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Use of Multi-Criteria Decision Making Method for the Selection of Optimum Maintenance Strategy

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Abstract: *Selection of appropriate maintenance strategy is key to economic viability and manufacturing industries as well as for small firms. Appropriate maintenance alternative decision making increases machine reliability and enhances both productivity and product quality. By contrast, poor decision making disrupts production and increases production costs. The study discusses and presents an approach to facilitate the selection of the most appropriate maintenance strategy using the MCDM techniques. The Project Work is an explanation of how to select best alternative by considering the various criteria, so that the maintenance cost can be reduced and reliability level can be increased.*
This work is intends to introduce a simple model in order to choose the optimum Maintenance Strategy based on the condition of the relevant company. The literature review section explains the introduction of MCDM methods and types of Maintenance strategy. In methodology section, a hypothetical example is taken to explain the use of MCDM as a maintenance strategy selection tool.

Keywords: *Multi-Criteria Decision Making, Analytical Hierarchy Process, Maintenance Strategy, Failure Mode Effects and Criticality Analysis*

1. INTRODUCTION

Maintenance is one of the most important activity for any machine or company for desirable results. According to [1], Maintenance has emerged since the construction of physical structures such as ship and machines. In general, maintenance is defined as the combination of all technical and administrative actions, including supervision and action intended to retain the machine or restore it to a state in which it can perform a required function. [2] Maintenance is going to play a remarkable role in the process and product lines regarding the competitive climate among companies in the current world.

Multi-Criteria decision making is a tool for decision making. In most of the decision making problem an attempt is make to select the best one according to the requirements and conditions. There are many tools available for decision making like FMECA, companies experience and knowledge, modeling the time to failure and optimization etc. The MCDM method is differing from all other tools in terms of its own properties as it facilitates the direct involvement of decision makers. In case of any inconsistency the decision maker can get another chance to change their decisions like in AHP method (Analytical Hierarchy Process). At present, MCDM is getting popularity all over the world for use in decision making problems.

1.1 Why there is a need to select the optimum maintenance strategy?

A Maintenance strategy highly affects the machine's performance and productivity. According to the M.Bevilaque [5], poor maintenance practice may result maintenance cost 15-70% of total production cost. The purpose of this research work is to reduce the maintenance cost as minimum as possible with increase in reliability.

1.2 How to select MCDM method?

To use the MCDM method, it is always beneficial to understand the nature of problem. There are so many methods of MCDM. According to Mark Velasquez and Hester [4], summary of MCDM is explained in table no.1. From table no.1 anyone can easily compare and understand the advantages, disadvantages and application of MCDM methods.

Table 1: Summary of MCDM methods [4]

Method	Advantages	Disadvantages	Areas of Application
Multi-Attribute Utility Theory(MAUT)	Takes uncertainty into account; can incorporate preferences.	Needs a lot of input; preferences need to precise.	Economics, finance, actuarial, water management, energy management, agriculture

Analytic Hierarchy Process(AHP)	Easy to use, scalable; hierarchy structure can easily adjust to fit many sized problems; not data intensive.	Problems due to interdependence between criteria and alternative; can lead to inconsistencies between judgment and ranking criteria; rank reversal.	Performance-type problems, resources management, corporate policy and strategy, public policy, political strategy and planning.
Case-Based Reasoning (CBR)	Not data intensive; can improve over time; can adapt to changes in environment.	Sensitive to inconsistent data; requires many cases.	Business, vehicle insurance, medicine, and engineering design.
Data Envelopment Analysis	Capable of handling multiple inputs and outputs; efficiency can be analyzed and quantified.	Does not deal with imprecise data; assumes that all input and output are exactly known.	Economics, medicine, utilities, road safety, agriculture, retail and business problems.
Fuzzy Set Theory	Allows for imprecise input; takes into account insufficient information.	Difficult to develop; can require numerous simulation before use.	Engineering, economics, environmental, social, medical, and management.
Simple Multi-Attribute Rating Technique (SMART)	Simple; allows for any type of weight assignment technique; less effort by decision makers.	Procedure may not be convenient considering the framework.	Environmental, construction, transportation and logistics, military, manufacturing and assembly problems.
Goal Programming(GP)	Capable of handling large scale problems; can produce infinite alternatives.	Its ability to weight coefficients; typically needs to be used in combination with other MCDM methods to weight coefficients.	Production planning, scheduling, health care, portfolio selection, distribution systems, energy planning, water reservoir management, scheduling, wildlife management.
ELECTRE	Takes uncertainty and vagueness into account.	It process and outcome can be difficult to explain in laymen's terms; outranking causes the strengths and weakness for the alternatives to not be directly identified.	Energy, economics, environmental, water management, and transportation problems.

