
Relationship of Reliability Centered Maintenance (RCM) with Safety, Environment and Morale of employees in Indian Process Industry

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Abstract

The purpose of this paper is to study the relation between the Reliability Centered Maintenance (RCM) implementation and Safety, Environment and Morale of the Employees in the Indian Process Industries. Data for the analysis collected through a structured questionnaire from process industries of India. Statistical analysis using cluster analysis, One Way ANOVA and Bivariate correlation techniques have been carried out. The study establishes the impact of RCM as a maintenance methodology on the improvement of Safety, Environment considerations and Morale of the employees in process industry. The emphasis on 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. The study is equally important and relevant in global scenario for risk reduction and providing the better safety climate with higher employee morale. The status and level of implementation of Reliability Centered Maintenance in the Indian Process Industry and contribution of the methodology in achieving the better and safe working conditions in the process industry has been discussed.

Keywords - Reliability Centered Maintenance, Safety, Environment, Morale, Process Industry.

Introduction

Health, environment and safety are the most important aspects of an organization's smooth and effective functioning. Good health and safety performance ensures an accident free industrial environment. The organization shall establish and maintain procedures for identification of hazards in all its activities and situations that could give rise to the potential of injury, illness, death or damage/loss of property. Good health, proper safety measures and environmental considerations considerably improves the morale of the employees in the process industry. Environment and safety are global concerns accompanied by laws and regulations that have great impact on maintenance activities across major industries such as oil, gas, chemical, petrochemical, mining and transportation (UmarAl-Turki, 2011). However, the developments in automation and the resulting complexity of the system involved have made the reliability of the machines even more important. The globalization and the fluctuation of the markets challenge all industries to be effective in designing their products, efficient in their manufacturing process, reliable in delivering their products and to pursue customer satisfaction during their products usage lifecycle phase (Durate *et al.*, 2013). 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 equipments and stringent environmental conditions. Maintenance policies and safety performance affect plant availability and capacity (Raouf, 2004) but till now maintenance and plant safety were treated as separate and independent sets of activities (Duffuaa *et al.*, 1998; Raouf and Dhillon, 1993; Raouf, 2004). The Bhopal tragedy which occurred in December 1984 and took lives of 2500 people was found to be due to poor maintenance (Kletz, 1985; Raouf, 2004). Plant performs maintenance for a number of reasons such as controlling systems, availability, increasing production

efficiency and meeting governmental regulations for safety and environment. (Koochaki *et al.*, 2011). Therefore it has been realized and well accepted by manufacturing organizations that the equipment maintenance and reliability are important strategies that can considerably influence the organizations ability to compete effectively (Madu, 2000).

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 equipment maintenance (Deshpande and Modak, 2002). 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 (Kumar and Chaturvedi, 2011). 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 (Aslam-Zainudeen and Ashraf, 2011).

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 (Suzuki, 1994).

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.

The safety of people, environment and assets is an important prerequisite for the success of any enterprise. Process safety is important, as its breach could result in major disasters, potentially with multiple fatalities. Asset integrity ensures that equipment performs effectively so that people and the environment are protected from foreseeable harm (Narayan, 2012). Therefore the improved safety and morale of the workforce can strategically enhance the productivity, quality and organizational achievements in the process industry.

This paper reports the effect of Reliability centered maintenance (RCM) on the safety, environment and morale of employees in the large and complex processing industries. It intends to highlight the importance of RCM as maintenance approach in improving the morale and safety of employees in the process industry. The major objective of this research is to examine if there is any relationship exists between RCM implementation with safety, environment and morale of the employees in the Indian process industry.

Steps of RCM

RCM methodology basically consists of the following seven questions to assure the success of the programme (Rausand, 1998; Deshpande and Modak, 2003; Ahmadi *et al.*, 2010):

1. What are the functions and associated performance standards of the equipment in its present operating context (functions)?
2. In what ways does it fail to fulfill its functions (functional failures)?
3. What is the cause of each functional failure (failure modes)?

