International Journal of Advanced Technology in Engineering and Science www.ijates.com
Volume No 03, Special Issue No. 01, March 2015 ISSN (online): 2348 – 7550

IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE (TPM) IN INDIAN INDUSTRIES USING LEAST SQUARE MULTI ATTRIBUTE DECISION MODEL (LSMADM)

Subhash Chandra[1], S. K. Sharma[2]

[1]Department of Mechanical & Industrial Engineering
College of Engineering, Majmaah University, Almajmaah Saudi Arbia -11952
[2]Department of Mathematics
College of Computer and Information Sciences, Majmaah University, Almajmaah Saudi Arbia -11952

ABSTRACT

Total Productive Maintenance (TPM) has gained wide spread acceptance for raising productivity, gaining profitability, improving the quality besides cutting down the break down costs immensely. The availability of a plant in general and machines in particular rises significantly if TPM strategies are implemented correctly and practiced companywide by one and all. A set of activities or practices that collectively decide the success or failure of TPM implementation are quantified using least square multi attribute decision model (LSMADM). The relative rankings of identifiedactivities which will be interchangeably called as attributes for the case situation are presented in this paper. The main attributes viz. productivity, quality, cost, safety, delivery, morale, work environment and competitive advantages are being considered as the major drivers to raise profitability of a firm. These attributes are determined on the basis of discussions held with industryexperts and literature survey. The prioritiesestablished using LSMADM will act as base line to implement the industrial activities in a more systematic and balanced way to gain far-reaching optimizedproductivity and quality standards.

Keyword: Attribute, Least Square Multicriteria Decision Model (LSMADM), Optimized Productivity, Total Productive Maintenance (TPM), World-class maintenance system [WCMS]

I INTRODUCTION

The unleash of liberalization and globalization have caused unprecedented business challenges making the maintenance function under the spotlight as never before. Industries all over the world are concerned to implement novel practices to reduce cost of operations to stay ahead and competitive (Monica R. 2014). Industries must gear up to set in place the priorities to guide their roles in a new era of competitiveness for sustainable, advanced and surging manufacturing systems (Prasanth et al 2015). The weightage of eachattributes must be known to establish the relative ranking among the attributes. The attributes which have high rank will contribute most towards raising the profitability, brand image etc. of the firm.

Every industry has to thrive to excel across all the business functions to gain the unparalleled productivity of all its resources. It is exhibited that the distinctive impact of TPM lies in raising the wide spectrum of productivity, quality and safety standards (RambabuKodali et al. 2001). An effective maintenance program is paramount towards making valuable contributions inenhancing production efficiency, plant availability, machinereliability and organizational productivity (Bamber, C.J., et al. 2003). World-class maintenance system [WCMS] has evolved through numerous tried and tested noble practices (Patterson et al 1995). These practices must be accorded priorities for satisfactory implementation and intervention within the scope of corporate work culture and work environment.

II DEFINITION OF TOTAL PRODUCTIVE MAINTENANCE

TPM differs from thetraditional practices in reinvigorating the compartment approach into a companywide culture of autonomous maintenance by everyone irrespective of department barriers. TPM aimsat improving the overall effectiveness, availability and restoration of plant performance to the maximum extent (Majumdar 1998). Traditional thinking has created an attitudinal barrier between production and maintenance departments. This creates the blame fixing and face saving environment across the various functions of industry. I operate you fix mentality has to be renounced.They indulged in passing the buck to each other. The production staff is providedmaintenance training to mend the machines themselves for minor ailments. Skilled maintenance craftsman ship is mostly a missing link in most traditional industries (Spratling, 1987). This often results in undue reliance on maintenance contracts with suppliers of original equipment and an erosion of in-house skills. Loss of in-house experience in maintenance, and of ownership of maintenance problems, has a devastating effect over time.

2.1 Description of Model

A methodical and comprehensive analysis of the problem is required along with the identification of the important attributes involved. A Delphi study is conducted to provide the initial relative importance of each attribute. There are variations in opinions. Only the most consistent data are averaged (Thakkar et al 2007). The effect of the variance is not considered. The relative importance provided here is solely based upon the data provided by expertsfrom industry and academia for the case situation given in table 1.

