Selection of optimum maintenance approach based on analytic hierarchy process (AHP)

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***Abstract*—Maintenance is considered as one of the most important factors that determine total cost of production. Every organization is different with its own working environment, so selecting the right maintenance approach appears to be a tough decision. So appropriate maintenance selection is important in the present industrial context. This study emphasizes on application of analytic hierarchy process (AHP) for an imperative feed production plant. A maintenance hierarchy was formulated for the concerned plant, which disintegrates the maintenance problem into sub problems for simplifying the maintenance decision. Inspection of all acquaintances was carried out in the form of measurable and non-measurable, financial and non-financial, tangible and intangible parameters, thereby providing a comprehensive method for optimum maintenance approach selection.**

***Index Terms*— AHP, MCDM, Maintenance approach selection**

I. INTRODUCTION

Maintenance Actions are necessary for retaining equipment or a system to the specified operable condition for achieving its maximum useful life. Normally companies consider the maintenance function as a remedial purpose and are only executed in the emergency situations. But this form of maintenance practice is no longer acceptable because of critical aspects, such as product quality, production plant safety, etc., are directly affects the overall production cost. So the selection of a suitable maintenance policy becomes crucial in maintenance decision. Therefore considering difficulty and complex nature of maintenance selection, analytic hierarchy process (AHP) technique is used in this research.

II. MAINTENANCE

Maintenance is defined as indispensable action for restoring equipment to its original state. Maintenance also includes routine actions which keep the device in working order. According to [8] Maintenance is defined as, activities to retain an item to a state to perform its required operation. Maintenance actions include the combination of all technical, administrative and managerial activities. Maintenance work is carried out to preserve assets such as boilers, roller mills, CNC machines, etc., in order to enable its continued operable stage above the minimum satisfactory level of performance, over its design and throughout its service life, without any major overhauling events. Recommended main alternatives are described as follows.

Preventive Maintenance

Maintenance is planned and performed intermittently to avoid frequent and sudden failure. This type maintenance strategy is called preventive maintenance (PM), where period of maintenance is structured according to design data. In preventive maintenance, adequate historical data is also necessary to determine best maintenance interval. According to [11] PM is carried out before machine breakdown by analyzing impend failure via inspection and detection. Preventive maintenance (PM) is applied extensively in industries to reduce the risk of failure, when the product is highly valuable, replacement of equipment is too tough and major shutdown maintenance is virtually impossible.

Reliability Centered Maintenance

Reliability Centered Maintenance (RCM) was primarily used in aircraft manufacturing industry for maintenance purpose as per [5]. RCM methodology deals with some key problems that are not dealt by other maintenance methods. It identifies that all equipment in an industry is not of equal importance either in the process or facility. If RCM identifies that maintenance is inexpensive, insignificant and not directly affect the current system, suggest a corrective maintenance action. RCM contains effective element of predictive maintenance technologies [6].so RCM is a combination maintenance strategy contains elements of other alternative strategies.

Condition Based Maintenance

As per [10] condition based maintenance (CBM) are also called predictive maintenance. Condition based maintenance is used to represent the strategy, that is able to outlook efficiency and performance degradation of machines and predicts fault by analyzing and monitoring the data. According to [3] different type of analyzing and monitoring techniques are used, such as vibration monitoring and analysis, lubrication analysis, and ultrasonic diagnostics. This maintenance strategy is best suited for rotating and reciprocating machines, turbines, centrifugal pumps and compressors etc.

Reactive Maintenance

According to [7] Reactive maintenance (RM) is done when it breaks or it fails. Reactive maintenance is also called as corrective maintenance. When the reactive maintenance strategy is implemented, maintenance is not initiated until failure occurs. Reactive maintenance is one of the oldest maintenance strategy established in the industry.

III. ANALYTIC HIERARCHY PROCESS (AHP)

The analytic hierarchy process (AHP) is a methodological procedure for organizing and analyzing complex decisions, based on mathematics. It was proposed by Thomas L. Saaty. AHP converts decision problem into a hierarchy of criteria, sub criteria and solved by pairwise comparison. In literature study [12] used AHP methodologies for the selection of the suitable maintenance strategy. AHP was implemented by [1] for the selection of appropriate maintenance strategy in the naval ships. As per [4] AHP was effectively used for choosing maintenance policy in an oil refinery.

