Implementation of Total Productive Maintenance in Manufacturing Industries: A Literature-Based Metadata Analysis

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This paper aims to understand the usage of Total Productive Maintenance (TPM) tools and extent of its implementation in manufacturing industry. The paper reviews in detail the various cases of implementation of TPM through the existing literature. The tools utilized for the implementation of TPM are selected from literature. A detailed metadata analysis of the 42 cases of implementation of TPM using these tools is carried out in this study to analyze the frequency, pattern and importance of certain tools in a holistic way. Again, the companies are segregated on the basis of region/zone and type of industry. The frequency of various tools used and the extent of TPM implementation under the various scenarios as obtained from the metadata analysis, demonstrate the current trend of the tools usage and TPM implementation in the industries. The results provide an increased understanding of how to better the implementation of TPM in the manufacturing industry and provide managers with improved guidelines for identifying the most important tools that will lead to success.

Introduction

Total Productive Maintenance (TPM) implies a close relationship between maintenance and productivity, highlighting how good care and up-keep of equipments will result in higher productivity. TPM is the equipment and process improvement strategy that links many of the elements of a good maintenance program to achieve higher levels of equipment effectiveness (Williamson, 2000). It is a philosophy of continuous improvement that creates a sense of ownership in the operator(s) as well as the supervisors of each machine. It is a process of maintenance management that empowers

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the organization with a progressive, continuous philosophy of enabling all manpower resources to work together to accomplish the mutual goal of manufacturing efficiency.

TPM is an innovative Japanese concept. The origin of TPM implementation can be traced back to 1951 when preventive maintenance was introduced in Japan. Nippondenso was the first company to introduce plant-wide preventive maintenance in 1960 (Venkatesh, 2005). Modern manufacturing requires that the organizations that want to be successful and achieve world-class manufacturing must have effective and efficient maintenance. One way to improve the performance of maintenance activities is to implement the TPM system (Hartmann, 2000). Today, the competition has increased dramatically. Customers focus on product quality, delivery time and cost of product. Due to these factors, the company should introduce a quality system to improve and increase both quality as well as productivity continuously. TPM is a methodology that aims to increase the availability of the existing equipments, hence reducing the need for further capital investment. Again, investment in human resources can further result in better hardware utilization, higher product quality and reduced labor costs (Chan *et al*., 2005). TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools such as employee empowerment, benchmarking, and documentation used in TQM are also used to implement and optimize TPM. The five key elements or pillars of TPM are:

1. Improving equipment effectiveness by targeting the major losses;
2. Involving operators in the daily, routine maintenance of the equipment;
3. Improving maintenance efficiency and effectiveness;
4. Training for everyone involved; and
5. Lifecycle equipment management and maintenance prevention design.

The TPM literature presents many success criteria for TPM implementation. In order to realize the true potential of TPM and ensure successful TPM implementation, TPM goals and objectives need to be fully integrated into the strategic and business plans of the organization because TPM affects the entire organization and is not limited to production. For TPM to be successful, the improvement process must be recognized as benefiting both the organization and the worker (Robinson and Ginder, 1995). Lycke (2000) suggested that careful, thorough planning and preparation are keys to successful company-wide implementation of TPM and so is senior management's understanding and belief in the concept. Bohoris (1995) emphasized bringing changes in the management structure, focusing on continuous production system improvements, managing synergic cooperation of production and maintenance, deployment of effective developed Computerized Maintenance Management System (CMMS) and gradual implementation of TPM on a handful of machines at a given time as key contributors to successful TPM implementation. Hartmann (2000) stressed on effectively managing organizational change for enhancing organization's performance for strategic survival

in the competitive environment. Various tools used as an enabler are mentioned in the literature.

TPM implementation is a big task and involves many decisions and factors. The factors which help successful implementation of TPM need to be identified correctly (Hartmann, 2000). A lot of studies have already been done on the implementation of TPM. But to the best of the authors' knowledge, no comparative study of the elements used for implementation in manufacturing sector has been done. This paper attempts to fill the gap in literature by understanding the usage of different TPM tools and extent of TPM implementation in manufacturing industry through a review of the existing related literature.

Data and Methodology

The search for studies was carried out using various search engines, e.g., Google Scholar and websites on TPM, using key words like TPM, implementation, cases, tools, etc. The search results gave over 150 papers. This search was then refined and only the papers strictly dealing with the implementation of TPM in manufacturing industries using certain tools were selected. The final search resulted in short listing of 42 papers. These 42 specific cases pertaining to various manufacturing sectors like product manufacturers, automobile manufacturers, and process manufacturers, were further analyzed.