Table 1. Case Situation

Industry type	Process
Production volume	High
Company vision	World class company of national repute
Mission	Continuous improvement of products, processes and people

The attributes and the sub-attributes used in the LSMADAM model for the evaluation of relative weights are (RambabuKodali et al. 2001):

1) Productivity [PRO]

- Equipment [EQP]
- Energy [ENE]
- Material [MAT]
- Manpower [MAN]

2) Quality [QUL]

- Defects in process [DIP]
- Defective products [DEP]
- Claims from clients [CFC]
- Customer complaints [CCP]

3) Cost [CST]

- Reduction in manpower [RIM]
- Reduction in maintenance cost [RMC]
- Reduction in power consumption [RPC]
- Reduction in heat consumption [RHC]
- Reduction in operating cost [ROC]
- Reduction in breakdown [RIB]
- Reduction in rework [RIR]

4) Delivery [DEL]

- Stock reduced [STR]
- Dependable delivery [DPD]

5) Safety [SAF]

- Zero accidents [ZAC]
- Zero pollution [ZPO]

6) Morale [MOR]

- Increase in improvement ideas [IIM]
- Small group meetings [SGM]
- Group culture [GCL]
- Motivation [MOT]

7) Work environment [WEN]

- Free flow of information [FFI]
- Owner-ship of equipment [OEQ]
- Improved cooperation and coordination [ICC]
- Self-confidence [SEC]

8) Competitive advantages [CMA]

- Customized service and product support [CSP]
- Customer delightment [CDT]

- Value addition [VAD]

III DESCRIPTION OF ATTRIBUTES

A general description of each attribute is provided here in the following paragraphs.

3.1 Productivity [PRO]

The productivity improvement is instrumental to mend the performance of the manufacturing systems. The manufacturing systemconsistsof the resourcesof varied types like materials, labor, plant and equipment, tools, and others, used for production (Prabhuswamy, 2013). Each resource needs proper planning and execution of plans to reduce costs.

A well thought maintenance plan is responsive to improve the equipment availability and reliability. Overall equipment effectiveness (OEE) goes hand in hand to achieve the plant effectiveness (Sharma et al., 2012) and gain the control over the objective of high profitability. There are six preventable losses. The downtime loss is responsible to demean the plant availability.

Energy saving methods, wastages of energies, under capacity utilization of machines need to be analyzed and promising solutions are sought. The timely identification of deficiencies of worker's skills and providing prompt training to bridge the gap is all time event. Saving energy is companywide drive. All ways and means are explored to reduce hourly cost of operating plant.

3.2 Quality [QUL]

The Company must bring down to zero the production of defective products. Ifany activity involved from customer needs, product development, and product design is defective, the product cannot be good to use no matter how carefully it is manufactured and vice versa (Sivaram et al 2014). Quality of late is about producing future products in present time.TPM systems unfurlnew promising vistas that use the untapped potential off all the individuals to harness their strength to the fullest capacity and capability to achieve quality goals (Sila et al 2003).

3.3 Cost [CST]

A cost reduction should be applied to any activity if it reduces the cost in totality. The axioms ofindustrial premise are technology driven. The methods of yesterday are ineffective or obsolete to provide the cutting edge solutions. In any industrial activity some waste is bound to occur. Waste of time could be in the form of break down, rework etc. Spare parts and raw materials stocked in godowns are waiting to be used (Chandra, 1991).

3.4 Delivery [DEL]

It is all about to provide the rightproduct at the right time, in the right quantity at the right place. It may devise its method to enable collaborative planning, forecasting and replenishment to meet stated objectives (Korgaonkar 1992).The continuous replenishment program and vender managed inventory through advanced methods, as electronic data interchanged will provide the added advantage toestablish a balance between supply and demand and to substantiate the level of future demand for the firm. The third party logistic provider can aggregate inbound and

outbound transportation to gain production economies of scale. Its functions include forecasting, monitoring, shipment and allocation planning, and interfacing with other established systems in an organization (Martin, 1990).