4. What happens when each failure occurs (failure effects)?
5. In what way does each failure matter (failure consequences)?
6. What can be done to prevent each failure (proactive tasks and tasks interval)?
7. What should be done if a suitable preventive task cannot be found (default action)?

Methodology

RCM is gaining popularity as the organizations across the globe have faced stiff cut throat competition in the last three decades. The Indian industry too could not escape the burnt of globalization. It has been observed from the literature that enhancing performance of complex system with effective implementation of RCM is an important task for an Indian process industry.

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 RCM towards improving safety, environment and morale in the process industry. The questionnaire survey technique has been developed in the present study for seeking information and establishing the relationship of RCM in improving the plant safety, environment and morale of employees in the industry. 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. (Kulas *et al.*, 2008; Bottani *et al.*, 2009). The questionnaire was divided into the two sections; first section includes the questions designed on the seven steps of RCM and in the second section the responses were obtained regarding the key manufacturing parameters i.e Safety, Environment considerations (Y1) and Morale of employees (Y2) on the quantitative scale(1-Nominal gain<15% to 4-High gain>60%). The details of the questionnaire are discussed here below:

Sections 1 contain four sub- sections (R1, R2, R3, and R4) and are considered to be the pillars of RCM. The four subsections were prepared on the basis of the seven steps of RCM. It is designated as R which is an overall RCM implementation and is a combined index of R1, R2, R3 and R4.

Section 1.1 (R1): 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 (Moubray, 1992; Rausand, 1998; Backlund and Akerten, 2003; Braaksma *et al.*, 2013).

Section 1.2(R2): contains questions relating to Functional mode failure related issues which include categorization of equipments on the basis of functions and the severity of failure of each equipment. The questions were also prepared to ascertain the assignment of scores on the basis of severity of failure by the organization. (Moubray, 1992; Rausand, 1998; Braaksma *et al.*, 2013).

Section 1.3(R3): contains questions regarding the Failure analysis related issue which include the use of Root cause analysis, fish bone diagram to critically analyze the cause of failure. Some questions were also asked regarding the analyzing the Mean Time to failure (MTTF) and Mean Time to Repair (MTTR) and failure rate function $z(t)$ for various equipments(Moubray, 1992; Rausand, 1998; Braaksma *et al.*, 2013).

Section 1.4(R4): is regarding the Maintenance policy selection and failure effect issues which contains questions relating to the effect of failure and how it matter to the system(Moubray, 1992; Rausand, 1998; Braaksma *et al.*, 2013).

Section 2 is subdivided into two sub sections as the Safety, Environment considerations (Y1) and Morale (Y2) as key performance parameters indicators.

Section 2.1: Y1 is regarding the safety and environment which include questions pertaining to improved safety, environment and health of employees.

Section 2.2: Y2 is Morale as key performance indicators which include questions regarding the high employee satisfaction and better employee commitment towards job.

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 Figure 1. On the basis of responses received from the companies the hierarchical clustering using Ward's method was done to categorize the companies in three clusters showing the low, medium and high level of RCM implementation (Figure 2). 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 Way ANOVA to study whether there is any significant difference between the environment, safety and morale of employees in these three groups.

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 (Cronbach, 1951). Reliability coefficients of 0.70 or higher are considered adequate (Cronbach, 1951; Nunnally, 1978). Therefore, accordingly the factors developed here were judged to be reliable. The reliability coefficients of RCM elements are shown in Table1.

Table 1 : Values of Cronbach's alpha.