Selection of TPM Tools

The implementation of TPM is reviewed through the existing literature. The authors selected several 'elements' (used here collectively for all the tools, techniques, pillars, etc.) which are used for the implementation of TPM, from various studies . Table 1 presents the list of elements chosen. These were chosen as they were frequently repeated at many instances in the literature. The justification for selecting the tools is given by enlisting some of the studies which used the same. Further, brief description of each of the tools is given in Table 2.

Selection of Cases on the Implementation of TPM

The case studies selected for this study were restricted to the manufacturing companies across the globe. Companies from different zones like Asia, Africa, America and Europe were considered. Based on the review of available literature (Bohoris, 1995; Groote, 1995; Steinbacher and Steinbacher, 1995; Fredendall *et al.*, 1997; Tsang and Chan, 2001; Willmott and McCarthy, 2001; George, 2002; Sun, 2003; Chan *et al.*, 2005; EPA, 2006; Sharma *et al.*, 2006; Badiger *et al.*, 2007; Ahuja and Kumar, 2009; Ravikant, 2011; Ohunakin and Leramo, 2012; and Sarvanan, 2012), 42 cases were selected for the study (see Table A1 in Appendix).

Metadata analysis is used in this study to analyze the different elements considered for different countries. This analytical tool is used for analyzing a large amount of data, as literature in the present study, and helps to derive successful conclusions based on the data.

Table 1: List of TPM Tools Selected for the Project and the Studies Which Used Them

Element	Study
5S	Ireland and Dale (2001), Sharma *et al*. (2006), and Ahmed *et al.* (2011),
Why Why Analysis	Ohunakin and Leramo (2012) and Badiger *et al*. (2007)
Pareto Chart	Ireland and Dale (2001) and Ohunakin and Leramo (2012)
3W 1H/6W 2H	Saravanan (2012)
Loss Tree Analysis	Saravanan (2012)
Poka Yoke	Venkatesh (2005) and Badiger *et al*. (2007)
Performance Gap Analysis	Ireland and Dale (2001) and Almeanazel (2010)
Computer Managed Maintenance System (CMMS)	Bohoris (1995) and Sun (2003)
ECRS Sheet	Saravanan (2012)
OEE	Ireland and Dale (2001), Badiger *et al.* (2007), Ahuja and Kumar (2009), Ohunakin and Leramo (2012), and Saravanan (2012)
Machine Chart	Saravanan (2012)
Educating and Training (E&T)	Ireland and Dale (2001) and Van der Wal and Lynn (2002)
Jishu Hozen (JH)	Ireland and Dale (2001), Badiger *et al.* (2007), Ahuja and Kumar (2009), and Saravanan (2012)
Kobetsu Kaizen (KK)	Ireland and Dale (2001), Van der Wal and Lynn (2002), Badiger *et al.* (2007), Ahuja and Kumar (2009), Ohunakin and Leramo (2012), and Saravanan (2012)
Planned Maintenance (PM)	Ireland and Dale (2001), Van der Wal and Lynn (2002), and Saravanan (2012)
Quality Maintenance (QM)	Ireland and Dale (2001), Van der Wal and Lynn (2002), and Saravanan (2012)
Safety, Health and Environment (SHE)	Ireland and Dale (2001), Badiger *et al.* (2007), Ahuja and Kumar (2009), and Saravanan (2012)
Office TPM	Ireland and Dale (2001) and Saravanan (2012)

