance and repairs applications. Balanced score card (BSC) provides a framework for measuring performance which has an integrative outlook to the performance of a company's business using a combination of both financial and nonfinancial measurements and it seems to be the appropriate solution. Balanced score card model is practically the only method that shows the effectiveness of the performance of all subsets and subdivisions of an organization in relation to the overall performance of the organization by implementing strategies and makes it possible to converge and integrate the whole organization in line with its aims. Balanced score card has its own shortcomings as well as any other new instrument including the fact that no technique and method can provide an estimate of the degree of the importance of the aspects and the indexes of each aspect neither relatively nor thoroughly. In order to remove this defect, in the present research, the fuzzy analytic hierarchy process (FAHP) and the aspects of the company's balanced score card (BSC) are used for weighing indexes. With the correct combination of AHP decision-making model and fuzzy sets theory, an optimum model is presented which overcomes the

[1]Corresponding author

shortcomings of the prevalent method of performance evaluation (Balanced Score Card).

2-Balanced Score Card and Analytic Hierarchy Process (AHP)

Balanced score card term was first used in 1992 by Robert Kaplan and David Norton in a published article in Harward Management Journal. In that article, they studied 12 big and well-known companies including Apple Computer, Bell South, General Electric, and Dopant and stated that what you get is what you measure and in this way they highlighted the importance of evaluating organizational performance. The key feature of balanced score card is the emphasis it puts on making a connection between indexes of performance and an organization's strategy (Otley., 1999). S. Wongrassamee et al, define balanced score card as follows: it is a conceptual framework that renders strategic goals to a collection of performance indexes. They also state that balanced score card makes the company's strategy and policy equal to evaluation of performance, as a result it is more flexible than EFQM (Wongrassamee et al., 2003). Edward et al., 2006. maintain that by using BSC, managers not only become aware of the past performance of the company but also realize where they are in their goals' path and how they can encounter and tackle future challenges and how to gain competitive advantages by expanding the scope of evaluation (Edward, 2006). It is noteworthy that the word “balanced” in balanced score card refers to creating and maintaining balance between financial and nonfinancial criteria, between internal and external criteria, between introspective criteria which focus on future activities and retrospective criteria which focus on past activities. It can be said that balanced score card complements financial indexes of past performance with indexes of determinants of future performance (Simons and Kaplan, 2000). The organization' future perspective is the core of the activities of balanced score card. Balanced score card renders strategy and policy to goals and aims and criteria regarding 4 aspects: financial, customer, internal processes, learning and growth of human resources aspects. Robert Kaplan and David Norton state in their book entitled “Strategic Convergence” that regarding the cause-effect relationship between the 4 aspects of balanced score card, we should put value on our customers (customer aspect) and consider them worthy in order to achieve financial success (financial aspect). It would be impossible unless we will be the best in our work and operational processes and conform them to customers' demands and requests (internal processes aspect). Being the best in operations and activities and creating worthwhile processes would be impossible unless we create a suitable working atmosphere and condition for our employees and reinforce and boost creativity, learning, and growth in the organization (learning and growth aspect).

A lot of organizations all around the world have used balanced score card for their successful implementation of strategies. However before implementing strategies and even before planning and designing them, the organization must determine its mission, values, and prospects. Eventually, balanced score card transforms mission, values, prospects and strategy to performance standard measurements which can be used for measuring success in attaining and pursuit of overall goals (Maxwell and Niven 2003).