IV. RESEARCH METHODOLOGY

This research study was carried out in feed production plant (FPP). Primary discussion was done with maintenance engineers, workers and technical support to find out various aspects of research problem. AHP hierarchy was developed using the data obtained from discussion and literature. This is the most creative and important part of decision-making. The problem is disintegrated into a hierarchy of goal, main criteria, sub-criteria and maintenance alternatives. Main questionnaire was designed according to hierarchy developed and data were collected from experts corresponding to the questionnaire by the pairwise comparison of criteria. Fundamental scale of AHP is used to rate the data input of pairwise comparison, is shown in table 1.

Table: 1 Fundamental scale of pairwise comparison.

Definition	Scale
Equal	1
Marginally strong	3
Strong	5
Very strong	7
Extremely strong	9
Intermediate values to reflect	2, 4, 6, 8

Row geometric mean method (RGMM) is used as prioritization method for solving individual priority, because it has less computation time when compare to other techniques. Questionnaire was given to multiple participant and their input data was aggregated using weighted geometric mean (WGMM).Aggregation of individual judgment (AIJ) is obligatory for finding consolidate judgment matrix when more than one participant is involved in data collection. Eigen vector method (EVM) is used for final prioritization calculation. In this study, alonson/lamata linear fit [2] is used for solving consistency ratio (CR).It helps to avoid biased decision, as per [9], if CR is greater than 1 reexamine the questionnaire. The final result was obtained is ranked according to priority of maintenance alternatives.

V. MAIN CRITERIA AND SUB CRITERIA

Following are the main and sub criteria finalized for development of maintenance hierarchy. Maintenance hierarchy contain six main criteria and twenty four sub criteria. Main and sub criteria are used to build maintenance hierarchy are shown in table 2.

Table: 2 Main and sub criteria.

Main And Sub Criteria		
Safety Requirement(SR)	Training cost(TC)	Cost Oriented(CO)
Labour Safety(LS)	Value Added Requirement(VAR)	Technical Requisite(TR)
Machine Safety(MS)	Special Software(SS)	Technical Innovation(TI)
Plant Safety(PS)	Fault Detection Equipment(FDE)	Technical Skill(TS)
External Environment Safety(EES)	Spare Part Inventory(SPI)	Technical Reliability(TRy)
Cost Aspects(CA)	Special Equipment(SE)	Technical Knowledge(TK)
Hardware/ Tools Cost(H/T C)	Strategic Perspective (SP)	Time Requirement(T)
Software Cost(SC)	Management Will(MW)	Spare Availability(SA)
Spare Part Cost(SPC)	Labour Acceptance(LA)	Man Power(MP)
Outsourcing Cost(OC)	Quality Assurance (QA)	Tool Availability(TA)

VI. AHP MAINTENANCE HIERARCHY

AHP final maintenance hierarchy was formulated using main criteria, sub criteria and alternatives are shown in figure 1