Table 2: Description/Importance of the Selected TPM Tools	
Tool Name	**Description**
1S Seiri	Distinguishes between wanted and unwanted items and eliminates the latter.
2S Seiton	Keeping workplace in order.
3S Seiso	Keeping workplace clean.
4S Sieketsu	Standardize clean-up procedure.
5S Shiktsuke	Maintaining the 5S.
Kobetsu Kaizen	Continuous Improvement.
Jishu Hozen	Autonomous maintenance (Kaizen and group activities) performed by equipment operators after they are trained and made 'equipment skilled'.
Planned Maintenance	Establishment of a planned maintenance (predictive, preventive and productive maintenance) system to increase maintenance efficiency.
Quality Maintenance	Complete removal of faults from the machine.
SHE	All activities to achieve and maintain zero accidents.
Education and Training	Establishment of training courses to bridge the skill gaps of employees.
Office TPM	PM activities (5S, Kaizen, Jishu Hozen, etc.) in administrative and support departments.
Why Why Analysis	Ask 'Why' as many times until the answer of the problem is obtained.
Pareto Chart	Measures the frequency of occurrence of an event.
3W 1H/6W 2H	Why?, What?, Where?, When?, Who? Whom? How? How much?
Loss Tree Analysis	To analyze the various sorts of losses.
Root Cause Analysis	Reaching the root cause of the problem by considering various parameters.
Poka Yoke	Mistake proofing technique.
Performance Gap Analysis	Analyzing the gap between the current and the desired performance.
Machine Chart	Plans the interaction between the worker and machine.
CMMS/IT	Maintains a computer database of information about an organization's maintenance operations.
ECRS (Checklist) Sheet	Helps in generating practical ideas for improvement.
OEE	Evaluates and indicates how effectively a manufacturing operation is utilized.

Results and Discussion

Each of the 42 cases was named as: Company 1 – Land Rover Transmissions, UK (C1), Company 2 – Steel Manufacturing, India (C2), and so on. Based on the cases of each company, the corresponding column below the company in the matrix is filled with numbers 1, 2, 3... depending on which a tool is utilized by the company. In the last row of the matrix, the total number of tools utilized by the corresponding company is obtained. Similarly, in the last column of the matrix, the sum of the number of times a tool has been used is calculated. Due to space constraint, only the sample part of calculation is presented in Table A2 in Appendix. The table directly shows how many times each tool was used by the company.

First, metadata analysis was carried out on the implementation of TPM for all 42 companies. Figure 1 shows that Education and Training is the most widely used pillar. It is closely followed by Jishu Hozen, Kobetsu Kaizen, Planned Maintenance and OEE.

Figure 1: Overview of Tools Usage

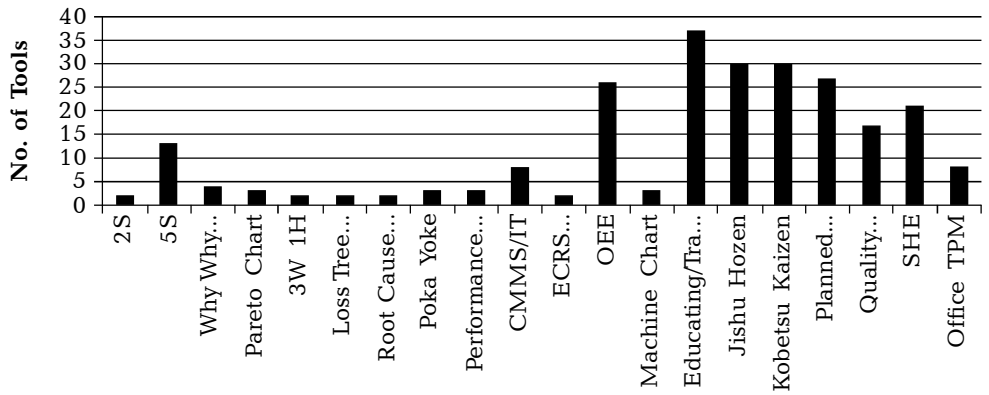
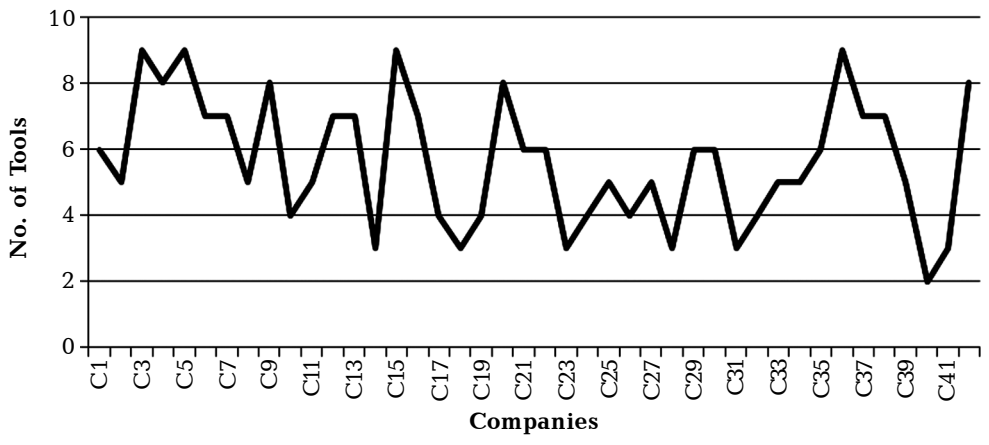


Figure 2: Overview of Extent of TPM Implementation



Companies 15 and 16 have utilized the maximum number of tools based on the literature. This is true because both these companies have been implementing TPM for many years and thus have achieved TPM implementation to a greater extent (Figure 2).