Analytic hierarchy process (AHP) was first introduced by Saaty for solving the issue of dedicating scares sources and the army's planning needs in 1971(Saaty 1980). Therefore, AHP became one of the most widespread multi-criteria decision-making methods and was applied for solving unstructured issues and problems in diverse range of human needs and interests such as political, economic, social, and managerial sciences. The procedure of AHP involves 6 essential stages (Cheng, 1999); (Chi, 2001); (Kang and Lee, 2006); (Lee, 2006); (Murtaza, 2003); (Zahedi, 1986):

1- Defining the unstructured and unorganized issue and clear explanation of goals and results
2- Decomposing the complicated issue to a hierarchic structure with decision elements (criteria, detailed criteria, and solutions)
3- Implementing pairwise comparison between elements and forming matrix comparison
4- Estimating weights related to elements of decision
5- Studying the rate of consistency of matrixes to ensure that judgments of decision makers are compatible and consistent.

6- Add up the relative weights of elements of decision in order to reach an overall rate for solutions.

3-Fuzzy Sets Theory

Due to the ambiguous and inaccurate nature of data and information in the real life and making decisions based on this incorrect and uncertain information, modeling process of several phenomena may not be done appropriately and efficiently. In order to remove ambiguity and lack of accuracy of individual subjective judgments, fuzzy sets theory was proposed to include verbal conditions (expressions) in the decision-making process. A verbal variable is a variable that its quantity and value is presented by verbal expressions. Applying these variables in complicated situations that are not defined appropriately is extremely beneficial because they can be described plausibly in prevalent quantitative mathematical relations (Saremi et al., 2009). Zadeh proposed the fuzzy sets theory for the first time in 1965 and revealed the nature fuzzy sets and some ideas playing fundamental role in evaluating fuzzy sets theory (Zadeh, 1965).

Generally, any verbal variable van be stated using triangular fuzzy numbers (TFN) and trapezoidal numbers. Due to the simplicity of calculations and practicality in presenting and processing information in fuzzy environment, working with triangular fuzzy numbers (TFN) is often more suitable and appropriate. The mark ~ is placed above each symbol that represents fuzzy sets. A triangular fuzzy number (TFN), Ũ is shown in Figure 1.

The triangular fuzzy number (TFN) is easily shown as (l,m,u). The parameters l, m, u show the lowest, the most likely and the utmost possible value respectively and a fuzzy phenomenon is described in this way (Kahraman.C, Cebeci.U et al., 2004). There is a linear representation of the left and right of each TFN whose membership function is defined as follows:

$$(1) \quad \mu_{\tilde{u}}(x) = \begin{cases} \frac{x-l}{m-l}, & l \leq x \leq m \\ \frac{u-x}{u-m}, & m \leq x \leq u \\ 0, & \text{otherwise} \end{cases}$$

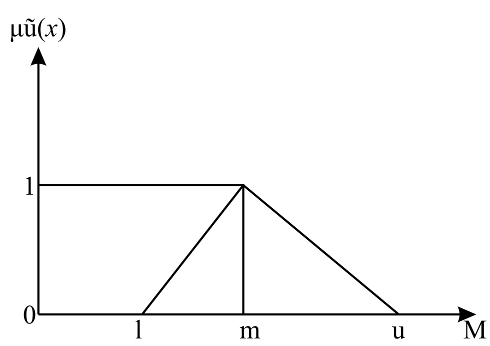

Figure 1 : A triangular fuzzy number (TFN) , Ũ

AHP method is widely used for selecting one alternative among other alternatives, but in this method pairwise comparisons for each level are done regarding the aim of selecting the best alternative using a one to nine scale. Therefore, applying Saaty's AHP has some deficiencies including:

1- AHp method has basically been used in crisp decision-makings.
2- It studies the extremely unbalanced scale of judgment.
3- It does not consider the uncertainties in individual subjective judgments.
4- The ranking of this method is almost inaccurate and imprecise.

As a result, classic standard AHP seems insufficient and inefficient for accurate fulfilling of decision makers' needs. For modeling such uncertainties in human's preferences, fuzzy sets theory must be combined with pairwise comparisons as an extension and development of AHP technique. This integrated decision-making technique provides a clearer picture and more precise understanding of decision-making process (Aya and Ozdemir 2006).

