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Selecting the most appropriate maintenance strategies using fuzzy Analytic Network Process: A case study of Saipa vehicle industry

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C H R O N I C L E

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A B S T R A C T

It is necessary for companies and industries to select the most appropriate maintenance strategy to increase the reliability and safety level with reasonable cost. The primary objective of this paper is to assess different maintenance strategies and to select the best and the most appropriate alternatives for Saipa vehicle industry in Tehran, Iran. For this purpose, we simultaneously consider numerous conflicting objectives and constraints. In this study to counter with this conflicting and to consider the dependency among the qualitative and quantitative criteria and sub-criteria, an integration of Analytic Network Process (ANP) and fuzzy set theory are considered. Therefore, factors playing important role in selecting the best maintenance strategy are determined by reviewing the research literature and interviewing with the experts by Delphi technique. Considering the relations among different factors, a network with 4 criteria and 28 sub-criteria are proposed. In the next step, ANP technique is applied for ranking effective factors in evolution of appropriate maintenance strategy. Results reveal that the best maintenance strategy for fixture body of pride (setter) is corrective maintenance.

1. Introduction

In the current competitive environment, vehicle industry managers are facing different challenges and they try to make their organization competitive. Maintenance plays a critical role in decreasing many expenses; it reduces failure productivity, improves quality and provides reliable equipment (Mobley, 2002; Shankar, & Sahani, 2003; Sadeghi & Manesh, 2012). This helps organizations reach their qualitative and quantitative goals. Analytical network process (ANP) is a technique to rank different alternatives by considering independency among various criteria (Saaty, 1996; Işıklar & Büyüközkan, 2007).

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In addition, ANP is a multiple criteria decision-making method that can handle all kinds of interactions (Saaty, 1996). Maintenance is an operation to maintain healthy and steady equipment and prevent downtime in place (Van Horenbeek et al., 2010). There are normally two parts of maintenance including services and planned periodic and emergency repair. Because of the critical importance of selecting the adequate maintenance strategy for whatever the case is, some studies have been considered on this problem. Liaghat et al. (2013), for instance, applied analytical hierarchy process (AHP) to analyze coastal tourism sites. Wang et al. (2007) made an assessment on different maintenance strategies including corrective maintenance, time-based preventive maintenance, condition-based maintenance, and predictive maintenance for various equipment. An optimal maintenance strategy mix seems essential for increasing availability and reliability levels of production facilities without a big increasing of investment. They used a fuzzy AHP to deal with the uncertain judgment of decision makers where uncertain and imprecise judgments of decision makers. Al-Najjar and Alsyouf (2003) evaluated the most popular maintenance approaches using a fuzzy multiple criteria decision making (MCDM) evaluation technique.

2. Analytic network process methodology

ANP method is developed based on the general form of AHP (1996) and it can manage interdependence and external dependencies among various factors. The decision-making is modeled by using hierarchy indirect relationships among the criteria in AHP. However, ANP creates the possibility of more complex inter-relationships among the criteria. In fact, the ANP method is a mathematical method that can deal with all types of dependencies and this is the main reason for choosing the ANP as an alternative for selecting the most appropriate maintenance strategy for the proposed case study of this paper.

According to Saaty (1996), ANP method can be described as follows:

Step 1: In this step, the problem is clearly defined and its components are classified in a systematic and logical structure as a network of logical relationships and the decision criteria that involved are identified. Senior executives and the main decision-makers determine the criteria and staffs are aware of the whole system and then relationships of options on each other can be entered.

Step 2: Similar to AHP, paired comparison matrix of criteria and sub criteria is formed taking into account the higher level of internal communication network to help them gain weight elements.

Step 3: Super-matrix are formed from the matrix of relationships among network components where it is derived from the priority vectors relationships. This matrix is a framework for determining the relative importance of the options provided in the following paired comparisons.

Step 4: Similar to the Markov chain with exponentiation super weighted matrix, the result is a large number.

Step 5: in this step, weight of each element is divided by the sum of column entries.

Step 6: Using the weights obtained in the previous step, we identify the best option.

3. Decision model application and results

This model is for evaluating the optimal maintenance strategy in Saipa vehicle industry in Tehran, Iran. The proposed model uses the method developed by Chang et al. (2009).

