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Importance of Training and Data management Issues in implementing Reliability Centered Maintenance (RCM)

Amit Chopra, Dr. Anish Sachdeva, Dr. Arvind Bhardwaj

***Abstract*— The purpose of this paper is to study the importance of employee training and data management issues for implementing Reliability Centered Maintenance (RCM) in the Indian process industries. Data for the analysis is collected through a structured questionnaire from process industries of India. Statistical analysis using cluster analysis, factor analysis and one sample t-test have been carried out. The study establishes the importance of training and data management in implementing RCM as a maintenance methodology. The present study emphasized that the extracted factors will help processing companies in realizing the benefits of adopting Reliability Centered Maintenance (RCM) in their maintenance approach and achieving the key manufacturing performance parameters.**

***Index Terms*— Data management, Employee training, Process industry, RCM.**

I. INTRODUCTION

Maintenance is becoming a critical functional area in most types of organizations and systems including construction, manufacturing, transportation, etc. It is becoming a major function that effects and is being affected by many other functional areas such as production, quality, inventory, marketing and human resources [1]. Maintenance is one of those policies which production industries with continuous arrangements are using to increase production and to decrease costs and it also to stay in circle of global competition [2]. Maintenance is generally identified as a single largest controllable costs and status quo represents a challenge for leading managements to re-evaluate their maintenance strategies and decision making work attempts to understand different maintenance policies making for better maintenance of assets[3].Thus, maintenance plays an important role in the production systems efficiency and maintenance systems can have a large impact on the profit of a plant, so selecting appropriate maintenance policies is vital for each manufacturing company [4].

In today's dynamic environment, a reliable production system must be seen as a critical factor for competitiveness, thus maintenance has become a strategic issue for manufacturers [5], [6].The effective integration of maintenance function with engineering and other manufacturing functions in the organization can help to save huge amounts of time, money, and the useful resources in dealing with reliability, maintainability and performances issues [7]. There is an increasing trend among manufacturing organizations in recognizing maintenance of assets and machines as an essential part of operations function, while realizing that an effective maintenance strategy can contribute significantly to the production activities [8]. The globalization and the fluctuation of the markets challenge all industries to be effective in designing their products, efficient in theirs manufacturing process, reliable in delivering their products and to pursue customer satisfaction during their products usage lifecycle phase [9].This is especially true in the process industry such as oil and gas processing, petrochemicals, general chemicals, pharmaceuticals, food processing etc. and is characterized by expensive specialized equipment and stringent environmental conditions. Maintenance policies and safety performance affect plant availability and capacity [10] but till now maintenance and plant safety were treated as separate and independent sets of activities [10]-[12].

Considering the reliability perspectives the process industries are different from other industries in having the diverse equipments such as rotating equipment (e.g. pumps, compressors, motors, turbines),static equipments(vessels, heat exchangers, columns, furnaces) and piping and instrumentation equipments. Round the clock operations in harsh operating conditions used to expose the equipments to high temperature, pressure, vibrations and toxic chemicals. Apart from these, the process industries are also characterized by periodic shutdown of the plant and risks of high accidents and pollution [13].

Maintenance concepts such as RCM have been successfully applied in the process industry to reduce unnecessary preventive maintenance actions and come up with a systematic and efficient maintenance plans. Reliability centered maintenance (RCM) is a most systematic and efficient process to address an overall programmatic approach to the optimization of plant and

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Amit Chopra, Ph.D. Dept. of Ind. and Prod. Engi. Dr. B.R. Ambedkar, National Institute of Technology, Jalandhar, Punjab, India, +919417066656.

Dr.Anish Sachdeva, Associate Prof., Dept. of Ind. and Prod. Engi. Dr. B.R. Ambedkar, National Institute of Technology, Jalandhar, Punjab, India, +919501019873.

Dr.Arvind Bhardwaj, Prof., Dept. of Ind. and Prod. Engi. Dr. B.R. Ambedkar, National Institute of Technology, Jalandhar, Punjab, India, +919465758362.

equipment maintenance [14]. Maintenance needs of the process plants equipments can be better addressed with RCM approach. Failure mode and effect analysis helps in identifying all possible failure cause with a specific reference to the component of systems and sub-systems [15]. RCM is a technique for prioritizing the maintenance strategy in a systematic and logical manner. The primary objective of RCM is to preserve functions. The RCM process consists of analyzing equipment failures, assessing the consequences of each failure (on production, safety etc.) and choosing the correct maintenance action to ensure that the desired overall level of system performance (i.e. availability, reliability) is met [16].