Zone-Wise Analysis

After the completion of the metadata analysis for 42 companies, the data was divided into zones, and a zone-wise metadata analysis was carried out one each for Asian and African companies, American and New Zealand companies and European companies. Thus, broadly the entire globe is covered. The zone-wise data distribution is presented in Figure 3. As the sample size of African countries is small, it was clubbed with the Asian countries. Table 3 presents the results of Asian and African metadata analysis.

Figure 3: Zone-Wise Data Distribution

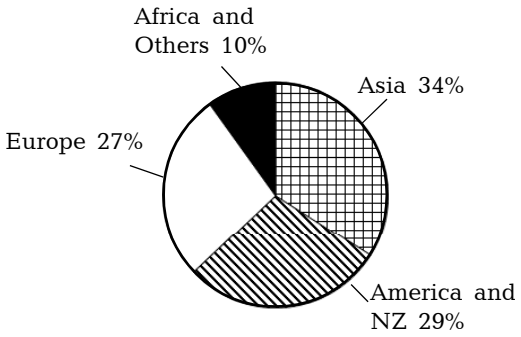


Table 3: Results of Metadata Analysis of Asian and African Countries

Tools/Company→	2	3	4	5	7	9	11	13	14	15	16	17	36	37	38	39	42	Total
1S																		
2S				2														1
3S																		
4S																		
5S		2	2		2	4				1			1					6
Why Why Analysis		4						4		8								3
Pareto Chart		5																1
3W 1H/6W 2H				3										4				2
Loss Tree Analysis										9					1			2
Root Cause Analysis																		
Poka Yoke								3										1
Performance Gap Analysis								1										

Table 3 (Cont.)

Tools/Company→	2	3	4	5	7	9	11	13	14	15	16	17	36	37	38	39	42	Total
CMMS/IT											3	1						2
ECRS (Checklist) Sheet																		
OEE	3	3		4	3	8	5	2			1	4	7		2		2	12
Machine Chart																		
Educating & Training	1	1	1	1	1	1	1	1	1		2	2	2	5		1	1	15
Autonomous Maintenance	4	6	4	5	4	3	2	6	3	2	4	3	3	1	4	3	4	17
Kobetsu Kaizen	2	5	3	7		7		5		3	6		4	3	3		5	15
Planned Maintenance		7	5	6	5	5	3		2	4	5		8	6	6	2	3	14
Quality Maintenance		8	6	8	6	6	4			5	4		9	7	7	4	6	13
SHE	5	9	8	9	7			7		6	7		5	2		5	7	12
Office TPM		10	7			2				7	5		6		5		8	8
Total	**5**	**9**	**8**	**9**	**7**	**8**	**5**	**7**	**3**	**9**	**7**	**4**	**9**	**7**	**7**	**5**	**8**	

Figures 4 and 5 show the frequency of the tools used and the extent of TPM implementation in the Asian and African companies. It is observed that compared to the holistic metadata analysis, Education and Training pillar is given comparatively lesser importance by Asian and African companies.

Similar metadata analysis was further carried out for the American companies and European companies individually.