Step 1: Determining the factors and sub-factors and their effect on each other: Effective factors are excavate by research literature and discussing with university professors and applying Delphi technique. Our experts are people who were maintenance managers of Saipa Company and they determined the factors, sub-factors, and formation matrices of paired comparisons used to calculate weights. (Fig.1)

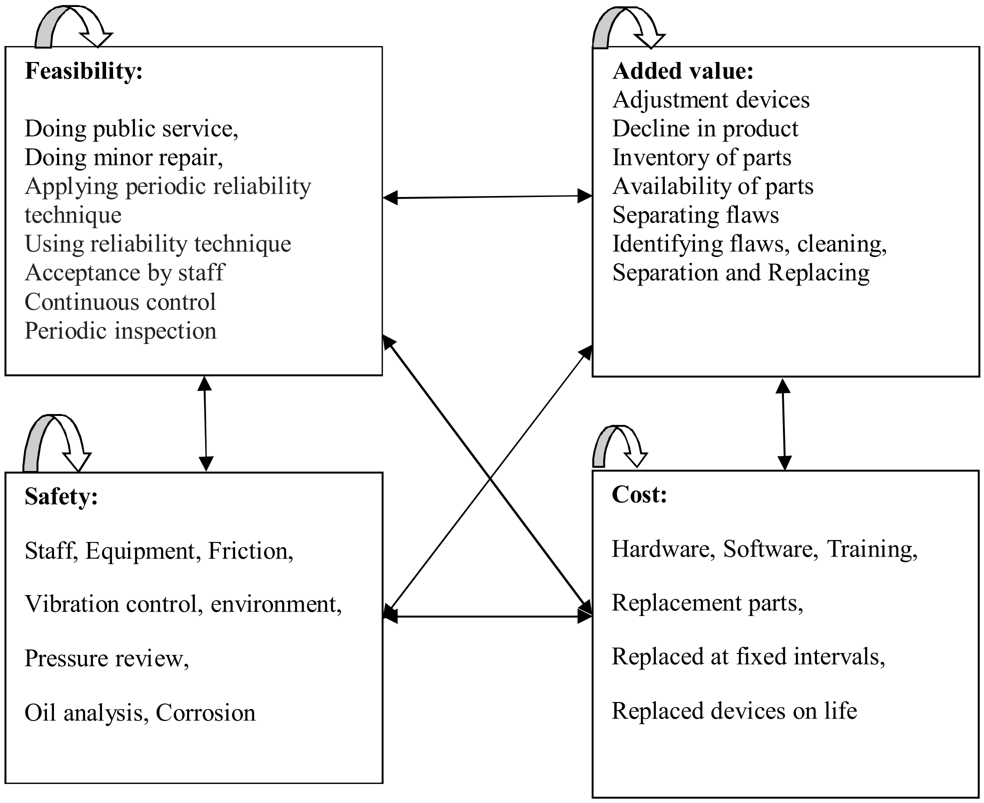

Fig. 1. Inter dependent factors

Step 2 & 3: Determining the significance level of the main factors assuming that there is no dependency among them:

Pair wise comparison of the scale factor was done with a triangular fuzzy number (TFN) and local weight is done. Fuzzy scale for measuring the relative importance weight is given in Table1. Integrated fuzzy pair wise comparison matrix and weights among the main causes of the major factors are shown in Table 2 and Table 3.

Table 1
The linguistic scale for importance and their triangular fuzzy number

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1,1,1)	(1,1,1)
Equal dominance	(1/2,1,3/2)	(2/3,1,2)
Weak Dominance	(1,3/2,2)	(1/2,2/3,1)
Strong dominance	(3/2,2,2.5)	(2/5,1/2,2/3)
Very strong dominance	(2,2.5,3)	(1/3,2/5,1/2)
Absolute dominance	(2.5,3,7/2)	(2/7,1/3,2/5)

Table 2
Combined matrix of paired comparisons of the main indicators

	Safety	Feasibility	Cost	Added value
Safety	(1,1,1)	(1,1.36,2)	(0.5,1,2)	(0.33,0.72,1)
Feasibility	(0.5,0.74,1)	(1,1,1)	(1,1.11,2)	(0.4,0.58,1)
Cost	(0.5,1,2)	(0.5,0.9,1)	(1,1,1)	(0.5,0.97,2.5)
Added value	(1,1.39,3.03)	(1,1.73,2.5)	(0.4,1.03,2)	(1,1,1)

Table 3
Weights of main factors (without dependency)

Criteria	Safety	Feasibility	Cost	added value
Weight	0.248	0.215	0.246	0.290

Step 4: Structuring model and determining with the mentioned fuzzy scale: In this step we determine all alternatives: Corrective maintenance (CM), Predictive maintenance (PDM), Preventive Maintenance(PM), Reliability Centered Maintenance (RCM), Condition based maintenance(CBM) and Total productive maintenance (TPM) and group them into clusters for the network (Table 4).

Table 4
Inter dependence among the main factors

	safety	Feasibility	cost	added value
Safety	0.29	0.22	0.25	0.33
Feasibility	0.35	0.28	0.26	0
Cost	0	0.24	0.24	0.33
added value	0.36	0.26	0.25	0.34

Step 5: Calculate the interdependent weights of the main factors with considering dependency (Table 5). It is shown there is a different between dependence of the main factors and apart from that.