So, it is very much clear and obvious that the process industries are highly complex systems and achieving high reliability, availability, and maintainability in these industries is a very crucial and challenging task. With a view to achieve production, safety and environmental goals, these industries should have rigorous maintenance programs that require considerable planning and devotion of significant amount of resources. [17], [18] emphasized that the safety management strategies for critical systems involve multiple dimensions including design, philosophy, maintenance policies and procedures for personnel hiring, training and evaluation. Management and employee commitment is a key factor before initiating the implementation process [19]. The implementation of RCM generally requires major resources such as human resources and funds [19]-[22]. So, it is very much essential that the maintenance staff must be well equipped and trained in the latest maintenance terminologies through various training programmes. On the other hand for a company to go in competitive advantage it must focus on managing the quality of data because data is a critical asset of any organization and it should be considered as valuable resource in building employee competence and product.

The major problem in the application of RCM is that the quality of RCM program is highly dependent on the skills of the RCM analyst [23],[24]. Therefore, majority of the RCM program can fail in the preliminary stage because of lack of knowledge about equipments, poor coordination among various departments. This paper reports the importance of training and data management issues in successful implementation of RCM program in the process industry.

II. METHODOLOGY

The study has been carried out in Indian process industry particularly textile, fertilizer, pharmaceuticals, food and beverages industries. The objective of the study is to investigate the contribution of training and data management in implementing RCM. The questionnaire survey technique has been developed in the present study for seeking information and establishing the importance of training in implementing RCM. A structured questionnaire was sent to 150 reputed process industries for obtaining the information on the topic. The respondents were asked to answers questions following a 4-points scale (Fully agree-4 to fully disagree-1). The presence of midpoints in odd likert scale may be viewed by the respondents as a "dumping ground" for unsure or non-applicable responses [25],[26].RCM implementation factor R1 contains questions pertaining to Data and management related issues like having well prepared drawings of equipments and processes. Availability of production procedures and operating manuals of equipments and their access to the personnel of maintenance department were also taken into consideration. Maintenance register of every equipment and their failure recording in the log books was also considered. The questions were also asked regarding the in house and outside training of employees to keep them updated regarding the latest maintenance terminologies [27]-[30].

64 companies have responded to the questionnaire. Most of the respondents were Heads of the concerned maintenance departments, Production heads and General Manager Operations. The turnover of the respondent companies has been shown in fig.1. The questionnaire was tested for reliability by using Cronbach's alpha which is a useful statistics for investigating the internal consistency of a questionnaire and is important for the measurement of the internal consistency and deletion of individual components [31]. Reliability coefficients of 0.70 or higher are considered adequate [31]-[32] and in the present study the value of Cronbach's alpha came to be 0.91 showing the reliability of the data for further study.

An exploratory study using factor analysis was conducted using principal component analysis (with Varimax rotation). Factor analysis is used with the aim of data reduction and therefore, to simplify the large number of items into a smaller set of representatives factors. The objective is to condense the information contained in number of original variables into a smaller set of factors with a minimal loss of information [33]. According to [33] factor analysis provides the basis for creating a new set of variables that incorporate the character and nature of the original variables in much smaller number of new variables, whether using representative variables, factor scores or summated scales. In this manner, problems associated with large number of variables or high inter correlations among variables can be substantially reduced by substitution of the new variables.

The next step involved is hierarchical clustering using Ward's method wherein we attempted to categorize the companies in three clusters showing the low, medium and high level of RCM implementation. With the aim to evaluate the level of difference among the three groups of companies (low, medium, high RCM implementation), additional statistical analysis was performed using one sample t- test to find the difference in the training and data management practices in these three groups.

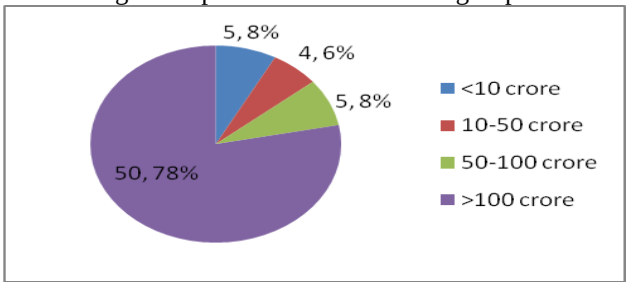

Fig.1. Turn over of the companies in Crores (Indian currency)

III. RESULTS AND DISCUSSION

An exploratory study using factor analysis was conducted using principal component analysis (with Varimax rotation). The Kaiser-Meyer-Olkin(KMO) indicator was calculated to assess sample size adequacy. The minimum acceptable level is 0.5[33]-[34]. Bartlett's test of sphericity is a statistical test for the overall significance of all the correlations within a correlation matrix. The KMO is 0.816 and Bartlett's test of sphericity X^2 = 615.156; df =66; p<0.00 which is acceptable. The total cumulative variance is 71.1%. In summary, the adequacy and reliability of the selected components are suitable for further study. The results of factor analysis are given in table 1.

Table 1: Factor analysis of various variables.