3.5 Safety [SAF]

Working environment must be safe from accidents and safety points of view. Identification, assessment and control of environmental factors that are harmful to the health of employees will have an adverse effect on the health conditions of employees. These factors may be physical, chemical or biological agents or ionizing radiation. The scientificapproach must be adopted in applying industrial hygiene includes, identifying the extent of toxicity (Ahuja and J.S. Khamba., 2008).

3.6 Morale [MOR]

Employees well being, engagement to work, passion, enthusiasm, and commitment are different facets of Morale. Almost everything which happens to a human being at work such as delay in payment, the amount of information they receive, their organization in general or the lighting in their work area can affect his or her experience of "well-being" or "morale" , positively, or negatively (David Bowles, 2009). TPM enables the need for the employee involvement in the improvement efforts, collaborative practices, and delegation of decision making, and extending self directed roles

The factors stated, when taken care of, the employee morale is sustained high even in hard time (Rodrigues et al 2006). All time respect, recognition, and duly appreciation to employees, Empowering and engaging employees in decision making.

3.7 Working Environment [WEN]

All employees must take pride in the quality of their workmanship. Everyone observes and practices honesty, respect, and ethics into their daily business practices. The poor performing worker is not discouraged but deficiencies are identified and corrective measures taken to up bring it. All must assume the responsibility of their work. Team work culture is highly prevalent. The knowledge transfer is facilitated to see that the team outperforms and objectives are met (Attri, et al. 2012). All feel motivated if the find that their services are important.

3.8 Competitive advantages

TPM has been envisioned as a comprehensive manufacturing strategy to improve the competitive position of the company. The efforts of small groups and individuals in their capacity are all well synced to exploit the synergy of human resource (Brahy and Chongy, 2004). The quality of the process, the product issubjected to periodic scrutiny and continuous improvement to enhance reliability, maintainability and restore deterioration to gain competitive advantage. The benchmarking is key to know the competitor's position (Abhijeet, 2014). It gives space to know how the new levels of performances can be gained. The value addition to the product or services must be done conspicuously. The worth that a product or service bears in the mind of the consumer. The value of the product or service must be worth of money.

IV NEW LEAST SQUARES METHOD

In least square method, the error is $x_{ij} - w_i/w_j$. The parameter xijis the element of judgement matrix. It is the relative importance of attribute ivis a vis attribute j. The expression $x_{ij} - w_i/w_j$ is nonlinear which leads in the form a nonlinear programming problem. If the error is $x_{ij}w_j - w_i$, the expression is linear. Using sum of squares of error as objective function, the model is

$$\min \sum_{i=1}^{n}\sum_{j=1}^{n}(x_{ij}w_j - w_i)^2$$

Subject to the condition $\sum_{i=1}^{n} w_i = 1 w_i \geq 0, i = 1, 2, \ldots\ldots, n$

The Lagrange's function is given below

$$Z = \min \sum_{i=1}^{n}\sum_{j=1}^{n}(x_{ij}w_j - w_i)^2 + \lambda \sum_{i=1}^{n}(w_i - 1)$$

where,λ is known as Lagrange's multiplier.

The weights can be calculated by equating $\frac{\partial Z}{\partial w_i} = 0$ to minimize the error.

$$\frac{\partial Z}{\partial w_i} = -2(x_{ij}w_1 - w_i) - -2(x_{ij}w_1 - w_i) -$$

$$-2(x_{ij}w_n - w_i) + 2x_{1i}(x_{1i}w_i - w_1) + 2x_{2i}(x_{2i}w_i - w_2) + \cdots\ldots\ldots + 2x_{ni}(x_{ni}w_i - w_n) + \lambda =$$

$$-2(x_{i1} + x_{1i})w_1 - -2(x_{i2} + x_{2i})w_2 - \cdots\ldots\ldots\ldots [2(n-1) + \sum_{\substack{j=1 \\ j\neq i}}^{n} x_{ji}^2]w_i - \ldots\ldots - 2(x_{in} + x_{ni})w_n + \lambda$$

….