Table 2: Comparison of AHP, ELECTRE, SAW, and TOPSIS Methods [1]

Methods → / Parameters ↓	AHP	ELECTRE	SAW	TOPSIS
Consistency	Yes	Yes	No	No
core process problem	hierarchy Principle	Pair wise Compression Principle	Weighted avg. Principle	Distance Principle
Structure	Few criteria & alternatives	Plenty criteria	Many criteria & alternatives	Many criteria & alternatives
Concept	Scoring modal	Concordance modal	Scoring modal	Compromising model
Final results	Global net ordering	Partial Pre-order	Global net ordering	Global net ordering

According to Jureenthor [1], MCDM methods can be compared as shown in table 2. Study of table 1 and table 2 can help for selecting the suitable method. In this research work AHP is found to be more suitable as it facilitate to measure consistency of results and possibility to change the decisions if it is not satisfactory or fail in consistency test.

2. METHODOLOGY OF RESEARCH WORK:

The study of maintenance work at industry, suggest that at present following strategy is in use,

Table 3: Current maintenance strategy and proposed next maintenance strategy

S. NO.	Name of Machine	Current Strategy	Next Proposal Strategy	
1.	Centre Lathe Boring Machine	CM	PM	CBM
2.	Milling machine	CM	PM	CBM
3.	Lathe machine	CM	PM	CBM
4.	Boring machine	CM	PM	CBM
5.	Drilling machine	CM	PM	CBM

Maintenance manager as well as technicians feels that the current maintenance strategy is not efficient to fulfill the company's present requirements. Now it is a big problem for them that what may be the next best maintenance strategy for the company's machines. In this research paper using AHP method following steps are suggested to solve the problem.

Step 1: Fixing of Criteria and Sub-Criteria

According to Ling-Wang [3], when different maintenance strategies are evaluated for different machines, the manufacturing firms must set maintenance goals taken as comparing criteria first. Different manufacturing companies may have different maintenance goals. But in most cases, these goals can be divided into four aspects analyzed as follows:

Table 4: Fixing Criteria and sub-criteria [3]

Criteria	Sub- Criteria
Cost (A)	Cost of poor maintenance practices (A1)
	Cost of using spare parts (A2)
	Staff training cost (A3)
Safety (B)	Environmental effects (B1)
	Personnel safety (B2)
Value –Added(C)	Role of professional specialist (C1)
	Spare parts quality and availability (C2)
	Customer satisfaction (C3)
Equipment and Technology(D)	Fault Identification (D1)
	Feasibility (D2)

Step 2: Fixing of alternatives:

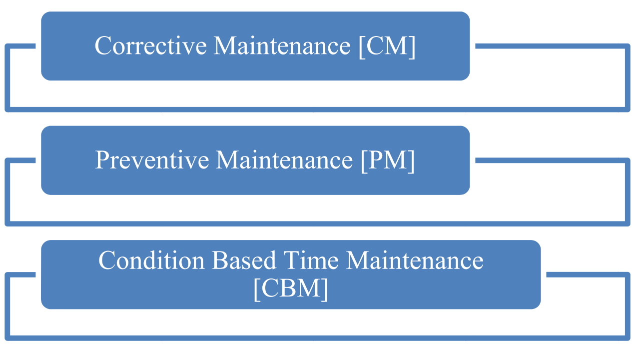

Fig. 1: Maintenance Approach [2]

Step 3: Generating Questionnaire for data collection

(a) Questionnaire 1 is generated to find the most important main criteria.

(b) Questionnaire 2 is generated to find the most important sub-criteria.

(c) Questionnaire 3 is generated to find the factor weight of alternatives with respect to different criteria's. [*see appendix A*]

Step 4: Generating comparison Matrix for each criteria, sub-criteria and alternatives.

For Criteria 1

C1	A1	A2	A3	Calculating Local Priority
A1				
A2				
A3				

Above matrix gives a comparison between alternatives A1, A2, and A3 from the Criteria 1(say cost) point of view then after we can generate a Global Matrix and calculate a Global Priority value for the given problem.

	C1	C2	C3	C4	C5	Global priority
A1						
A2						
A3						

Step 5: Use of suitable tool for matrix calculation like Mat lab, MS-Excel etc. In this work Mat lab is used for matrix calculation.