Factor1: Importance of training and availability of drawings and manuals in the organization.			
S. No	**Factor**	**Factor loading**	**Variance (%)**
1.	**Availability of production procedures and operating manuals.**	**.720**	**49.346**
2.	**Access of operating manuals to maintenance personnel.**	**.899**	
3.	**Maintenance history register of every equipment.**	**.770**	
4.	**Maintenance log books to record failure.**	**.785**	
5.	**Qualification of maintenance personnel.**	**.813**	
6	**Employing experienced personnel for maintenance activities.**	**.867**	
7.	**Maintenance staff awareness of latest maintenance terminologies.**	**.847**	
8.	**Updation of maintenance through in house training.**	**.805**	
9.	**Goals and benefits of maintenance displayed at various locations.**	**.703**	
Factor 2: Importance of outside training and employing scientific techniques for maintenance activities.			
S. No	**Factor**	**Factor loading**	**Variance (%)**
1.	**Availability of drawings depicting production processes**	**.862**	**21.763**
2.	**Analyzing the various reliability factors**	**.897**	
3.	**Sending the maintenance personnel outside the organization for training**	**.887**	

The factor analysis categorizes the variables in two factors. Factor one is regarding the importance of training and availability of drawings and manuals in the organization. The variance of factor one is 49.346%. It considers various factors like:

A1: Availability of production procedures and operating manuals.
A2: Access of operating manuals to maintenance personnel.
A3: Maintenance history register of every equipment.
A4: Maintenance log books to record failure.
A5: Qualification of maintenance personnel.
A6: Employing experienced personnel for maintenance activities.
A7: Maintenance staff awareness of latest maintenance terminologies.
A8: Updation of maintenance through in house training.
A9: Goals and benefits of maintenance displayed at various locations.

Similarly, the variance of factor two is 21.76% and is regarding the importance of outside training and employing scientific techniques in the maintenance methodologies.

B1: Availability of drawings depicting production processes.
B2: Analyzing the various reliability factors.
B3: Sending the maintenance personnel outside the organization for training.

This indicates the companies are not focussing on analyzing the maintenance data and are reluctant to send their maintenance personnel for advanced outside training. The factor loading also suggests companies are not maintaining the history books and have not displayed the benefits and goals of maintenance at various locations. Additionally, hierarchical clustering and Ward's method are used upon data and the companies are categorized in three clusters showing the low (17%), medium(63%) and high(20%) level of RCM implementation as shown in fig.2

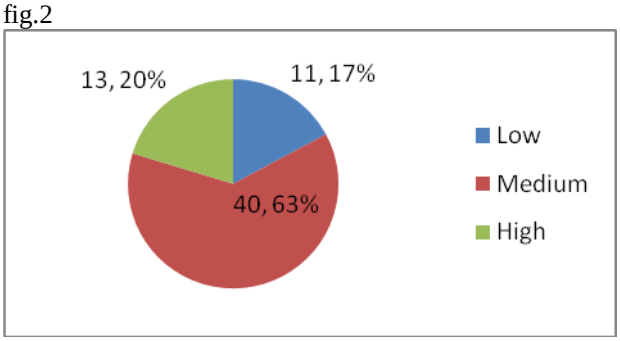

Fig.2. Number of Companies Implementing RCM at different levels.

Then the various variables pertaining to data and management issues were compared for different companies based on low, medium and high level of RCM

implementation with one sample t-test. The overall mean of the sample size came to be 2.99 and the values of mean and t-value for all variables are represented in table 2.

Table2. One sample t-test (Overall Mean =2.99)

S. No	Variable	Low RCM Implementation		Medium RCM Implementation		High RCM Implementation	
		Mean	t-value	Mean	t-value	Mean	t-value
1.	Availability of drawings depicting production processes and their relationships	2.54 ±.247[b]	1.79	3.0 ±.151	.066	3.92 ± .07[a]	12.13
2.	Availability of Production proc- edures and operating manual of each equipment	2.64 ±.24[b]	1.45	3.45 ±0.79[a]	5.77	3.92 ±.07[a]	12.13
3.	Access of operating manuals to maintenance personnel	1.81 ±.12[b]	9.60	3.42 ±.079[a]	5.49	3.92 ±.07[a]	12.13
4.	Maintenance history register of every equipment	2.00 ±.190[b]	5.19	3.25 ±.009[a]	2.61	3.84 ±.10[a]	8.22
5.	Maintenance log books to record the equipment failure	1.91 ±.25[b]	4.31	3.5 ± .094[a]	5.38	3.84 ±.10[a]	8.22
6.	Analyzing the reliability indica-tors like Failure rate, MTTF, MTTR etc.	1.45 ±.157[b]	9.75	2.1 ±.137[b]	6.46	3.23 ±.12	1.98
7.	Maintenance personnel employ-yed are adequately qualified	2.09 ±.211[b]	4.25	3.32 ±.09[a]	3.70	3.84 ±.10[a]	8.22
8.	Emphasis on employing exper-ienced personnel for various maintenance activities	2.00 ±.233[b]	4.24	3.4 ±.07[a]	5.22	3.92 ±.07[a]	12.13
9.	Maintenance staff is kept aware of the latest maintenance terminologies	1.63 ±.2[b]	6.65	3.3 ±.09[a]	3.23	3.46 ±.14[a]	3.27
10.	Updation of maintenance staff through in house trainings and seminars regarding the latest proactive maintenance techniques	1.81 ±.121[b]	9.60	3.2 ±.096[a]	2.18	3.53 ±.14[a]	3.81
11.	Displaying goals and benefits of maintenance at different loca-tions.	1.63 ±.20[b]	6.65	2.47 ±.094[b]	5.44	3.61 ±.14[a]	4.45
12.	Sending the maintenance personnel outside the organiz-ation for training.	1.63 ±.152[b]	8.89	2.2 ±.144[b]	5.48	3.46 ±.14[a]	3.27

