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Evaluation of optimum maintenance and repair strategy by multi-criteria decision-making method in textile industry

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Abstract. One of the most important problems in production management and operations is maintenance & repair. Setting up a proper maintenance & repair program prevents either unexpected failures and production disorders or time loss and expensive costs. On the other hand, this program increases useful life of machinery and keeps moderate level of productivity. The goal of this research is identification of suitable criterion for selection of an optimum maintenance & repair strategy, with their weighted importance, by Fuzzy-ANP method in textile industry. Thus, a model was designed for selection of proper criteria for maintenance & repair. After identification of proper criteria, the optimum maintenance & repair strategy in textile industry was selected by Expert Analysis method by a questionnaire. Then ANP technique was used to determine weights of indices. In this step, views of experts for pair comparisons of indices and their weights were extracted from the questionnaires. Finally, the results show that preventive repair strategy has the highest score of 0.43703, situation-based strategy with 0.242812, and predictive strategy with 0.16236. The score of maintenance & repair based on reliability is 0.157798, which is the lowest score.

Keywords: Maintenance & repair, multi-criteria decision-making, Fuzzy-ANP method, textile industry.

1. INTRODUCTION

Maintenance and repair discussions have been studies either in industry or in service areas. Briefly, the goals of this field are reliability increment, cost decrement, failure duration decrement, and safety increment. Systems become more complex by passing time and progress of technology unwantedly and in turn, maintenance and repair issues are becoming more complex (Jalili, 1998).

Applying a maintenance and repair system in an organization plays an important role in decrement of finished price of final products. However, these effects are not limited to cost and also affects delivery velocity in total supply chain, product quality, reliability, organizational agility, and so on. Thus, we see the important roles of different maintenance and repair strategies on business of an economic agent and discussion about this issue is very important. All economic and industrial agents compete in market according to their priorities and potentials.

2. LITERATURE AND REVIEW

In 1970, Thomas L. Saaty proposed Analytic Hierarchy Process (AHP), which removes decision-making problems in different levels including goal, criterion, sub-criterion, and decision options. AHP's theoretical and mathematical backgrounds have been mentioned in different references (Vargas, 1990; Saaty, 1990; Vargas and Saaty, 2001).

Because of mathematical flexibility and simplicity, AHP is a desirable decision-making tool which has been entered in many fields including engineering, food, business, ecology, health, and overrule. Rather than AHP, Analytic Network Process (ANP) was also suggested by Saaty, which is a general form of AHP that is used for more complex feedback and relations between elements in a hierarchy (Saaty, 2001). ANP has been used in many decision applications, especially for uncertainty and loss probability (Sepahi and Timor, 2010).

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Maintenance & repair is a theory that was introduced by Japanese in 1960 by their experiences in maintenance & repair during 1950s in USA. Nipondinso was the first company that executed preventive repairs in 1960 broadly. Preventive repair was an opening for creation of new thoughts.

Operators produced by different machines and maintenance & repair personnel repaired these machines. Maintenance & repair work volume was increased by automation and new labor force must be employed.

Bansal et al. (2005) studied about application of real time predictive maintenance & repair system for production machines by nervous network approach. This research used nervous network learning feature for non-linear maps to recognize machine parameters for movement permission. This prevented expensive costs of measuring parameters. Data of this research was categorized into three groups of training, reliability, and model test. Then data was normalized and Principle Component Analysis (PCA) was used to summarize data; then data dimensions were diminished from 400 to 14.

Noori (2009) fulfilled a research titled “Study of reliability in maintenance & repair process of Kermanshah Oil Refinery”. The goal of this research was creating a proper fault-finding mechanism for failure of centrifugal pumps in the refinery by two algorithms of nervous networks and fuzzy intelligent system. The goals of this algorithm were: 1. Decrement of human errors; 2. Decrement of repair time; 3. Decrement of maintenance & repair costs; 4. Decrement of unnecessary consumptions to improve facilities. The innovation of this research was extraction of lingual rules to make an intelligent rule database by considering mutual effects of critical failures on operational and mechanical parameters such as debit, temperature, input pressure, output pressure, velocity, and vibrations. The case study of this research was Kermanshah Oil Refinery.

The pattern of present research comes from a research by Shijis et al. (2008) in India. In this research, the following criteria were used:

1. **Level 1:** Goal: The goal of this research was finding the best maintenance & repair strategy in textile industry.

2. **Level 2:** Criteria, including flexibility, training, environmental conditions, and components breakage.