Figure 4: Frequency of Tools Used by Asian and African Companies

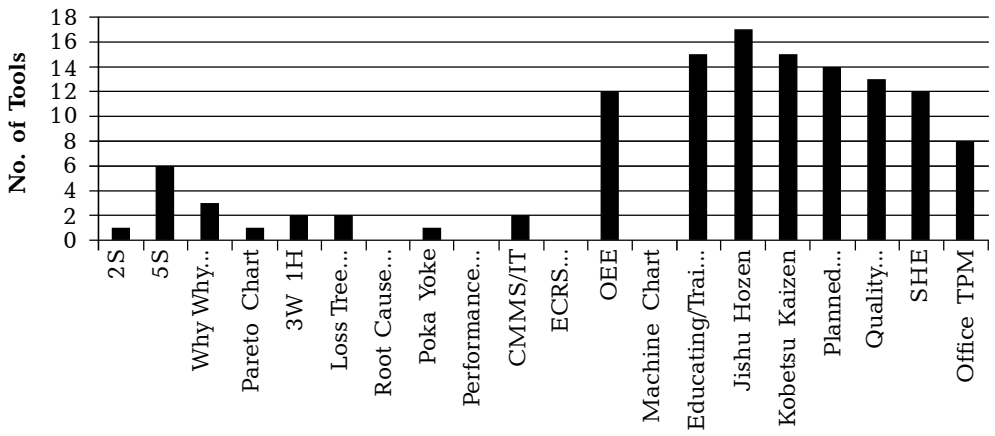
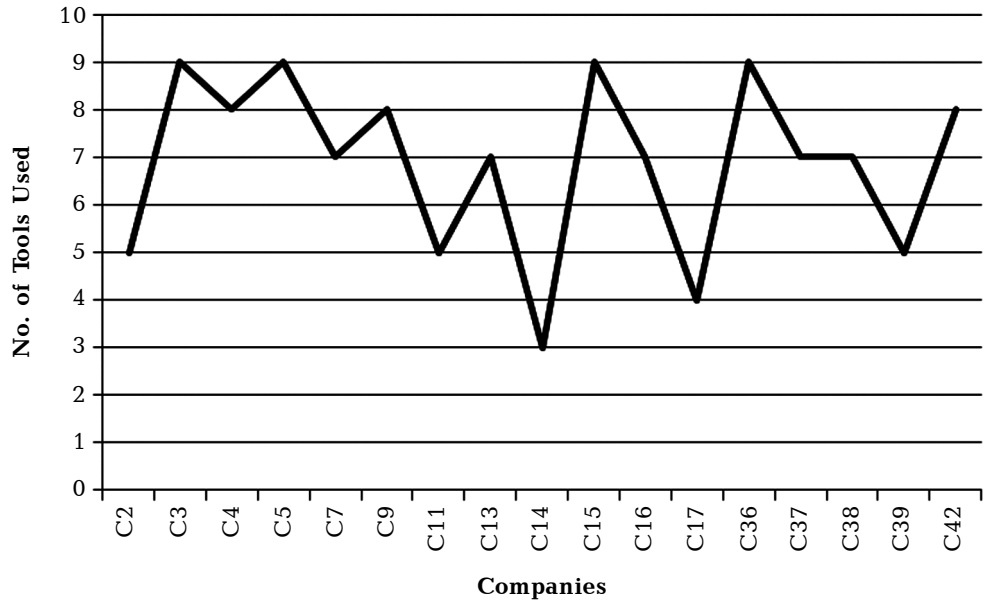


Figure 5: Extent of TPM Implementation in Asian and African Companies



Industry-Wise Analysis

Further, the companies were segregated on the basis of their industry types, viz., product, process and food manufacturing industries, and metadata analysis was carried out on each one of them individually to further analyze and categorize the various cases in depth. Industry-wise sample size is given in Table 4.

Table 4: Industry-Wise Sample Size

Industry	Sample Size
Product	22
Process	13
Food	5

Figures 6 and 7 show the frequency of tools used by product-type companies and the extent of TPM implementation by them respectively. Figure 6 shows that for companies differentiated by product- type, education and training and Jishu Hozen are the most important pillars. Further, Figure 7 shows that many companies like C4, C8, and C21 seem to use TPM up to a great extent with at least 7-8 tools each.

A similar analysis was also carried out for the processing and food manufacturing industries individually.

Table 5 summarizes the results of frequency of tools usage by companies obtained from the metadata analysis of the implementation of TPM.

