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SELECTION OF PLANT MAINTENANCE STRATEGY AND PERFORMANCE ENHANCEMENT OF A WIRE MANUFACTURING INDUSTRY USING AHP

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Abstract

The focus of this research is in the area of Selection of Plant Maintenance strategies and Performance enhancement of a wire manufacturing industry using various MCDM techniques. Various Maintenance strategies are in practice in different organization. Maintenance strategy is responsible behind 10-40% cost of the organization. The goal of the research is in the area of the selection of the best plant Maintenance strategy and performance enhancement of the organization. For selecting appropriate Maintenance strategy, it is felt that some Multi Criteria Decision Making Methods must be used due to their ability of converting a complex problem to a paired comparison. These methods are used to provide a hierarchy based relationship between goal of the research, criteria, sub-criteria and alternatives. Certain methods such as; Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (FAHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are very effective now a days. AHP method has to be used for solving the problem of selection of plant maintenance strategy in manufacturing organization. For solving these type of problems, some criteria (Cost, Safety, Value Added and Execution) are selected. The main conclusions drawn from this study are that, Safety criterion is more important for selecting plant maintenance strategy, and Condition based Maintenance is the best maintenance strategy for wire manufacturing organization.

Keywords: Maintenance, AHP, criteria, Cost, Safety, Execution, alternatives, Consistency.

1. Introduction

To make a decision we need to know the problem, the need and purpose of the decision, the criteria of the decision, their sub criteria and the alternative actions to take. We then try to determine the best alternative. [1] Decision making involves many criteria and sub criteria used to rank the alternatives of a decision. The criteria may be intangible, and have no measurements to serve as a guide to rank the alternatives, and creating priorities for the criteria themselves in order to weight the priorities of the alternatives and add over all the criteria to obtain the desired overall ranks of the alternatives is a challenging task. [2]

2. Maintenance

Maintenance is defined as: "Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform a required function." [3] According to IAEA (international atomic energy agency) maintenance costs are the major part of the total operating costs of all manufacturing or production plants. Depending on the type of industry, Maintenance costs have 10 to 40 per cent of the costs of goods produced. For example in food process industries, the average maintenance cost represents about 15 per cent of the total cost of goods produced; while in iron and

steel, pulp and paper and other heavy industries maintenance cost represents up to 40 per cent of the total production costs. [4]

3. Principles of Maintenance

The maintenance principles provide fundamentals of maintenance strategy. The brief descriptions of principles of maintenance are as follows:

a. Maintenance objectives and standards must be established.
b. Maintenance should be performed with economy of time, personnel, equipment and materials.
c. Maintenance operations should be based on a sound, written maintenance plan.
d. Scheduling of maintenance work must be based on sound policies and priorities.
e. The maintenance department must be well organized.
f. Organizations must provide adequate fiscal resources to support the maintenance program.
g. Maintenance employee should be responsible for the public image of the organization. [5]

4. Objectives

a. To identify the strategies of maintenance used in wire manufacturing industry.
b. To identify the criteria for selection of strategy of maintenance.
c. To identify the sub criteria within a criterion for selection of maintenance strategy.
d. To priorities the choices of maintenance strategy using AHP method on the basis of criteria and sub-criteria.

5. Methodology

The Analytic Hierarchy Process: **-** The AHP was developed in the 1980s by Saaty. It is a systematic decision making method which includes both qualitative and quantitative techniques.[6]

Table1. Assessment of a_{ij} values

Value of a_{ij}	Interpretation
1	Equal importance of i and j
2	Between equal and weak importance of i over j
3	Weak importance of i over j
4	Between weak and strong importance of i over j
5	Strong importance of i over j
6	Between strong and demonstrated importance of i over j
7	Demonstrated importance of i over j
8	Between demonstrated and absolute importance of i over j
9	Absolute importance of i over j[7]