4-Review of Literature

A lot of researches have been done using AHP and different fuzzy AHP models have been made (Laarhoeven 1983); (Boender et al., 1989); (Chen, 1996);(Cheng, 1996); (Cheng, 1999); (Murtaza, 2003); (Lee, 2006); (Kang and Lee, 2006). While (Ngai and Chan, 2005) presented the application of classic AHP for selecting the appropriate instrument for supporting knowledge management (KM), (Wang and Chan, 2006) proposed the presumptive analytic hierarchy model based on fuzzy preferential relations for identifying essential factors for an organization's success in implementing knowledge management, predicting knowledge management project, and recognizing essential operations and processes before establishing knowledge management. Bozbua , Beskese, and Kahraman (2006) proposed FAHP methodology for enhancing and promoting the quality of prioritizing measurement criteria of human resources. Chaing and Li (2006) designed the general quantitative evaluation model which takes into consideration the internal artificial relations between criteria and fuzzy mental perception simultaneously for evaluating the effectiveness of electronic learning.

Furthermore, fuzzy AHP model has been combined with BSC in different fields. For instance, Lee et al. proposed An FAHP model for evaluating the performance of IT in BSC framework in Taiwan's industry (Lee A., 2008). This research provides an approach based on BSC (Balanced Score Card method) and FAHP (fuzzy analytic Hierarchy Process) for evaluating the performance of IT departments in industry. In an article entitled Studying the Evaluation System of the Performance of after-sale Services of Armarium based on BSC and FAHP, Shanshan و YangYouye, 2011 concluded that this evaluation system can contribute to optimizing after-sale services. Considering the results of feedback and constant improvement, this system helps with the development of Armarium (Zhong shanshan, 2011). The combination or integration of BSC and FAHP methods has not been applied yet in the field of evaluating the performance of maintenance and repairs.

5-The Proposed Model

The present research is an applied descriptive-cross sectional one which was carried out in the summer in 2013 in Nina factory. As it was mentioned in the explanation of balanced score card model, first an organization's perspective or outlook, mission, and strategies must be specified and according to these concepts a list of performance indexes is made which conforms to BSC aspects and interviews with maintenance and repairs experts. Then, a questionnaire is designed with classic AHP questionnaire format including 4 aspects of BSC and performance indexes of selection. The questionnaire is distributed among senior managers of the company and the feedbacks are analyzed using FAHP technique for obtaining the significance of the four aspects and performance indexes of each aspect.

The research's conceptual model is shown in Figure 2. In this research, it is attempted to propose and apply a comprehensive model considering all financial and nonfinancial aspects (obvious and obscure assets and finances) for evaluating the system's performance of maintenance and repairs system. In the conceptual presented model, the company's future outlook is the main core of BSC's activities. In this model, the balanced score card renders the organization's policy and strategies to goals and indexes through the four aspects of financial, customers', internal processes, and growth and learning aspects. Given the top-down approach in the balanced score card, it is expected that the four aspects do not have the same level of importance and the growth and learning aspect is more significant which is dealt with in the present research.