Let $\frac{\partial Z}{\partial w_i} = 0 (i = 1, 2, 3, \ldots\ldots, n)$, the result are

$$-2(x_{i1} + x_{1i})w_{1 \text{ for } i=1} - 2(x_{i2} + x_{2i})w_{2 \text{ for } i=2} - \cdots\cdots\cdots + [2(n-1) + 2\sum_{\substack{j=1 \\ j\neq i}}^{n} x_{ji}^2]w_i - \cdots\cdots \text{ for above diagonal elements eg. for 3rd row } i = 3, \text{and } n > 3, \quad -2(x_{in} + x_{ni})w_n + \lambda = 0$$

$$(i = 1, 2, 3, \ldots\ldots, n),$$

Add $\sum_{i=1}^{n} w_i = 1$, We have alinear system about $n + 1$ equations . Solve the linear system, We obtain w1, w2, w3, ……wn and λ.

The a_{ij} values for Attribute Cost [CST] is given below:

Table 2: Relative importance of attributes of Costcriterion

$$A = \begin{bmatrix} 1 & 1/3 & 1 & 3 & 1/3 & 1/7 & 1/3 \\ 3 & 1 & 1 & 3 & 1/3 & 1/5 & 1/7 \\ 1 & 1 & 1 & 2 & 1/5 & 1/3 & 1/3 \\ 1/3 & 1/3 & 1/2 & 1 & 1/5 & 1/9 & 1/5 \\ 3 & 3 & 5 & 5 & 1 & 3 & 5 \\ 7 & 5 & 3 & 9 & 1/3 & 1 & 2 \\ 3 & 7 & 3 & 5 & 1/5 & 1/2 & 1 \end{bmatrix}$$

On applying the new least square method

$$\begin{bmatrix} -162.22 & 6.6667 & 4.0000 & 6.6667 & 6.6667 & 14.285 & 6.6667 & -1 \\ 6.6667 & -176.44 & 4.0000 & 6.6667 & 6.6667 & 10.400 & 14.285 & -1 \\ 4.0000 & 4.0000 & -98.500 & 5.0000 & 10.400 & 6.6667 & 6.6667 & -1 \\ 6.6667 & 6.6667 & 5.0000 & -314.00 & 10.400 & 18.222 & 10.400 & -1 \\ 6.6667 & 6.6667 & 10.400 & 10.400 & -8.9067 & 6.6667 & 10.400 & -1 \\ 14.2857 & 10.4000 & 6.6667 & 0.4444 & 6.6667 & -26.867 & 5.0000 & -1 \\ 6.6667 & 14.2857 & 6.6667 & 0.8000 & 10.400 & 5.0000 & -66.5652 & -1 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.000 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \\ w_7 \\ \lambda \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

The values of weights W_1, W_2, W_3, W_4, W_5, W_6, W_7 are 0.0473, 0.0441, 0.0776, 0.0346, 0.4815, 0.2022, and 0.1127 respectively.

Data Summary: The weights of attribute level 2, attribute level 3 and overall weights are given in the table

Table 3: Data Summary

Attribute	Weights Attribute Level 2	Sub-Attribute Level 3	Weights Sub-Attribute Level 3	Overall criteria weight
Productivity [PRO]	0.6053	Equipment [EQP]	0.6966	0.42
		Energy [[ENE]	0.1128	0.07
		Material [MAT]	0.0819	0.05
		Manpower[MAN]	0.1086	0.07
Quality [QUL]	0.1323	Defects in Process [DIP]	0.7182	0.10
		Defective Products [DEP]	0.1213	0.02
		Claims from clients [CFC]	0.0753	0.01
		Customer Complaints [CCP]	0.0852	0.01
Cost [CST]	0.0805	Reduction in Manpower [RIM]	0.047	0.00
		Reduction in maintenance cost [RMC]	0.044	0.00
		Reduction in Power consumption [RPC]	0.078	0.01
		Reduction in heat consumption[RHC]	0.035	0.00
		Reduction in operating cost [ROC]	0.482	0.04
		Reduction in break down [RIB]	0.202	0.02
		Reduction in rework[RIR]	0.113	0.01
Delivery [DEL]	0.0557	Stock reduced [STR]	0.7817	0.04
		Dependable delivery [DPD]	0.2183	0.01
Safety [SAF]	0.0419	Zero accident [ZAC]	0.8521	0.04
		Zero Pollution [ZPO]	0.1479	0.01
Moral [MOR]	0.0333	Increase in improvement ideas [IIM]	0.0704	0.00
		Small group activities [SGM]	0.0504	0.00
		Group Culture [GCL]	0.511	0.02
		Motivation [MOT]	0.3682	0.01
Work Environment [WEN]	0.0275	Free flow of information [FFI]	0.0668	0.00
		ownership of Equipment [OEQ]	0.2863	0.01
		Improve cooperation and coordination [ICC]	0.1321	0.00
		Self-confidence [SEC]	0.5149	0.01
Competitive Advantage [CMA]	0.0234	Customize service and product support [CSP]	0.1079	0.00
		Customer delightment [CDT]	0.1753	0.00
		Value addition [VAD]	0.7168	0.02