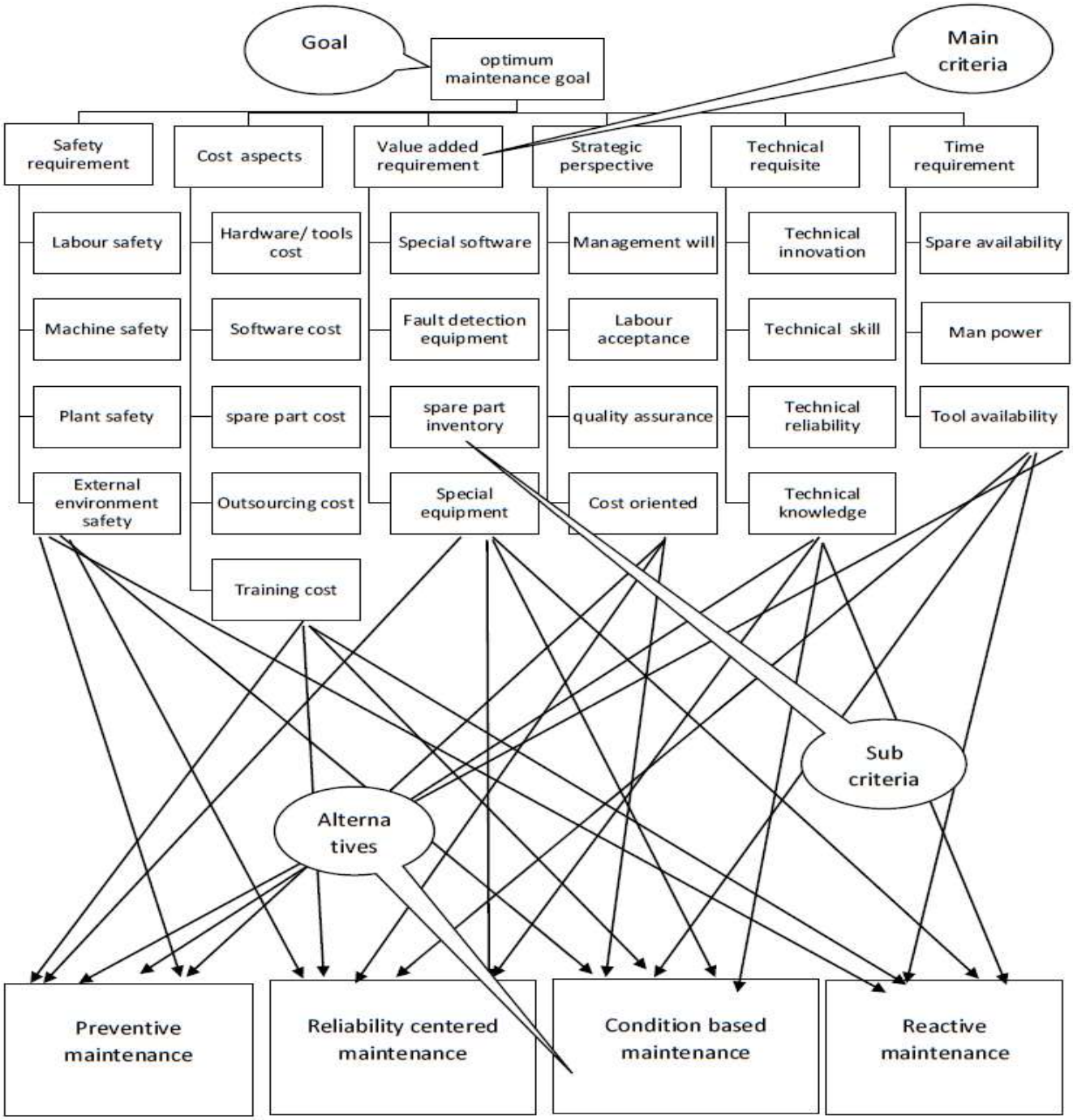

Fig: 1 AHP maintenance hierarchy.

VII. QUESTIONNAIRE FORMULATION AND DATA COLLECTION

AHP main questionnaire is developed from the AHP maintenance hierarchy. Data was collected through main questionnaire by conducting various sessions with multiple participants. A questionnaire consists of main criteria, sub criteria and alternatives was formulated, with a total of 196 comparison questions. The participant can rate data as weights, from 1 to 9 according to the relative importance criteria with another one.

VIII. RESULT AND DISCUSSION

This research study developed an AHP maintenance hierarchy model for FPP, is the main achievement of this project. AHP maintenance model integrates diversified parameters of the FPP and incorporates into a maintenance hierarchy, to simplify the maintenance selection procedure. Optimum maintenance approach selection is the final result, is shown in table 3.

From the table 3, reveals that Safety requirement (SR) has highest global priority of 0.44 followed cost aspects (CA) 0.23, technical requisite (TR) 0.158, value added requirement (VAR) 0.043, strategic perspective (SP) 0.041 and finally time requirement

(T) 0.088. Here safety requirement (SR) and cost aspects (CA) are the most important factors/criteria that determine the maintenance selection.