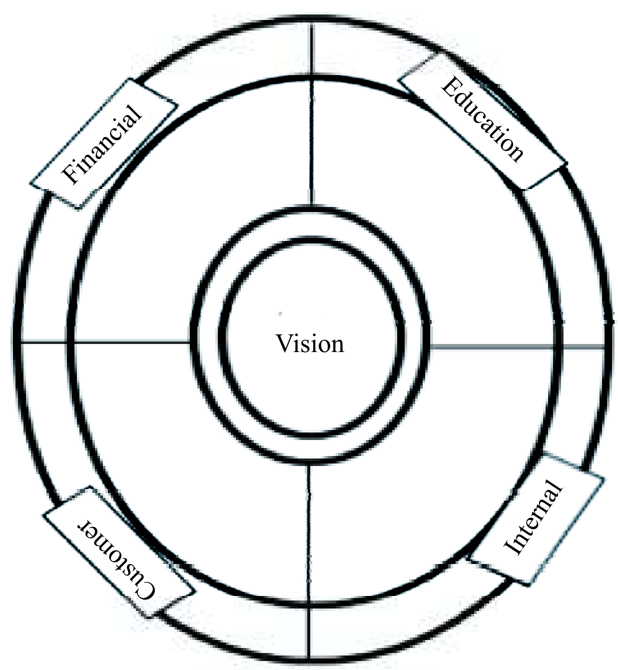

Figure 2: Conceptual Model

5.1. Drawing Indexes' Hierarchy Diagram, Designing and Distributing the Analytic Hierarchy Questionnaire

The indexes' hierarchy tree is depicted in figure 3. In this structure, main indexes (aspects) are depicted by and inferior subordinate indexes by. In this stage, the designed questionnaire is used in order to obtain the experts' ideas in pairwise comparisons of the given indexes. The questionnaire is designed in matrix in order to ease the answering by experts in decision-making based on Saaty's range, therefore, decision makers do pairwise comparisons of indexes and aspects separately based on Saaty's 1-9 scale (table 1)

Table 1 : The degree of used preferences

Kind of verbal judgment	The degree of preference (priority)
Equal preference	1
Equal to poor preference	2
Poor preference	3
Poor to rather high preference	4
Rather high preference	5
Rather high to highly superior preference	6
Highly superior preference	7
Highly superior to completely superior preference	8
Completely superior preference	9

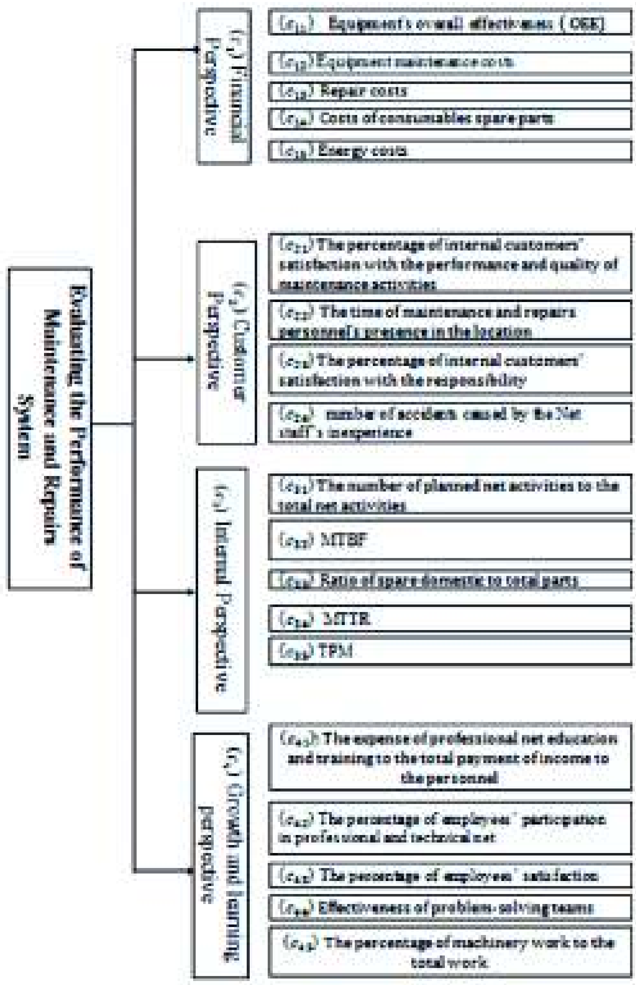

Figure 3 : The indexes' hierarchy tree

The reliability of the present questionnaire is measured based on the consistency ration (CR) which is calculated as follows:.