Figure 6: Industry-Wise Frequency of Tools Used by Companies

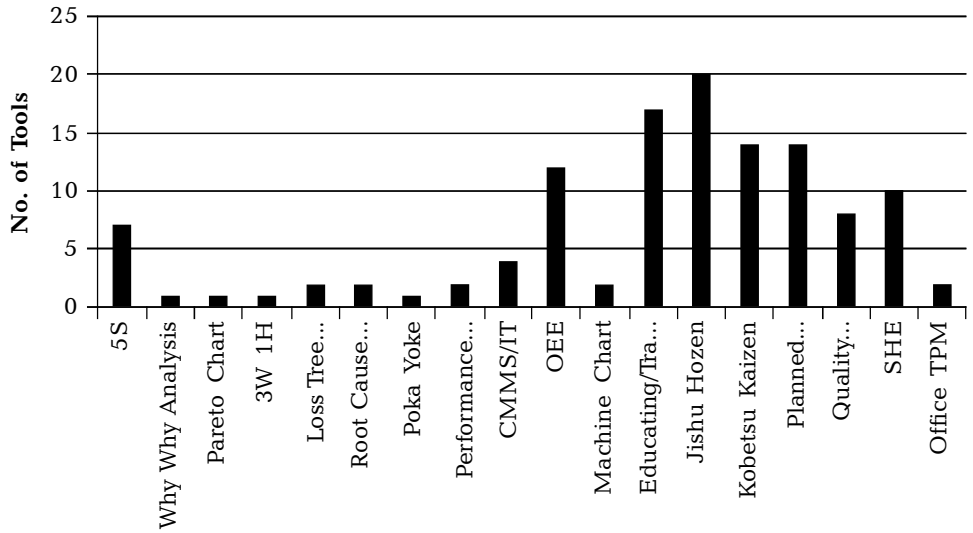


Figure 7: Industry-Wise Extent of TPM Implementation by Companies

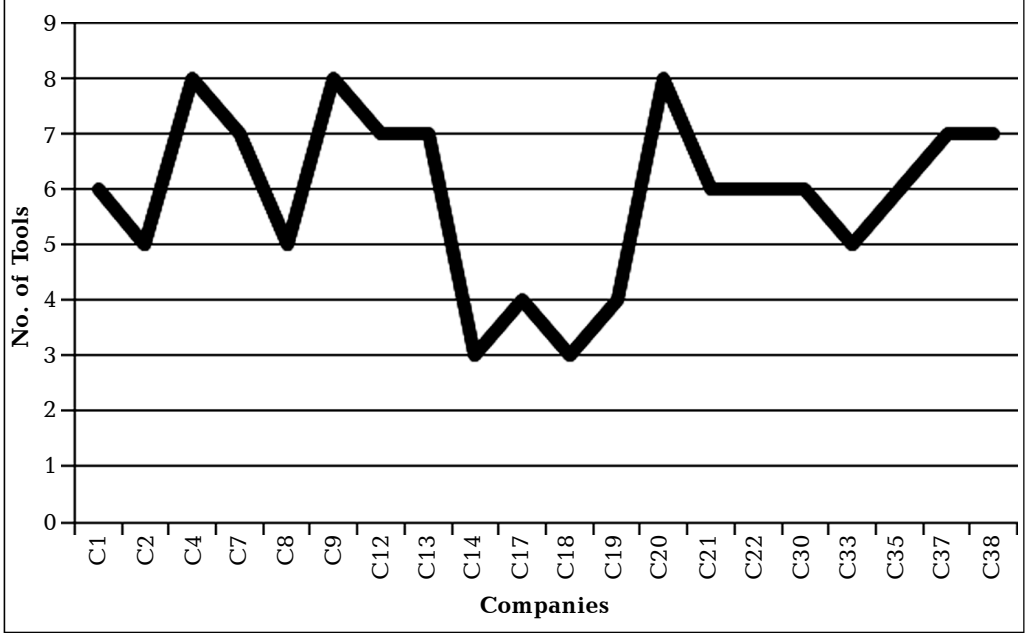


Table 5: Summary of Results of Frequency of Tools Used by Companies

Category	Most Frequently Used Tools
Holistic Analysis	E&T, JH, KK, PM, OEE
Asian and African Companies	JH, E&T, KK, PM, QM

Table 5 (Cont.)

Category	Most Frequently Used Tools
American Companies	E&T, PM, JH, KK, OEE
European Companies	E&T, OEE, JH, KK, PM, SHE
Product-Type Industries	JH, E&T, PM, KK, OEE, SHE
Process-Type Industries	E&T, OEE, JH, PM, KK, SHE
Food Manufactures	E&T, OEE, SHE, PM, JH

Note: E&T – Education and Training; OEE – Overall Equipment Effectiveness; JH – Jishu Hozen; PM – Planned Maintenance; SHE – Safety, Health and Environment; and KK – Kobetsu Kaizen.