3. **Level 3:** Sub-criteria, including implementation problem, availability, work knowledge, training hardness, improper continuity, more exploitation, humidity, suffocation,…

4. **Level 4:** Anticipated maintenance & repair options and alternatives, preventive maintenance, situation-based maintenance & repair, reliable maintenance & repair (Shijis & Kumanan, 2008).

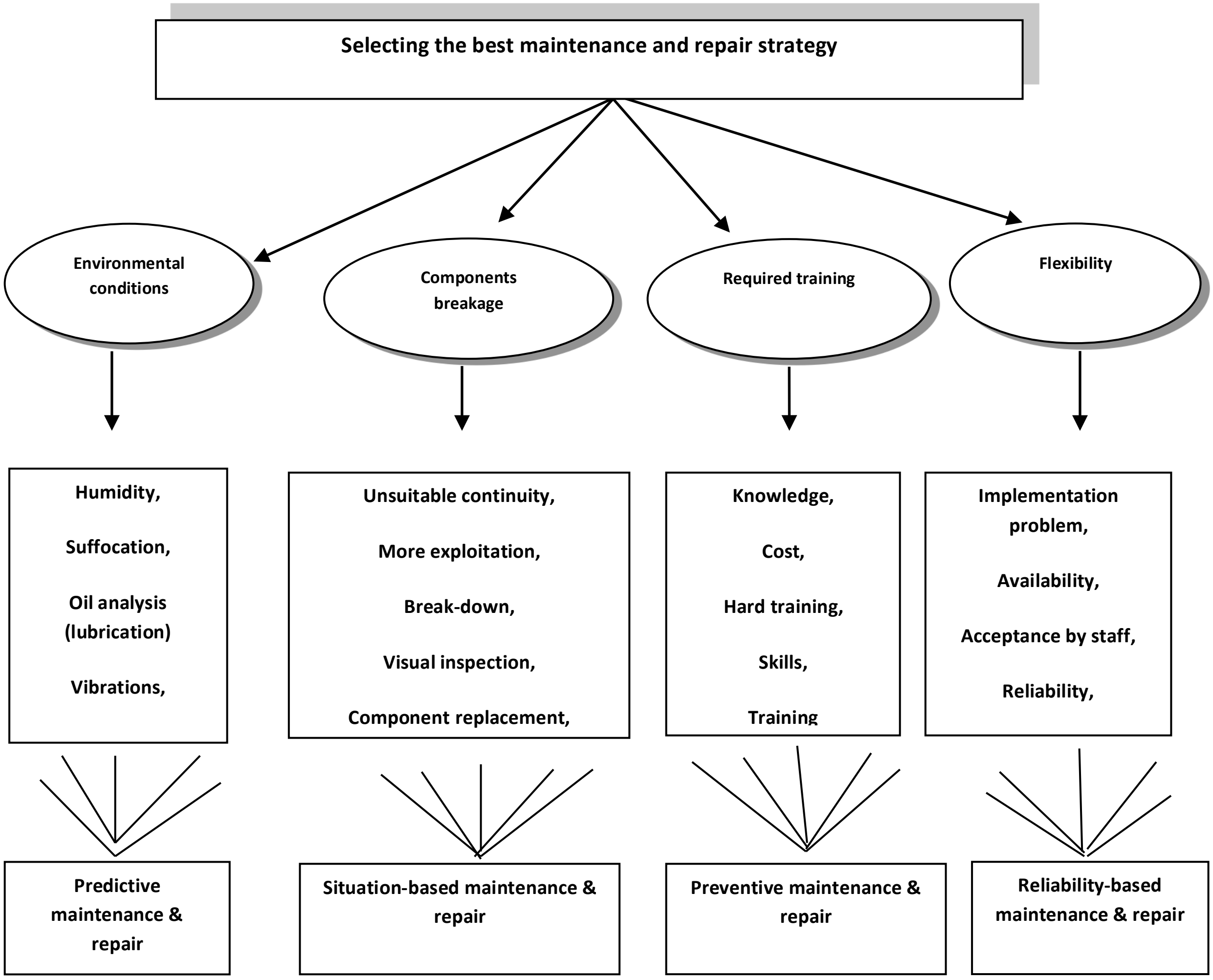

Figure 1. Conceptual model of research

3. RESEARCH ASSUMPTIONS

1. What are suitable criteria for selection of optimum maintenance & repair strategy?
2. What are weights of these criteria regarding to the internal and feedback of different factors?
3. What is the optimum maintenance & repair strategy regarding to the evaluated criteria?