$$(2) \quad CI = \frac{\lambda_{max} - n}{n-1}$$

In the above relation, n represents the number of criteria and represents the maximum specific amount. In order to calculating the consistency ration which is shown by CR, CI is divided by random consistency index (RI) (Lai.Y.T, Wang.W.C et al. 2008). The amounts of random indexes (RI) are given in table 2.

$$(3) \quad CR = \frac{CI}{RI}$$

5.2. Fuzzy Analytic Hierarchy Process

In the following, Cheng's extent analysis method (EA) will be presented for solving the issue of fuzzy analytic

Table2 : RI index

N	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.19	1.51	1.48	1.56	1.57	1.59

hierarchy process:

Suppose that X stands for a set of subjects or topics (members) and U stands for a set of goals. According to Cheng's extent analysis method (1996), each topic (member) for each goal is analyzed in the order that it is done. Therefore, m or the value of extent analysis is obtained for each subject with the following symbols:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m \qquad i = 1, 2, \ldots, n$$

In the above equation, all M_{gi}^j (j = 1, 2, ..., m) are triangular fuzzy numbers (TFN). The steps of Cheng's extent analysis are as follows

Step 1:

The value of fuzzy combinational extent with respect to i-th item shall be defined as follows:

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

To obtain $\sum_{i=1}^{m} M_{gi}^j$ the process of fuzzy addition of the values of the analysis of the extent m for a particular matrix is as follows:

$$(5)\quad \sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

To obtain the expression $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}$ the process of fuzzy adding of the values M_{gi}^j (j=1, 2, …,m) is performed as follows:

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

and then the inverse of the above equation is calculated:

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

Step 2:

The degree of possibility that $M_2=(l_2, m_2, u_2) \geq M_1=(l_1, m_2, u_2)$ is defined as follows:

$$(8)\quad V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 & m_2 \geq m_1 \\ 0 & l_1 \geq u_2 \\ \frac{(l_1 - u_2)}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases}$$

In the above equation, d is the highest width of intersection point D, between and (figure 4).

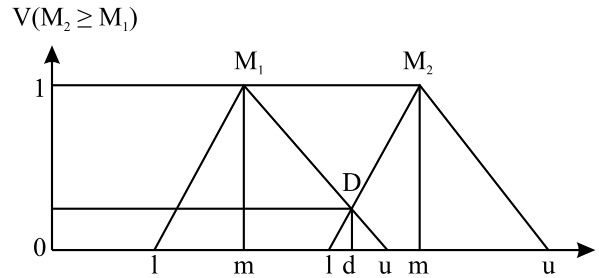

Figure 4 : Comparing between M_1 and M_2

For comparing M_1 and M_2 the values of both $V(M_1 \geq M_{21})$ and $V(M_2 \geq M_1)$ are needed.

Step 3:

The degree of possibility that a fuzzy number is greater that K fuzzy number is defined as follows:

$$(9)\quad V(M \geq M_1, M_2, \ldots, M_K) = V[(M \geq M_1), (M \geq M_2), \ldots, (M \geq M_K)] = \min V(M \geq M_i)\ i=1,2,\ldots,K$$

Also, calculating the weights of criteria in paired comparisons matrix is as follows:

$$(10)\quad \acute{W}(Xi) = \min V(Si \geq Sk) \qquad k = 1, 2, \ldots, n \qquad k \neq i$$

Therefore, the weights of criteria will be as follows:

$$(11)\quad \acute{W} = (\acute{W}(X_1), \acute{W}(X_2), \ldots, \acute{W}(X_n))^T$$

which is the non-normal coefficients vector of fuzzy analytic hierarchy process. The normalized weights of criteria are obtained as follows (Saremi.M, Mousavi.S.F et al. 2009):