Conclusion

The results show that education and training is the most commonly used tool. It is very closely followed by overall equipment effectiveness, Jishu Hozen, planned maintenance and Kobetsu Kaizen. In countries like Asia and Africa, the education and training pillar is still not the most used tool. Further, process and food industries give more importance to safety, health and environment tool. Many companies like CPCL, India and BP Amoco Forties Field, USA have used over nine tools, and also literature shows that they have been implementing TPM in a very effective manner. The various TPM awards won by these companies prove the same. The frequency of various tools used and the extent of TPM implementation under the various scenarios as obtained from meta data analysis demonstrate the current trend of the tools usage and TPM implementation in the industries. The results provide an increased understanding of how to better the implementation of TPM in the manufacturing industry, and provide managers with improved guidelines for identifying the most important tools that will lead to success.❖

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Appendix

Table A1: Selected Companies/Industries for the Study

Company	Company Name/Type	Country
1.	Land Rover Transmissions	UK
2.	Steel Manufacturing Company	India
3.	Beverage Manufacturing Industry	Nigeria
4.	Semiconductor Company	Malaysia
5.	Safety Equipment Manufacturing	India
6.	Rubber Manufacturer	UK
7.	Motorized Vehicle Manufacturer	Japan
8.	Global Part Manufacturer	USA
9.	Automotive Spares	South-East Asia

Appendix (Cont.)

Company	Company Name/Type	Country
10.	Pizza Factory	Switzerland
11.	Pulp and Paper Factory	South Africa
12.	Packaging Plant	Europe
13.	Indian Manufacturing Company	India
14.	High Precision Machining Factory	China
15.	CPCL	India
16.	Textile Manufacturing Company	Ethiopia
17.	Hong Kong Manufacturing Company	Hong Kong
18.	Whirlpool-Findlay	Ohio
19.	Steel Manufacturing Company	Jordan
20.	Thorsman & Co. Ltd (TCE)	UK
21.	Kaiser Aluminum	Ohio
22.	National Semiconductor Plant	Maine
23.	Metro Parks	Spain
24.	Kodak	USA
25.	3M Aycliffe	USA
26.	Adams (Warner Lambert)	UK
27.	BP Amoco Forties Field	USA
28.	Elkes Biscuits	UK
29.	Henkel Consumer Adhesives	UK
30.	RHP Bearings	UK
31.	RJB Mining	UK
32.	Gaffeney Bearing	USA
33.	Two Wheeler Manufacturer	USA
34.	AT&T	USA
35.	Magnavox Electronic System	USA
36.	Process Plant	India
37.	Bajaj Auto	India
38.	Piston Ring Manufacturer	India
39.	HUL-Haldia Plant	India
40.	Hynds Pipe	New Zealand
41.	Milk Processing Plant	New Zealand
42.	Frito Lays Division	India

Appendix

Table A2: Metadata Analysis on the Holistic Data

↓ Tools/Company→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1S																
2S					2											
3S																
4S																
5S			2	2			2	2	4						1	
Why Why Analysis			4										4		8	
Pareto Chart			5			2										
3W 1H/6W 2H					3											
Loss Tree Analysis								5							9	
Root Cause Analyis												2				
Poka Yoke													3			
Performance Gap Analysis								1								
CMMS/IT	2															3
ECRS (Checklist) Sheet																
OEE		3	3		4	3	3		8	2	5		2			1
Machine Chart	3															
Educating/Training	1	1	1	1	1	1	1	1	1	1	1	1	1	1		2
Autonomous Maintenance	4	4	6	4	5		4	3	3	3	2	3	6	3	2	4
Kobetsu Kaizen	5	2	5	3	7	4			7			5	5		3	6
Planned Maintenance			7	5	6	5	5	4	5	4	3	4		2	4	5
Quality Maintenance			8	6	8	6	6		6		4	6			5	4
Safety, Health and Environment	6	5	9	8	9	7	7					7	7		6	7
Office TPM			10	7					2						7	5
Total	**6**	**5**	**11**	**8**	**9**	**7**	**7**	**6**	**8**	**4**	**5**	**7**	**7**	**3**	**9**	**7**

Note: Based on which tool is utilized by the company, the column below the corresponding company is filled by numbers 1, 2, 3... . In the last row of the matrix, the number of tools utilized by the corresponding company is added and given as a total. Due to space constraint, only sample part of calculation is presented in the table.

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