Considering the sub criteria under SR, labour safety (LS) has highest priority followed by external environment safety (EES).Under cost aspect (CA), hardware cost (H/TC) has highest priority followed by spare part cost (SPC).

Table: 3 AHP global weight/priority calculation.

Global priority							
Main criteria(MC)		Sub criteria(SC)		Alternatives(AE)			
				PM	RCM	CBM	RM
Safety Requirement(SR)	0.44	LS	0.253	0.0327	0.0547	0.1437	0.0223
		MS	0.025	0.0038	0.0073	0.0125	0.0015
		PS	0.067	0.0077	0.0286	0.0266	0.0046
		EES	0.094	0.0133	0.0387	0.0371	0.0050
Cost Aspects(CA)	0.23	H/TC	0.117	0.0282	0.0125	0.0691	0.0068
		SC	0.029	0.0156	0.0016	0.0037	0.0083
		SPC	0.048	0.0045	0.0292	0.0117	0.0023
		OC	0.014	0.0069	0.0018	0.0039	0.0011
		TC	0.022	0.0022	0.0113	0.0021	0.0067
Value Added Requirement(VAR)	0.043	SS	0.008	0.0010	0.0040	0.0026	0.0006
		FDE	0.002	0.0002	0.0005	0.0015	0.0002
		SPI	0.023	0.0015	0.0129	0.0067	0.0018
		SE	0.01	0.0010	0.0031	0.0048	0.0007
Strategic Perspective(SP)	0.041	MW	0.006	0.0017	0.0006	0.0031	0.0008
		LA	0.002	0.0003	0.0005	0.0012	0.0002
		QA	0.022	0.0020	0.0114	0.0077	0.0011
		CO	0.011	0.0054	0.0023	0.0024	0.0005
Technical Requisite(TR)	0.158	TI	0.088	0.0115	0.0461	0.0250	0.0056
		TS	0.009	0.0009	0.0042	0.0030	0.0004
		TRy	0.024	0.0022	0.0130	0.0079	0.0011
		TK	0.037	0.0032	0.0197	0.0113	0.0030
Time Requirement(T)	0.088	SA	0.032	0.0022	0.0155	0.0130	0.0013
		MP	0.045	0.0038	0.0128	0.0242	0.0042
		TA	0.011	0.0018	0.0051	0.0029	0.0010
Total	1		1	0.154	0.337	0.428	0.081
RESULT				**0.154**	**0.337**	**0.428**	**0.081**
RANK				**3**	**2**	**1**	**4**

In the value added requirement (VAR), spare part inventory (SPI) has highest priority. In strategic perspective (SP), quality assurance (QA) has highest priority. In technical requisite (TR), technical innovation (TI) has highest priority. In time requirement (T), man power (MP) has highest priority.

Here, finally Solving maintenance hierarchy, optimum maintenance approach selection yields following result, Condition Based Maintenance (CBM) has the highest priority of 0.428 followed by Reliability Centered Maintenance (RCM) 0.337, then Preventive Maintenance (PM) 0.154, finally least relevant result is Reactive Maintenance (RM) 0.081.

So from this research study for selecting maintenance approach for FPP, CBM yields maximum priority of 0.428 out of total priority 1, and CBM is ranked 1 and selected as the optimum maintenance approach for FPP.

IX. CONCLUSION

Maintenance selection and management is an important scenario in the present industrial situation. Considering the complex nature of research problem analytic hierarchy process (AHP), a multi criteria decision making method is used to select the proper maintenance approach.

From the recommended maintenance AHP model, Condition based maintenance (CBM) with a highest weightage/priority is selected as the optimum maintenance approach. Here safety and cost are major factors that determine the optimum maintenance approach selection. The proposed AHP maintenance model in this research paper, guides the production/maintenance managers to envisage the influence of various criteria in the forecast of the maintenance goal.

So to conclude, Maintenance approach plays a very crucial role because it ensures reliability of equipment in the manufacturing industries. AHP can be effectively used for solving the maintenance selection process in the industrial sector. Condition based maintenance (CBM) is highly recommended to be implemented in FPP as per this study. For adopting condition based maintenance, must initiate a maintenance audit to identify suitable CBM technique pertinent to FPP environment.

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