4. METHODOLOGY

Scientific researches can be divided into two categories by data gathering method: a) Experimental; b) Descriptive (non-experimental) (Khaki, 2008).

Experimental researches include those in which the researcher selects at least two similar groups, tests independent variable on the first group, and evaluates the effect of this variable against the control group. However, descriptive researches include those with description of conditions of phenomena. Descriptive method is an analytical-surveying one, since it is non-experimental, and it is done by Fuzzy-ANP method.

4.1. Data gathering method

Generally, data gathering methods are divided into two library and field methods. This research uses field method for gathering data. Data is gathered by questionnaires.

Rather than using valid papers and books, the views of experts in textile industry were used to determine the most important criteria affecting maintenance & repair. To do this, they were asked to give scores to criteria and sub-criteria on a form; which some of sub-criteria were deleted after summation of scores. After determination of criteria and sub-criteria, a questionnaire was designed that was weighted for these criteria and sub-criteria by AHP method. In other words, these criteria and sub-criteria were compared in pairs. The questionnaires were distributed between managers and directors of maintenance & repair departments in many textile centers in Isfahan, Iran. Also, pair comparison table for mutual effects of criteria was designed from "very low" to "very high" score levels in the form of lingual frames. After converting these lingual frames to the triangular fuzzy numbers (Table 1), the views of decision group was summed by calculation of triangular average of fuzzy numbers.

Table 1: Fuzzy linguistic variables

Option	Quality number	Fuzzy number (m, α, β)
1	Very Low (VL)	(0, 0, 0.1)
2	Low (L)	(0, 0.1, 0.3)
3	Medium Low (ML)	(0.1, 0.3, 0.5)
4	Medium (M)	(0.3, 0.5, 0.7)
5	Medium High (MH)	(0.5, 0.7, 0.9)
6	High (H)	(0.7, 0.9, 1)
7	Very High (VH)	(0.9, 1, 1)

After gathering the views of experts, the researcher converts lingual variables to triangular fuzzy numbers using Table 1.

4.2. AHP process steps

The main AHP process steps are:

Step 1: Determination of goals, criteria, sub-criteria, options

Step 2: Making graphical hierarchical chart

Graphical chart is a simple display for a complex problem, which the general goal of problem is at its center, criteria and sub-criteria are on the next level, and options are at the last level.

Step 3: Pair comparisons

Saaty proposed the following method for pair comparisons in each level:

For pair comparison of elements, if we compare element i with element j, then one of the following cases determines priority of element i than j:

1. Complete priority

2. Very strong priority

3. Strong priority
4. Low priority
5. Equal priority

Saaty has used numbers 1, 3, 5, 7, and 9 for above evaluation, respectively. So, 1, 3, 5, 7, 9 were used for expressing priority of i than j, and $1,\frac{1}{3},\frac{1}{5},\frac{1}{7},\frac{1}{9}$ were used for expressing priority of j than i, according to the reverse principle in AHP. Also, 2, 4, 6, 8 can be used as middle values. For example, if element i has strong priority than j, then it corresponds with 5. Thus, pair comparison matrices for each level are constructed (Asgharpur, 2009).

Step 4: Ranking replacements

4.3. Problem-solving by ANP method

After introducing ANP method, this method has been used for many problems, and this technique has been changed in some applications. However, this technique has the following steps:

1. Problem description
2. Comparison of benefits, opportunities, costs, risks and model construction
3. Providing relational network between clusters (main criteria) and separation of sub-criteria
4. Providing a supermatrix for each cluster
5. Doing pair comparisons and completion of supermatrix
6. Calculation of limit of supermatrix
7. Calculation of compliance by supermatrix vector for each option

The concepts and definitions of fuzzy AHP are as follows according to developmental analysis. At first, consider two triangular numbers $M_1=(l_1, m_1, u_1)$ and $M_1=(l_2, m_2, u_2)$ (Fig. 2).