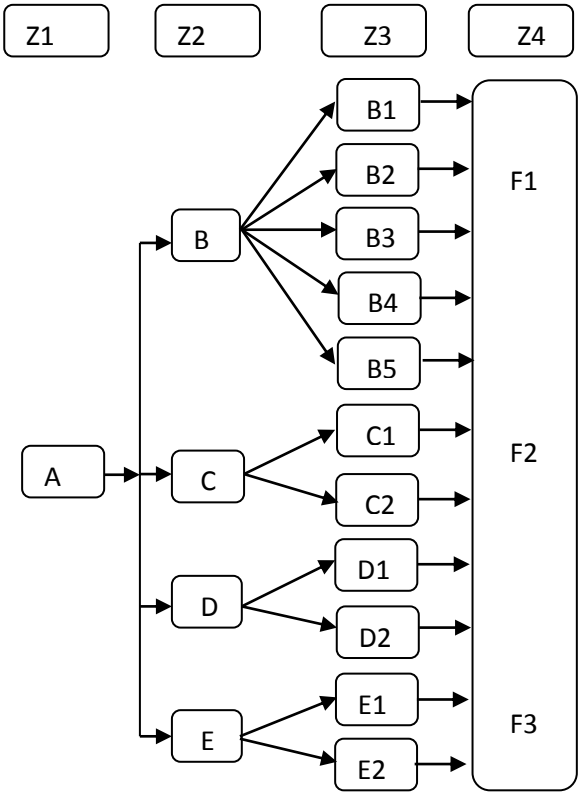

Fig.1. Hierarchy of Goal, Criteria, Sub-Criteria and Alternatives

Where-

A= Selection of plant maintenance strategy, Z1 = Goal, Z2 = criteria, Z3 = sub-criteria, Z4= Alternatives
B= Cost, C= Safety, D= Value Added, E- Execution, B1= Cost of poor Maintenance, B2= Cost of using Spare parts with more efficiency, B3= Cost of providing new software for recognizing failures, B4= Staff training, B5= Customer satisfaction, C1= Environmental Effects, C2= Personnel Safety, D1= Professional Specialist, D2= Spare parts quality and Availability, E1= Technological Complexity, E2= Acceptance by management
F1= Corrective Maintenance, F2= Predictive Maintenance, F3= Condition based Maintenance.

Various steps of Analytic Hierarchy Process are as follows:-
1. State the problem and define the objectives.
2. Develop the hierarchy from the top through the intermediate levels to the lowest level of the hierarchy.
3. Construct a pair-wise comparison matrix using a scale of relative importance. Determine the maximum Eigen value λ_{max} that is the average of matrix.
4. Calculate the consistency index CI = (λ_{max} - n) / (n -1). The smaller the value of CI, the smaller is the deviation from the consistency.
5. Calculate the consistency ratio CR = CI/RI. Usually, CR of 0.1 or less value is considered as acceptable.
6. Compare the pair-wise alternatives with respect to how much better they are in satisfying each of the attributes.[8]

6. Data Analysis

On the basis of AHP procedure and with the discussion from industrial expert following analysis is done.
The calculation of AHP method is as follows:-

Table 2. Comparison matrix for criteria-

	B	C	D	E	Priority weight
B	1	1/9	5	2	0.15418
C	9	1	9	9	0.70521
D	1/5	1/9	1	1/3	0.04615
E	1/2	1/9	3	1	0.09445

Consistency check-
λ_{max} = 4.28797
Consistency Index (CI) = (λ_{max} – n)/(n-1)
CI = 0.096
Consistency Ratio (CR) = CI/RI
CR = 0.1067
The value of CR is more than 0.1, so the inconsistency is generated.
After discussion with the experts the following change is made and further CR is calculated.

Table 3. Comparison matrix for criteria-

	B	C	D	E	Priority weight
B	1	1/7	5	2	0.1648
C	7	1	9	9	0.6917
D	1/5	1/9	1	1/3	0.0467
E	1/2	1/9	3	1	0.0966

Consistency check-
λ_{max} = 4.2154
Consistency index (CI) = 0.0718
Consistency Ratio (CR) = 0.0798
The value of CR is less than 0.10, so the result is consistent.