S. No.	Factors	Cronbach's alpha
	Data and Management Related Issues(R1)	0.91
	Functional Mode Failure Related Issues(R2)	0.93
	Failure Analysis Related Issues(R3)	0.85
	Maintenance Policy Selection and Failure Effect Issues(R4)	0.85
	Safety and Environment(Y1)	0.86
	Morale of employees(Y2)	0.93

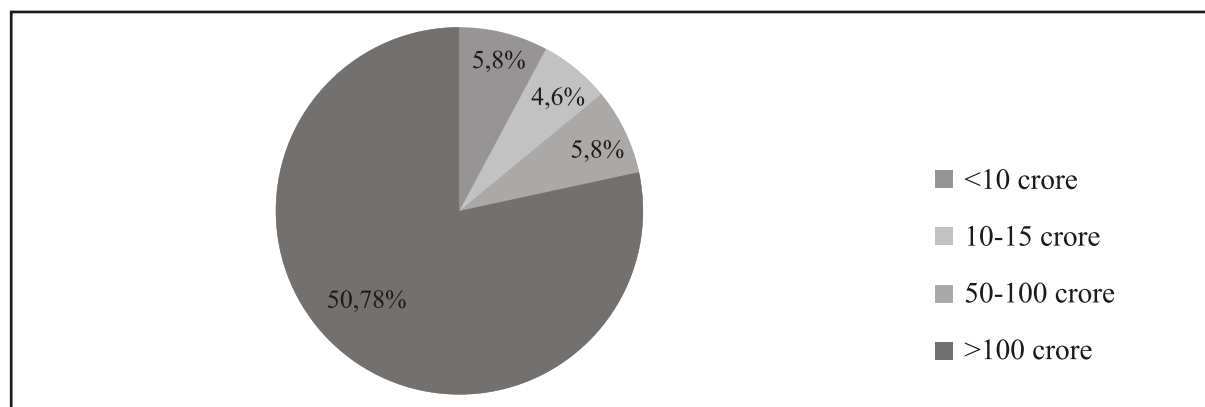


Figure 1: Turnover of the companies in Crores (Indian currency).

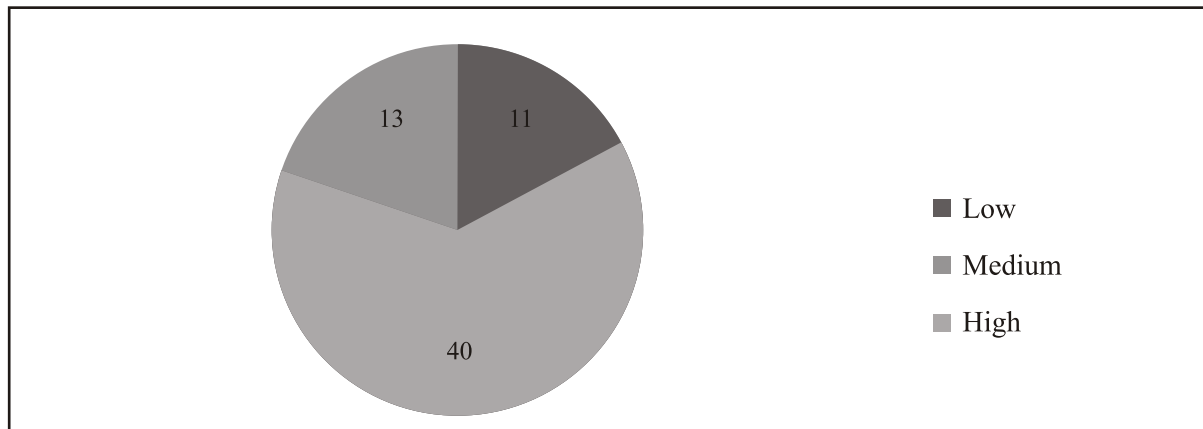


Figure 2: Number of Companies Implementing RCM at different levels.