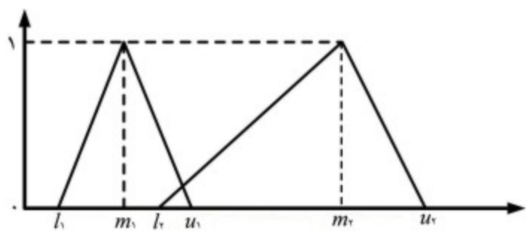

Figure 2. Triangular numbers M_1 and M_2

Related mathematical operators are:

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{1}$$

$$M_1 * M_2 = (l_1 * l_2, m_1 * m_2, u_1 * u_2) \tag{2}$$

$$M_1^{-1} = \left[\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right], \quad M_2^{-1} = \left[\frac{1}{u_2}, \frac{1}{m_2}, \frac{1}{l_2}\right] \tag{3}$$

It must be noted that multiplication of two triangular fuzzy numbers, or an inverse triangular fuzzy number, is not a triangular fuzzy number. These relations express an approximation of real multiplication of two triangular fuzzy numbers and inverse triangular fuzzy numbers. In the Developmental Analysis Method (DAM), S_k is calculated for each row of pair comparison matrix, which itself is a triangular number:

$$S_k = \sum_{j=1}^{n} M_{kj} * \left[\sum_{i=1}^{m}\sum_{j=1}^{n} M_{\psi}\right]^{-1} \tag{4}$$

By DAM, after doing calculations, the "magnitude degree" of them must be obtained. Generally, if M_1 and M_2 are two triangular fuzzy numbers, magnitude degree of M_1 than M_2, or $V(M_1 \geq M_2)$, is as eq. (5). We have:

$$\begin{cases} V(M_1 \geq M_2) = 1 & if\, m_1 \geq m_2 \\ V(M_1 \geq M_2 = hgt(M_1 \cap M_2) & otherwise \end{cases} \tag{5}$$

Magnitude degree of a triangular fuzzy number than another triangular fuzzy number is obtained by eq. (6):

$$hgt(M_1 \cap M_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)} \tag{6}$$

Weights of indices in the pair comparison matrix are as eq. (7):

$$W'(x_t) = [Min\{V(S_t \geq S_k)\}, \quad ,k = 1,2,\ldots,n. \quad k \neq i \tag{7}$$

Therefore, weight vector of indices is as eq. (8), which is abnormal factors vector in fuzzy AHP:

$$W'(x_t) = [W'(c_1), W'(c_2), \ldots, W'(Cn)]^T \tag{8}$$

4.4. Sampling method and sample volume

The best work in a questionnaire analysis is selection of persons whom data should be obtained. Sometimes finding the required group is easy, but sometimes a researcher may send a questionnaire for a group without enough information. So, sample must be selected carefully (Delavar, 1996).

A sample is a set of our observations in the studies society or a selection of that statistical society with main features of that society (Azarmomeni, 2006).

There are different sampling methods, and random sampling method is used for this research. In this method, many managers and directors of Maintenance & Repair Departments of textile industry in Isfahan were selected randomly. The sample size was 20 questionnaires by views of consultants and advising professors.

5. FINDINGS OF RESEARCH AND CONCLUSION

5.1. Test of assumption 1

As you see in Table 2, suitable criteria for selection of optimum strategy for maintenance & repair in a factory are environmental conditions (0.536231), component breakage (0.347473), training (0.081708), and flexibility (0.034588), respectively.

5.2. Limit Supermatrix

The Limit supermatrix is obtained by consecutive powering (Markov theorem). When numbers in columns are equal, Limit supermatrix is obtained and the process is stopped.

Table 2

Cluster node label		Best maintenance policy	Top level model			
		Goal node	Environmental conditions	Flexibility	Training	Breakage
Best maintenance policy	Goal node	0.000000	0.000000	0.000000	0.000000	0.000000
Top level model	Environmental conditions	0.536231	0.000000	0.000000	0.000000	0.000000
	Flexibility	0.034588	0.000000	0.000000	0.000000	0.000000
	Training	0.081708	0.000000	0.000000	0.000000	0.000000
	Breakage	0.347473	0.000000	0.000000	0.000000	0.000000

5.3. Test of assumption 2

Priorities in supermatrix and normal priorities in the node are shown in Table 3.

Table 3. Limit supermatrix.

Name	Normalized by cluster	Limit
Best maintenance policy	0.00000	0.000000
Environmental conditions	0.53623	0.536226
Flexibility	0.03459	0.034588
Training	0.08171	0.081705
Breakage	0.34748	0.347481

Environmental sub-criteria after pair comparisons are:

Table 4. Ranking environmental sub-criteria.

Oil analysis	0.192290
Friction	0.052129
Corrosion	0.033846
Humidity	0.585682
Vibration	0.136053

As you see in Table 4, environmental sub-criteria and their priority are: 1. Humidity, 2. Oil analysis, 3. Vibrations control, 4. Friction, and 5. Corrosion.

As you seen in Table 5, flexibility sub-criteria and their priority are: 1. Implementation problem, 2. Staff acceptance, 3. Availability.