Table 4. Comparison matrix for sub-criteria under Cost criterion-

	B1	B2	B3	B4	B5	Priority weight
B1	1	5	5	1/5	1	0.1921
B2	1/5	1	4	1/8	1/6	0.06635
B3	1/5	1/4	1	1/7	1/9	0.03392
B4	5	8	7	1	1	0.41005
B5	1	6	9	1	1	0.29758

Consistency check-
λ_{max} = 5.4762, and CR = 0.1063

The value of CR is more than 0.1, so the inconsistency is generated.
After discussion with the experts the following change is made and further CR is calculated.

Table 5. Comparison matrix for sub-criteria under Cost criterion-

	B1	B2	B3	B4	B5	Priority Weight
B1	1	2	5	1/5	1	0.1649
B2	1/2	1	4	1/8	1/6	0.0757
B3	1/5	1/4	1	1/7	1/9	0.0341
B4	5	8	7	1	1	0.4185
B5	1	6	9	1	1	0.3068

Consistency check-
$\lambda_{max} = 5.3912$,
Consistency index (CI) = 0.0978

CR = 0.0873

The value of CR is less than 0.10, so the result is consistent.

Now same procedure is applied and the Priority weights of various sub criteria under Safety, Value Added and Execution criteria is calculated here.

Table 6. Priority Weights of various sub criteria under Safety, Value Added and Execution criteria-

Sub-Criteria (Safety)	Priority Weights	Sub-Criteria (Value Added)	Priority Weights	Sub-Criteria (Execution)	Priority Weights
C1	0.1	D1	0.5	E1	0.5
C2	0.9	D2	0.5	E2	0.5

Again same procedure is applied and the Priority Weights of alternatives under various sub criteria for the criteria are calculated.

Table 7. Priority Weights of alternatives under various sub criteria for Cost criterion-

	Priority Weights for B1	Priority Weights for B2	Priority Weights for B3	Priority Weights for B4	Priority Weights for B5
CM	0.0737	0.6877	0.7765	0.6333	0.0853
PdM	0.2828	0.2344	0.1548	0.2604	0.2132
CbM	0.6433	0.0778	0.0685	0.1062	0.7014

Table 8. Priority weights of alternatives under sub various criteria for Safety, Value Added and Execution criteria-

	PW of alternatives under sub criteria for Safety criterion		PW of alternatives under sub criteria for VA criterion		PW of alternatives under sub criteria for Execution criterion	
	C1	C2	D1	D2	E1	E2
CM	0.0622	0.0685	0.0767	0.1062	0.6333	0.0737
PdM	0.2364	0.1549	0.1862	0.2604	0.2605	0.6433
CbM	0.7013	0.7766	0.7369	0.6333	0.1061	0.2828

After these findings we are going towards calculating the weights of different criteria, the findings are given in table below-

Table 9. Calculating weights for various criteria-

Alternatives	Priority Weights for criteria			
	Cost	Safety	Value Added	Execution
CM	0.6197	0.068	0.0914	0.3535
PdM	0.2496	0.163	0.2233	0.4519
CbM	0.3949	0.769	0.6851	0.1945

With the help of weight of weight of the criteria given in above tables now we are going to calculate the Preference Ratio of given alternatives which are 0.1876, 0.2079 and 0.6477 for CM, PdM and CbM respectively.

7. Result

It can be incurred that, the Condition based Maintenance is more effective maintenance strategy in Wire manufacturing industry.

8. Conclusion

Today various wire manufacturing industries are working in India for manufacturing various varieties of wires. In every Industry proper and accurate maintenance planning is necessary for reducing cost of manufacturing and manufacturing cycle time. This is also important for increasing the capacity of production and for improving the working conditions.

Various strategies of maintenance such as: Corrective Maintenance, Predictive Maintenance, Condition based Maintenance; Reliability Centred Maintenance etc are used in different industries. For selecting the best maintenance strategy, certain Multi Criteria Decision Making Methods (based on different criteria and sub-criteria) are employed. These methods based on pair wise comparison matrices and after calculating the weights of all selected alternatives, it can be concluded that, the safety criteria is more important for selecting the strategy of plant maintenance and Condition based maintenance strategy is the most efficient and accurate for wire manufacturing Industry.

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