V RESULTS

The continuously improving and learningculture is essential to embark the implementation of TPM. There are a number of practices that are always discussed. All the organizations claim about knowledge ofthe same, but some are performing well compared to other. The implantation of these practices must be managed carefully. The priorities are given in figure 1.0 for main criteria. Now the industry must embrace what all needs to achieve the best performance in productivity, followed by quality, then safety and so on. The relative rank of all sub-attributes under main attributes is also given in the data summary table. The relative ranking of sub attributes of criterion cost is summarized below in figure 2.0. The quantitative ratings will help to know the priorities of the attributes. The deficiencies may sometime lead to disastrous situations if not safeguarded.

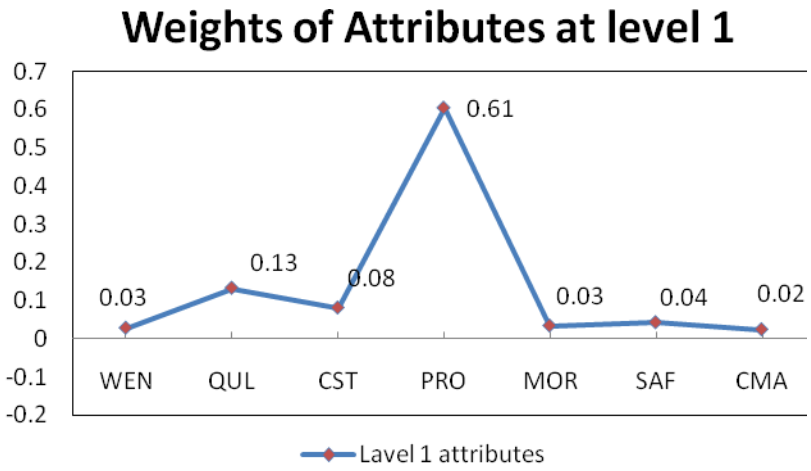

Figure 1.0: Relative weights of Main Attributes

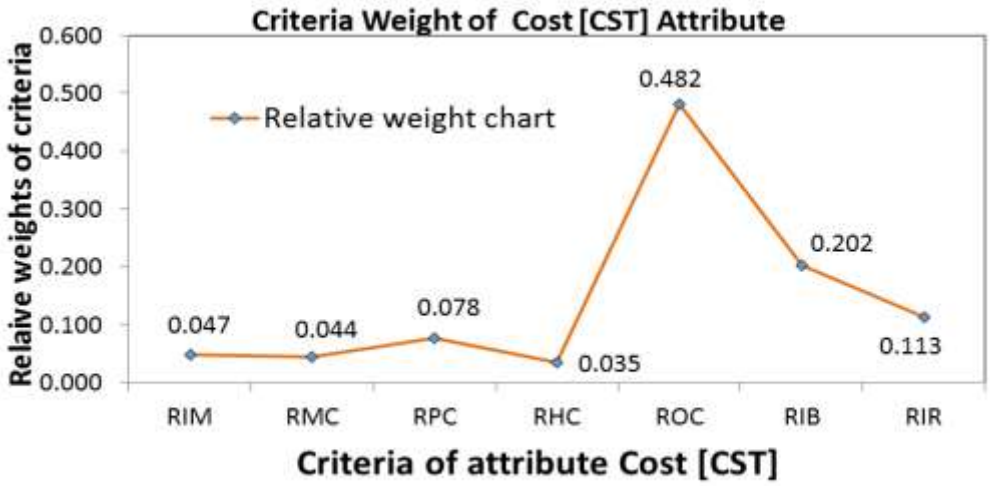

Figure 2.0: Relative weights of sub-attributes

The relative weights of all the sub attributes of all the main attributes are summarized below (refer figure 3.0). Equipment (EQP) is highest, followed by defects in process (DIP), then manpower (MAN), then energy (ENE) and so on. The priorities can be used for strategic decisions and operational planning.