Table 5
Weights of main factors (with dependency)

Criteria	Safety	Feasibility	Cost	added value
Weight	0.277	0.211	0.209	0.303

Step 6: Determine the local degrees of the sub-factors with a fuzzy scale. At this stage, with using the matrix of paired comparisons, the relative priority of each subdirectory of the main indicators is calculated according to them.

Step 7: Determine the global degrees of the sub-factors. It is multiplying of weight of the main indicators (W_Factor) that calculated in step 5 and the corresponding subdirectory relative weights that determined in Step 6.

Step 8: Determine local weights of the alternative strategies with regard to each of the sub-factor. The results of steps 6-8 is summarized in Table 6.

Table 6
The final weights

Main Criteria	Weight	Sub criteria	Local Weight	Global Weight	CM	PM	PDM	RCM	CBM	TPM
Safety	0.277	Environment	0.14	0.0402	0.17	0.17	0.17	0.17	0.16	0.17
		Staff	0.13	0.0355	0.18	0.17	0.16	0.17	0.17	0.15
		Equipment	0.15	0.0407	0.17	0.17	0.17	0.16	0.17	0.16
		Friction	0.13	0.0349	0.17	0.17	0.18	0.16	0.17	0.16
		Vibration control	0.13	0.0356	0.17	0.16	0.16	0.16	0.17	0.18
		Pressure review	0.11	0.0311	0.17	0.15	0.16	0.15	0.15	0.00
		Oil analysis	0.10	0.0264	0.16	0.15	0.17	0.17	0.16	0.19
		Corrosion	0.12	0.0326	0.16	0.17	0.14	0.14	0.18	0.00
Feasibility	0.211	Doing public service	0.16	0.0329	0.15	0.18	0.17	0.15	0.17	0.18
		Doing minor repair	0.16	0.0343	0.16	0.16	0.18	0.16	0.15	0.20
		Applying periodic reliability technique	0.16	0.0344	0.17	0.18	0.15	0.15	0.16	0.19
		Using reliability technique	0.12	0.0260	0.18	0.17	0.15	0.16	0.16	0.17
		Acceptance by staff	0.13	0.0275	0.18	0.17	0.15	0.17	0.18	0.14
		Continuous control	0.11	0.0232	0.16	0.17	0.17	0.18	0.18	0.15
		Periodic inspection	0.16	0.0329	0.17	0.17	0.16	0.17	0.17	0.16
Cost	0.209	Hardware	0.19	0.0405	0.17	0.16	0.18	0.17	0.16	0.16
		Software	0.19	0.0400	0.18	0.17	0.15	0.18	0.15	0.17
		Training	0.15	0.0309	0.17	0.17	0.17	0.17	0.15	0.16
		Replacement parts	0.16	0.0337	0.17	0.17	0.16	0.15	0.18	0.16
		Replaced at fixed intervals	0.16	0.0328	0.16	0.18	0.16	0.18	0.18	0.15
		Replaced devices on life	0.15	0.0311	0.17	0.18	0.16	0.17	0.16	0.17
Added value	0.303	Adjustment devices	0.12	0.0372	0.15	0.17	0.17	0.18	0.16	0.17
		Decline in product	0.11	0.0327	0.17	0.18	0.17	0.15	0.16	0.17
		Inventory of parts	0.13	0.0393	0.18	0.17	0.16	0.18	0.17	0.15
		Availability of parts	0.13	0.0388	0.18	0.18	0.17	0.16	0.17	0.15
		Separating flaws	0.14	0.0414	0.19	0.16	0.17	0.15	0.16	0.17
		Identifying flaws	0.13	0.0386	0.17	0.17	0.16	0.17	0.16	0.17
		Separation	0.12	0.0360	0.19	0.15	0.16	0.18	0.16	0.16
		Replacing and cleaning	0.13	0.0385	0.19	0.18	0.17	0.16	0.16	0.13

Step 9: Determine the final weight with regard to each of the sub criteria options: At this stage, the final weight of each sub-criterion by multiplying the weight of each of the following criteria options, weigh the alternatives is obtained.

Table 7
Final priorities of alternative maintenance strategies

Maintenance Strategy	CM	PM	PDM	RCM	CBM	TPM
Weight	0.1706	0.1687	0.1644	0.1642	0.1646	0.1538

4. Conclusion

An appropriate maintenance strategy plays a vital role in reduction of unnecessary investment and increasing availability of equipment and safety level. The primary objective of this study was to select a maintenance strategy by combining detailed criteria and sub-criteria and by considering the relationship among them using ANP technique. This technique can make the interdependency between criteria and sub-criteria.

In this paper, the case of Saipa Company in Tehran was presented to illustrate the proposed approach. The results showed that effective factors in evolution of optimized maintenance strategy in Saipa are: Security, cost, added value and feasibility. The results showed that added value requirements influence on optimizing maintenance strategy.

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