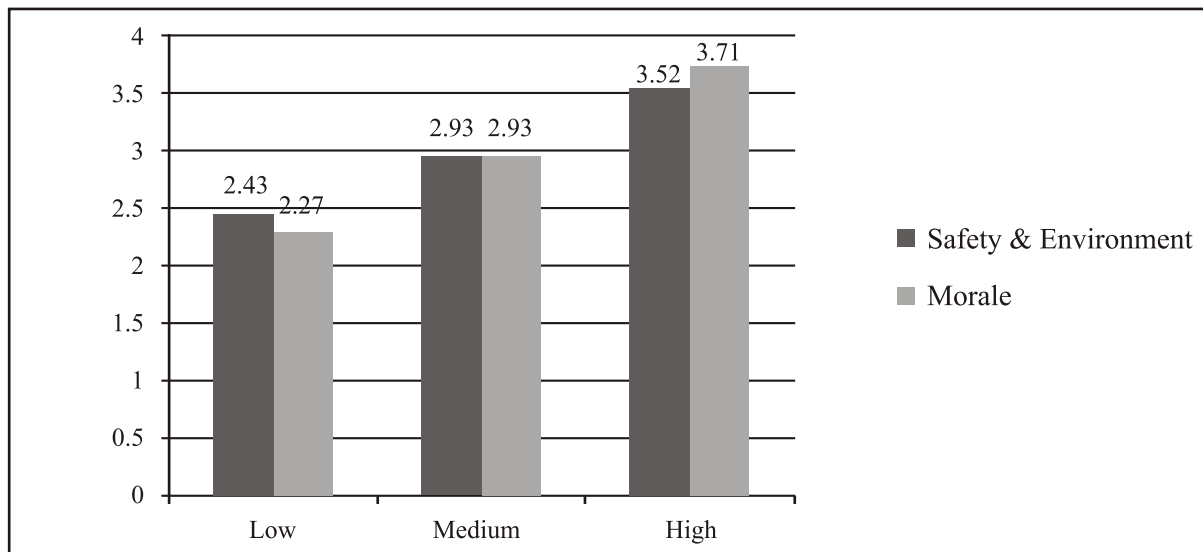


Figure 3 : Values of the Mean scores for the safety, environment and morale for different levels of RCM implementing companies.

Results and Discussion

Asset reliability and integrity ensures that the equipment perform effectively and efficiently. Safety of people, environment and asset performance is very much essential for the success of an organization. The effect of implementation of RCM at different levels (low, medium, high) and relationship of safety, environment and morale of employees was analyzed in the present study. The mean values of safety and environment and morale for low, medium and high levels of RCM implementing companies are shown in Figure 3.

One-way ANOVA test was performed followed by Post Hoc test (Tukey HSD) to know the significance of difference between different levels of RCM implementing companies. The result showed that the high RCM implementation companies have better consideration for safety, environment and morale of employees as compared to the low RCM implementation companies.

Table 2 : One-way ANOVA results for RCM(R) and Safety& Environment (Y1).

ANOVA					
Y1					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7.150	2	3.575	7.112	.002
Within Groups	30.663	61	.503		
Total	37.812	63			

Multiple Comparisons

Y1

Tukey HSD

(I) R	(J) R	J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	.50568	.24138	.099	1.0855	.0742
	3	1.08741	.29045	.001	1.7851	.3897
2	1	.50568	.24138	.099	.0742	1.0855
	3	.58173	.22635	.033	1.1255	.0380
3	1	1.08741	.29045	.001	.3897	1.7851
	2	.58173	.22635	.033	.0380	1.1255

*. The mean difference is significant at the 0.05 level.

Table 3 : One-way ANOVA results for RCM(R) and Morale of employees (Y2).

ANOVA					
Y2					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	12.602	2	6.301	11.092	.000
Within Groups	34.654	61	.568		
Total	47.256	63			

Multiple Comparisons

Y2

Tukey HSD

(I) R	(J) R	J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.66061*	.25661	.033	-1.2770	-.0442
	3	-1.44175*	.30878	.000	-2.1835	-.7000
2	1	.66061*	.25661	.033	.0442	1.2770
	3	-.78113*	.24063	.005	-1.3592	-.2031
3	1	1.44175*	.30878	.000	.7000	2.1835
	2	.78113*	.24063	.005	.2031	1.3592

*. The mean difference is significant at the 0.05 level.