$$(12)\quad W_i = \frac{\acute{W}_i}{\sum \acute{W}_i}$$

5.3. Data Analysis

After the questionnaire of analytic hierarchy process was designed and distributed to 6 experts and the pairwise comparisons' matrix of each expert was obtained, the validity of experts' opinions was calculated through the calculation of consistency ratio of pairwise comparisons' matrices of each decision-maker and all the ratios were smaller than 1/0. Pairwise comparison matrices obtained from experts' opinions whose compatibility has been confirmed are combined using the following relations, and the total matrix is composed (Lai et al., 2008):

$$l_{ij} = min_k\{a_{ijk}\}$$

(13) $$m_{ij} = \frac{1}{k}\sum_{k=1}^{k} a_{ijk}$$

$$u_{ij} = max_k\{a_{ijk}\}$$

In this way, the values of decision makers' pairwise comparison are converted into triangular fuzzy numbers, and the first number represents the minimum amount of preference given by experts, the second number represents the average of preferences given by experts, and the third number indicates the maximum of these amounts. As a result, the pairwise comparison matrices similar to fuzzy ternary (triangular) numbers are formed to compare aspects and also to compare each aspects' indexes.

So, after forming the fuzzy pairwise comparison matrix of all the major and minor indexes, the weights of all of them was calculated using the EA. According to this method, first the combined values were calculated, and then the obtained fuzzy values were compared in order to calculate the weights of indexes and a magnitude degree of each was calculated in relation to another. The lowest value obtained from the magnitude degree of each index in relation to other indexes makes vector.

6- The Results and the Evaluation of the Research's Conceptual Model

Eventually after descaling this weighted vector, W weight vector was obtained for main indexes as it is shown in Table 3. This vector is non-fuzzy and represents the final weight of the main indexes (aspects). According to this vector, the coefficient of the significance of the financial aspect (c_1) is equal to 25/47 %, the coefficient of the significance of the customer aspect (c_2) is equal to 23/25%, the coefficient of the significance of the internal processes aspect (c_3) is equal to 24/79%, and the coefficient of the significance of the growth and learning (c_4) was calculated to be 26/48%.

Similarly, the weight of each sub-index or minor index is obtained (figure 5). Regarding the overall prioritizing of indexes (it is calculated according to absolute weights), as it is shown the following indexes are more significant in the performance of maintenance and repairs system of the studied factory with the following percentages: the overall effectiveness of equipment 14/68%, the employees' participation in Net professional courses 9/91%, employees' satisfaction 9/58%, the expense of used for maintenance of equipment 7/91%, MTBF 6/17%, and the number of accidents caused by the Net staff's inexperience 6/12%. For calculating the final score of performance, first the percentage of each index's fulfillment or completion is obtained in the given time interval based on the balanced score card and then is multiplied by the related weight and finally their total is the final score of performance of the maintenance and repairs system in Nina factory.

Table 3 : Fuzzy values, preferred weights, and the aspects' weight vector

	C1	C2	C3	C4	W'	W
C1	-	$V(s_{c1} \geq s_{c2}) = 1$	$V(s_{c1} \geq s_{c3}) = 1$	$V(s_{c1} \geq s_{c4}) = 0.9618$	0.9618	**0.2547**
C2	$V(s_{c2} \geq s_{c1}) = 0.9681$	-	$V(s_{c2} \geq s_{c3}) = 0.878$	$V(s_{c2} \geq s_{c4}) = 0.9115$	0.878	**0.2325**
C3	$V(s_{c3} \geq s_{c1}) = 0.9930$	$V(s_{c3} \geq s_{c2}) = 1$	-	$V(s_{c3} \geq s_{c4}) = 0.9362$	0.9362	**0.2479**
C4	$V(s_{c4} \geq s_{c1}) = 1$	$V(s_{c4} \geq s_{c2}) = 1$	$V(s_{c4} \geq s_{c3}) = 1$	-	1	**0.2648**