a= significantly high, b=significantly low

The graphical representation for various factors of three clusters i.e low, medium and high RCM implementing companies are shown in fig.3

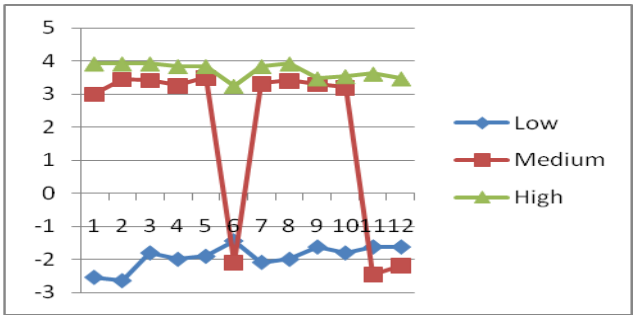

Fig. 3. Graphical representation of various factors having Low, Medium and High RCM Implementation

The result indicate that high RCM implementing companies give due importance to the employee training and data management related issues which is essential for RCM implementation and ultimately ensure the availability and safe working of the critical equipments. The mean values for all the variables considered came to be significantly higher in high RCM implementing companies. Only for variable 6 related to analyze reliability indicators like MTTF, MTTR the mean values came to be non significant showing that there is still need to focus on analysis of these indicators in these companies. On the other hand, the mean values of all variables came to be significantly lower in case of companies having low level of RCM implementation showing the great ignorance of these companies.

regarding the Data management relates issues. For the companies which lie in the medium category regarding RCM implementation the results for availability, maintainability and access for various history register and operating manuals came to be significantly higher but significantly low values are found for the practices such as analyzing the various reliability factors, displaying of goals and benefits of maintenance in the organization and sending the maintenance personnel outside the organization for learning new maintenance techniques.

Training education are activities that develop employee competence, skills and knowledge [35]-[37][19]. Training helps in promoting employee belief that the company is investing in them. The study highlighted the importance of training, availability of operating manuals and drawings and the use of scientific techniques in evaluating the maintenance of the complex process plants. The literature highlighted that TQM, TPM and RCM implementation often fail because of poor execution. This affects organizational's performance and ultimately survival in a competitive environment [19]. References [38] also emphasized on identifying the potential source of data and its collection and align them to RCM so that right analysis can be carried out. Reference [19] also highlighted the role of management and employee commitment for implementing and executing RCM process. Leadership support, strategic planning, training and education, monitoring and evaluation, evaluation buying in and empowerment and communication are essential for successful RCM implementation was stressed by [19]. Reference [39] also proposed that suitable training is to be provided to large number of people to acquire the required skills in RCM.

IV. CONCLUSION

The present study highlighted on RCM philosophy which put lot of emphasis on employee training and data management and encourages the cross functional team competence in handling the maintenance activities. The study concluded that training and data management is key for successful implementation of RCM. The high RCM implementing companies give more consideration to employee training and scientific analysis of the data comparing to the medium and low RCM implementing companies. Proper training and data management ensures better understanding of the equipments and their cause of failure thus ensuring their availability for production. The process industry needs to give more attention to the employee training and data management so that business excellence can be achieved.

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Amit Chopra, Ph.D. Scholar Department of Industrial and Production Engineering Dr. B.R. Ambedkar, National Institute of Technology, Jalandhar, Punjab, India, +919417066656,

Dr.Anish Sachdeva, Associate Professor, Department of Industrial and Production Engineering Dr. B.R. Ambedkar, National Institute of Technology, Jalandhar, Punjab, India, +919501019873,

Dr.Arvind Bhardwaj, Professor, Department of Industrial and Production Engineering Dr. B.R. Ambedkar, National Institute of Technology, Jalandhar, Punjab, India, +919465758362,