The Table 2. shows the significant difference exists for the safety and environment(Y1) in the companies implementing RCM at different levels. The post Hoc (Tukey test) clearly shows that significant difference is found between the low and high level of RCM implementing companies ($P < .005$) and also between medium and high level of RCM implementing companies.

Similarly, significant difference exists in the morale of employees (Y2) of companies employing RCM at different levels as shown in Table3. Further, Post Hoc (Tukey test) highlight that significant difference exist among low, medium and high level of RCM implementing companies.

The bivariate correlation was also calculated to ascertain the relationship of RCM (R) with safety, environment and morale. The values of correlation coefficient are shown in Table.4 which reveals a positive correlation between RCM implementation with the safety, environment and morale of the employees in the process industry.

Table 4 : Correlation coefficient between RCM and safety, environment and morale.

	RCM
Safety& Environment(Y1)	.556*
Morale(Y2)	.607*

* Correlation is significant at the 0.01 level (2-tailed).

The result indicated that the companies having high level of RCM implementation in their maintenance approach are having better safety, environment and morale of the employees as compared to the companies having low or medium RCM implementation. RCM is a method for developing and selecting maintenance approach alternatives based on safety operations and economic criteria (Yssaad, 2014). It is described as a systematic approach for identifying effective and efficient preventive maintenance task by means of functions and risk analysis. Risk analysis is the understanding of the nature of risks in the working environment and has been widely studied subject. It is a key to enable people for taking actions to prevent, avoid or mitigate hazards (Cooper and Cotton, 2000).

RCM process considers the safety and environment consequences of each failure mode so that it should not hurt or kill someone or breach any known environmental standard or regulations (Deshpande and Modak, 2003). Raouf (2004) outlined the relationship between the plant productivity, safety and maintenance activities. It was highlighted in the study that to increase the productivity we have to develop safety conscious workers. Similarly, Koc *et al.*, (2012) emphasized the importance of safety measures for a more profitable operation of process system and concluded that process safety investments may result in enhanced techno economic performance of industry. Bertolini *et al.*, (2009), shows a strong relationship between maintenance practices and the occurrence of serious accidents. Narayan (2012) also emphasized that to ensure safe working environment for protection of workers, asset integrity must be considered.

In the present study a strong relationship between RCM implementation and safety, environment was found showing that the companies which are employing RCM at high level are getting more safe working environmental conditions which also lead to enhance the morale of the employees. A significant effect of high RCM implementation with morale of employee was also revealed by the study. High morale means high satisfaction, motivation and also more commitment towards the job. Mostia Jr (2009) described the motivation of the employee as a complex subject and suggested that any company which do not consider it's importance will find employees at all levels much more mobile. Hansson and Backland (2002) emphasized the importance of employee commitment in obtaining successful implementation of various maintenance methodologies as TQM, TPM and RCM.

Earlier Selvik and Aven (2011) stressed on the RCM implementation and increased safety and reliability

of the system. So, RCM as a maintenance approach used to give due consideration to safety and morale of employees and our study justify it well as high level of RCM implementing companies are showing to obtain high values for safety and morale of the employees.

It has been observed in the study that RCM implementation factors have significant correlation with the safety, environment and morale of the employees.

Conclusion

The present study highlighted on RCM philosophy which put a lot of emphasis on employee training and encourages the cross-functional team's competence in handling the maintenance activities. RCM calculates the criticalities associated with each equipment and suggest suitable maintenance interval and appropriate policy to provide a healthy, safe working environment which has great influence not only on the productivity, profitability of the business enterprise but also on the employee morale and their commitment towards job. The study highlighted the importance and effectiveness of RCM in improving the maintenance performance of the process industry. The study concluded that high RCM implementing companies achieve better and improved safety, environment and morale of the employees comparing to the low and medium RCM implementing companies. This, in turn improves the business performance and overall competitive image of the company.

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