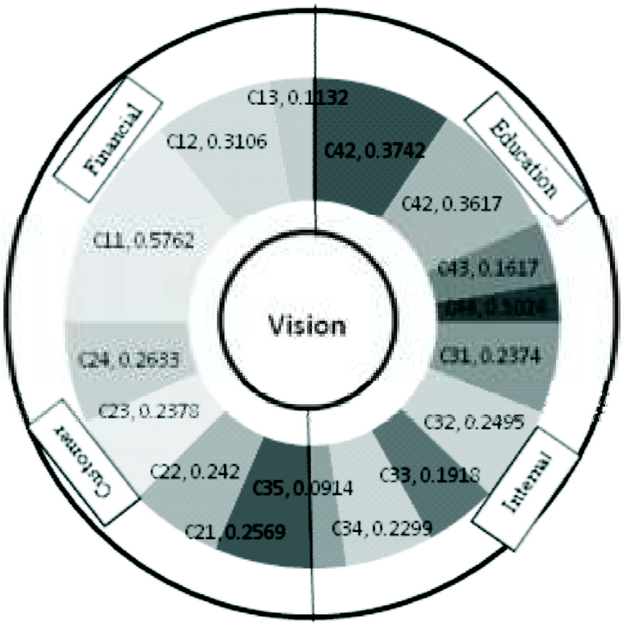

Figure 5 : The weight of each sub-index or minor index

DISCUSSION

Nowadays, because of effective quantitative and qualitative factors in organizational decisions, managers are required to apply new approaches in order to involve these factors in decision making and take them into consideration to make appropriate decisions. One of the new instruments that corresponds to managerial systems is balanced score card method with the viewpoint of implementing strategies in practice. The aim of this research was to apply FAHP technique with a strong scientific basis for solving the problem of weighing the indexes of evaluation performance using balanced score card approach in the studies factory. Although a lot of researches have been done in the field of applying decision-making techniques and evaluating the performance of an organization using balances score card model, none of these researches have applied these two techniques jointly together in evaluating the performance of maintenance and repairs systems.

Comparing the results of this study with other studies revealed that learning and growth aspect and subsequently all its subsidiary indexes are the most important and significant indexes among all aspects and indexes of the maintenance and repairs' balanced score card. One of the prominent features of the present study is to evaluation of performance using balanced score card which makes it possible to measure the value of intangible or obscure assets and finance in Nina factory well. Furthermore, using fuzzy numbers instead of absolute numbers is safer in the alteration and variation process of analytic hierarchy of decision making.

CONCLUSION

The present research provides an approach based on BSC and FAHP for evaluating the performance of maintenance and repairs section in Nina factory in Sirjan. The analytic hierarchy is structured based on 4 main aspects of BSC including financial, customer, internal business processes, and learning and growth aspects followed by indexes of performance. Due to the general ambiguity and uncertainty of human decision- making process, FAHP was applied for solving problems. In the end, it was determined that learning and growth aspect (C4) with 26/48% and customer aspect (C2) with 23/25% have the most and the least significance respectively in the performance evaluation of maintenance and repairs system in the factory and the indexes of the general effectiveness of equipment (57/62%), participation of employees in professional Net courses (37/42%), and employees' satisfaction (36/17) are highly important in the fulfillment and achievement of the functioning of maintenance and repairs system that must be focused on. In addition, the results showed that Nina factory's maintenance and repair system achieved 96/29% of its financial goals in the summer of 2013. The obtained results for other aspects are 102/78% for customer aspect, 83/67% for internal processes, 49/70% for learning and growth aspect. Generally by considering the weights it can be said that the maintenance and repairs system of Nina factory has been 82/35% successful in achieving its strategic goals and codified indexes in the summer of 2013. This information shows that although Nina factory has been successful in financial and customer fields, it could not reach its goals completely due to its poorer performance in learning and growth aspect.

Therefore, it is recommended to Nina factory to take the weight and priority of each aspect and index into consideration regarding its resources' limitations and its conditions for future planning and decisions so that it can take more effective action for better performance by proper prioritizing of its goals and defining appropriate improvement projects.

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