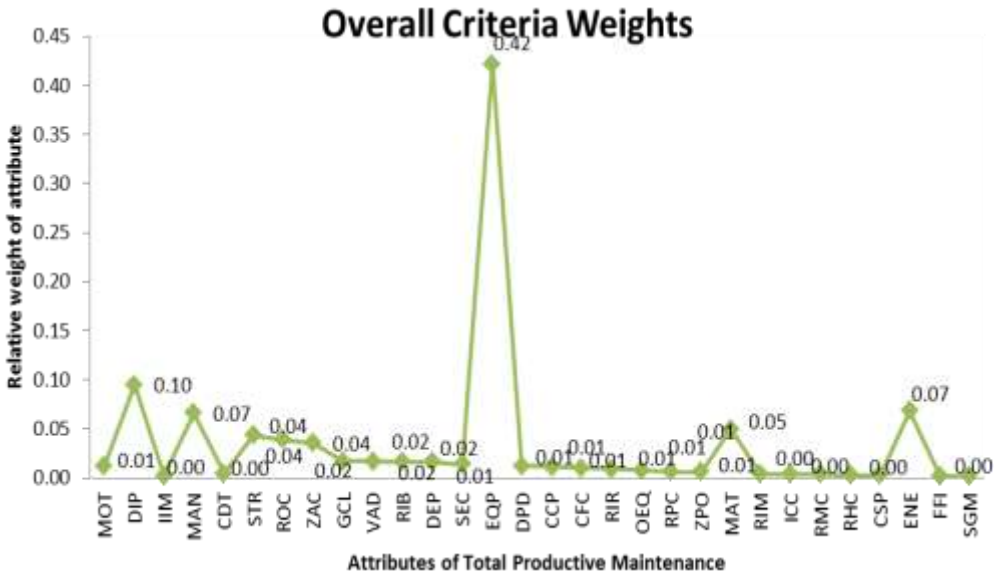

Figure 3.0: Relative weights of all the sub-attributes

VI CONCLUSIONS

The dynamically changing needs of manufacturing and formidable challenges coming from increasing global competition are making industries to re-examine the role of improved maintenance management towards enhancing organization's competitiveness. Unless the efforts are directed in required magnitude and ratio, it may be difficult to get optimal performance. The paper presents the hierarchy of rank so that efforts must align accordingly. Organization though committed their required resources and still confronted with the reality of poor performance, falls under great pressure to reinstate their competencies to create value to customers. Theimplementation has been failure in many organizations due to some or the other reason. Some makes management commitment responsible, some the training and skill levels, some blame corporate culture, some feels lack of understanding, the list goes on. This paper gives insight to implement under the scheme of the specific heads like productivity, quality, morale as the outcomes of performance. The present paper attempts to summarize the relative ranking of attributes of successful companies. The relative weights will help new organization to make their own frame work and embark upon the implementation of TPM. Equipment productivity form productivity is highly weighted, followed by defects in process of quality, then energy, man power, and material for productivity. So productivity is first to be emphasized. The quality is at second ranking thus a lot has to be done on quality.

Cost is coming next in the row, then safety and so on.