For example

From questionnaire 1

Table 5: Main Criteria and their respective weight

Main Criteria	Weight	λmax	CI	CR	Accepted/ Rejected
Cost	0.2000	4.1164	0.0388	0.0431	Accepted
Safety	0.5668				
Value-Added	0.1328				
Equipment and Technology	0.1004				

3. RESULT OF THE STANDARD ANALYTIC HIERARCHY PROCESS APPROACH

Table 6: Result of Standard AHP method

Criteria's	CM	PM	CBM	Global Weight	Rank
Cost of poor maintenance practices (A1)	0.0810	0.7306	0.1884	0.12740	3
Cost of using spare parts (A2)	0.7306	0.1884	0.0810	0.05166	6
Staff training cost (A3)	0.6483	0.1220	0.2297	0.02094	9
Environmental effects (B1)	0.0526	0.4737	0.4737	0.1417	2
Personnel safety (B2)	0.0667	0.4667	0.4667	0.4251	1
Role of professional special (C1)	0.0909	0.4545	0.4545	0.03430	7
Spare parts quality and availability (C2)	0.0667	0.4667	0.4667	0.01390	10
Customer satisfaction (C3)	0.0667	0.4667	0.4667	0.08460	4
Fault Identification (D1)	0.0719	0.6491	0.2790	0.03346	8
Feasibility (D2)	0.0719	0.2790	0.6491	0.06694	5
Global Score	0.114351768	0.47283777	0.412859392		

The table no. 6 and graph shows that the most important criteria for company is "personnel safety" and the most suitable alternative is Preventive Maintenance as it score 47.2838% weight and second most suitable alternative is Condition Based Maintenance as its score is 41.2859% weight.