Table 5. Ranking flexibility sub-criteria.

Availability	0.062698
Implementation problem	0.633005
Staff acceptance	0.304297

As you see in Table 6, component breakage sub-criteria and their priority are: 1. Unsuitable continuity, 2. More exploitation, 3. Visual inspection, 4. Preventive replacement, 5. Regular replacement, 6. Life replacement.

Table 6. Ranking component breakage sub-criteria.

Visual inspection	0.115486
More exploitation	0.215780
Life replacement	0.043544
Regular replacement	0.056653
Preventive replacement	0.072310
Unsuitable continuity	0.496227

Training sub-criteria and their priority are: 1. Cost, 2. Training services, 3. Knowledge.

Table 7. Ranking of training sub-criteria.

Training services	0.196306
Knowledge	0.146626
Cost	0.657069

5.4. Test of assumption 3

Regarding to the evaluated criteria for preventive maintenance strategies (0.43703), most scores are for situation-based maintenance & repair (0.242812), predictive strategy (0.16236), and reliability-based maintenance & repair (0.157798), respectively. The results are shown in Table 8.

Table 8. Selection of best strategy.

Reliability centered maintenance	0.157798
Situation-based maintenance	0.242812
predictive maintenance	0.162360
Preventive maintenance	0.437030

REFERENCES

[1] Asgharpur, M. (2009), "Multi-criteria decisions", University of Tehran, 7th edition.

[2] Bujadeziov; Mohammad Hosseini, J. (2002), "Fuzzy logics and its application in management", Tehran, Ishif Publications, 1st edition.

[3] Khaki, Gh. (2008), "Research method by an approach to thesis writing", Tehran, Baztab Publications, 4th edition.

[4] Delavar, A. (2006), "Research methods in behavioral sciences", Tehran, Agah Publications.

[5] Kolahan, F.; Dustparast, Mohammad; Mamurian, Mojtaba (2007), "Determination of optimum preventive maintenance and repair type and schedule in multi-component systems by reliability", Journal of Technical Faculty, pp. 511-523.

[6] Albert H.C. Tsang; W.K. Yeung; Andrew K.S.; Jardine, Bartholomew; P.K. Leung (2006), “Data management for CBM optimization,Journal of Quality in Maintenance Engineering”, Vol. 12, No. 1, pp. 37-51.

[7] Banjevic, D.; Jardine, A.K.S.; Makis, V.; Ennis, E. (2001), “A control-limit policy and software for CBM”, INFOR, Vol. 39, No. 1, pp. 32-50.

[8] Bansal, D.; Evansb DJ.; Jones B. (2005), “Application of a real-time predictive maintenance system to a production machine system”, Journal of Machine tools and manufacture; 1210-1221.

[9] Franc, Ois; Boulet, Jean; Ali Gharbi (2009), ”Multiobjective optimization in an unreliable failure-prone manufacturing system”, Journal of Quality in Maintenance Engineering, Vol. 15, No. 4, pp. 397-411.

[10] Hax, A.C.; Majluf, N.S. (1991), “The Strategy Concept and Process: A Pragmatic Approach”, Prentice-Hall International Inc., New Jersey.

[11] Lie, C.H.; Chun, Y.H. (1986), “An algorithm for preventive maintenance policy”, IEEE Trans Reliab, Vol. 35, No. 1, PP.71-5.

[12] Lin R.H. (2008), “An integrated FANP–MOLP for supplier evaluation and order allocation”, Applied Mathematical Modeling, Article in Press.

[13] Mann, L. Jr.; Anuj, S.; Gerald, M.K. (1995), “Statistical-based or condition-based preventive maintenance?”, Journal of Quality in Maintenance Engineering, Vol. 1, No. 1, pp. 46-59.

[14] Saaty, Thomas L. (1999), “Fundamentals of the Analytic Network Process”, ISAHP Japan, pp. 12-14.

[15] Saaty, Thomas L (1990) “The Analytic Hierarchy Process”, RWS Publications, Pittsburg, pp. 184-192.

[16] Shyjith, K.; Ilangkumaran, Kumanan M.S. (2008), “Multi-criteria decision-making approach to evaluate optimum maintenance strategy in textile industry”, Journal of Quality in Maintenance Engineering, Vol. 14, No. 4, pp. 375-386.

[17] Sipahi, Seyhan; Mehpare, Timor (2010), ”The analytic hierarchy process and analytic network process: An overview of applications”, Management Decision, Vol. 48, No. 5, pp. 775-808.