REFERENCES

1. Ahuja and J.S. Khamba., 2008, An evaluation of TPM initiatives in Indian industry for enhanced manufacturing performance, International Journal of Quality & Reliability Management Vol. 25 No. 2, 2008 pp. 147-172.
2. Andrew, C., 1987, Extending JIT into distribution. In APICS Conference, Proceedings, pp. 698–701.
3. Ashok Kumar Sharma et al. (2012),Manufacturing Performance And Evolution of TPM , International Journal of Engineering Science and Technology.
4. Attri R. , (2012), Analysis of barriers of total productive maintenance (TPM), Int J SystAssurEngManag (Oct-Dec 2013) 4(4):365–377.
5. Bamber, C.J., Castka, P., Sharp, J.M. and Motara, Y(2003), Cross-functional team working foroverall equipment effectiveness (OEE), Journal of Quality in Maintenance Engineering, Vol. 9 No. 3, pp. 223-38.
6. Brunn, R., 1987, How to improve on-time delivery using operation sequencing. In APICS Conference Proceedings, pp. 62–4.
7. Chandra D., 1991, Managing for Profit , New Delhi, India: Universal Publishing House.
8. David Bowles, 2009, Employee Morale: Driving performance in challenging time, Palgrave Macmillan
9. Ford, Q., 1987, DRP/MRP: distribution JIT. APICS Conference Proceedings, pp. 672–676.
10. Kidd, J., and Reinbott, L., 1990, Delivery reduction time at Bourns: a case study. In APICS Conference Proceedings,pp. 121–124.
11. Korgaonkar, M. G., 1992, Just-in-Time Manufacturing , Delhi: Macmillan India Ltd..
12. Krishmaiah, J. M., 1995, Total productive maintenance (TPM) – 5Ps to equipment management. Maintenance, July-September, 8–10.
13. Majumdar, N.(1998), TPM: the philosophy of the zero. Business Today, 7 August, 60–73.
14. Martin, A., and Sandras, W. A., 1990, JIT/DRP: key to high velocity customer response. In APICS Conference, Proceedings, pp. 337–338
15. Monica R. (2014),"A blueprint paradox ", Journal of Quality in Maintenance Engineering, Vol. 20 Iss 4 pp. 402 – 414.
16. Nakajima, S. (1982), Introduction to TPM Development Program for Production Management. Tokyo: Japan Management Association.
17. Nicholas John (1998), Competitive manufacturing management. Europe: McGraw-Hill
18. Patterson, J.W., Kennedy, W.J. and Fredendall, L.D. (1995), “Total productive maintenance is not for this company”, Production and Inventory Management Journal, Vol. 36 No. 2, pp. 61-4.
19. Prabhuswamy, M, Nagesh, P, Ravikumar, K (2013), Statistical Analysis and Reliability Estimation of Total Productive Maintenance. IUP Journal of Operations Management (Rochester), NY
20. Prasanth S. Poduval V. R. PramodJagathy Raj V. P. , (2015),"Interpretive Structural Modeling (ISM) and its application in analyzing factors inhibiting implementation of Total Productive Maintenance (TPM)", International Journal of Quality & Reliability Management, Vol. 32 Iss 3 pp. 308 - 331

21. RambabuKodali et al. (2001), Analytical hierarchy process for justification of total productive maintenance, Journal of Production Planning & Control, VOL. 12, NO. 7, 695–705
22. Rodrigues, M. and Hatakeyama, K. (2006), "Analysis of the fall of TPM in companies", Journal of
23. Sharma, R. K. and Kumar, S., "Performance modelling in critical engineering systems using RAM analysis", Reliability Engineering and System Safety, 2008, Vol. 93, pp. 891-7.
24. Sila, I. and Ebrahimpour, M. (2003), "Examination and comparison of the critical factors of total quality management (TQM) across countries", International Journal of Production Research, Vol. 41 No. 2, pp. 235-268.
25. Sivaram N.M. Devadasan S.R. Murugesh R. Karthi S. Sreenivasa C.G., (2014),"Synergising total productive maintenance elements with ISO 9001:2008 standard based quality management system", The TQM Journal, Vol. 26 Iss 6 pp. 534 - 549
26. Spratling, C. (1987), JIT and its implications for maintenance. Int J. Mortimer (ed.) JIT Manufacturing –An Executive Briefing (Bedford: IFS).
27. Thakkar J, Deshmukh SG, Gupta AD, Shankar R (2007) Development of Score card: an integrated approach of ISM and ANP. Int J Prod Perform Manag 56(1):25–59