4. GRAPH OF RESULTS:

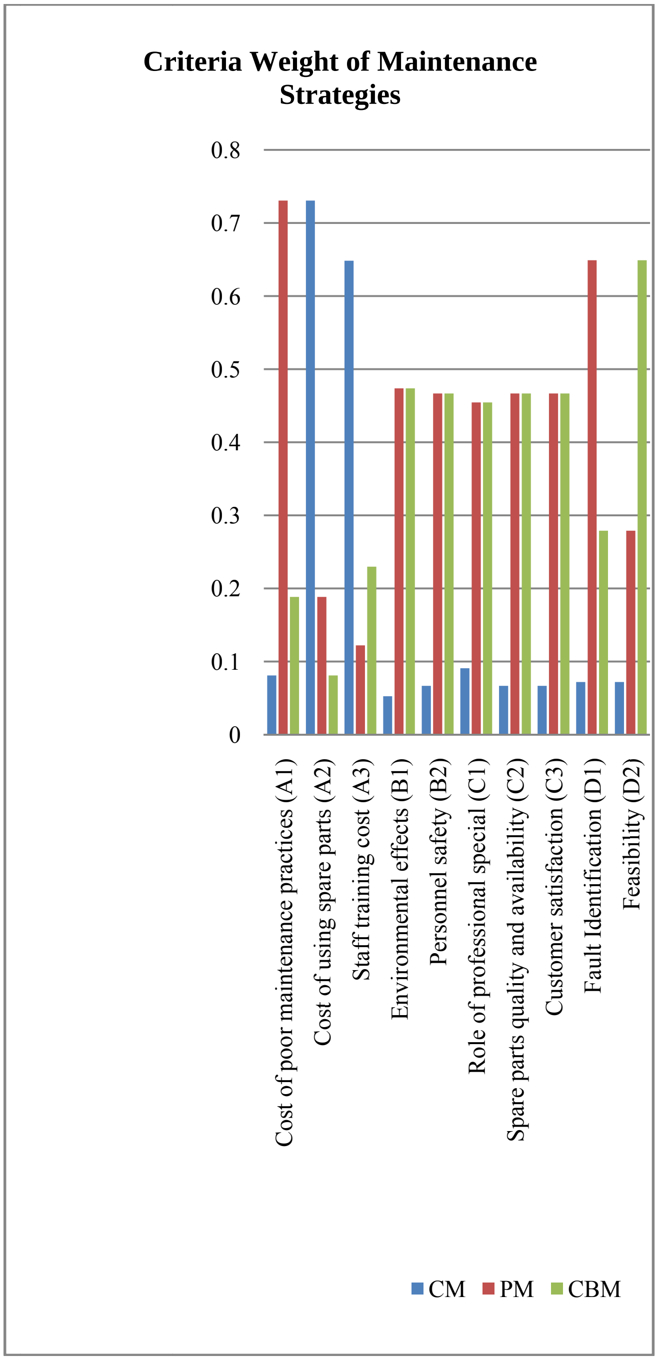

Fig. 2: Graph of criteria weight for different maintenance strategy

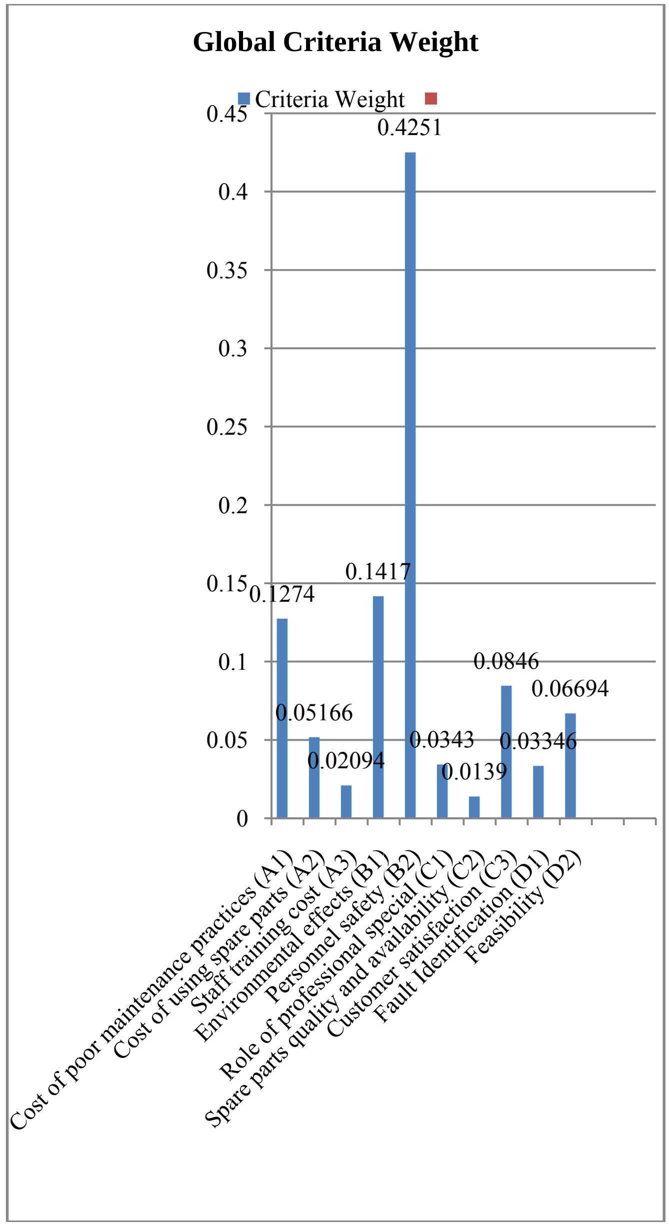

Fig.3: Graph for global criteria weight

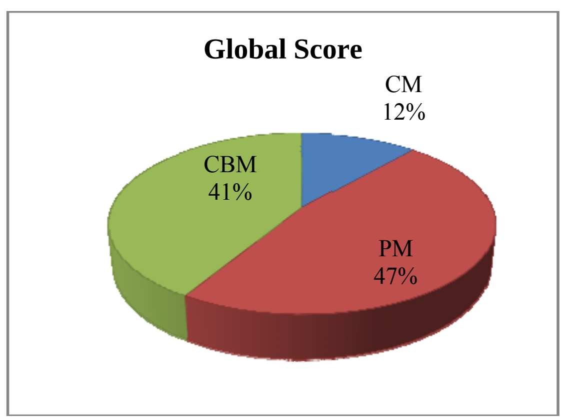

Fig. 4: Pie chart for global score

5. CONCLUSIONS

The proposed method provides a simple approach of complex theory to access alternative projects and selects the best set of project by using the described integral approach of AHP method. This research introduces, Analytical Hierarchy Process as an efficient method for the selection of best maintenance strategy. A complex problem can be divided into small problems and then after an effort can be make to solve for the same. In this research work complex critical problems like Cost, Safety, Value-Added and Equipment & Technology are sub-divided into their relevant sub-criteria's. The priority value of each maintenance strategy is found for every criteria and sub-criteria. The global score simply represent the best alternative as a most suitable solution/choice of the problem. As every decision what decision maker/maintenance manager has made is in terms of mathematical form so there is a good chance for the decision maker to control the effect of most critical criteria on the goal of company. This suggested method provides an opportunity to know the cause of lacking in achieving goal or performance of machine. The kind of questionnaire can be upgrade if there is considerable change in working environment and competition in market. Thus, it is concluded that by using " Standard AHP Method" which is a type of MCDM Method and suitable software, Maintenance manager can make a trustable decision for selecting the optimum maintenance strategy.

Appendix: Appendix A

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