

## **SURVEY RESULTS OF TOTAL PRODUCTIVE MAINTENANCE EFFECTS ON MANUFACTURING PERFORMANCE IN MALAYSIA ELECTRICAL AND ELECTRONICS INDUSTRY**

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### **ABSTRACT**

*Many frameworks of Total Productive Maintenance (TPM) elements have been proposed by different authors in the literature. However, most of them are based on studies done in countries such Japan, Italy, USA, China and India. There is a need to evaluate TPM elements/strategies and their contribution towards manufacturing performance in electrical and electronics industry in Malaysia. Towards that end, a survey was conducted where questionnaires are sent to 240 companies in the electrical and electronic industry in Malaysia with the resulting response rate of 12.5 %. The TPM element most emphasized in Malaysian electrical and electronics industry is planned maintenance management while the least emphasized element is top management leadership. Using Pearson Correlation Coefficient, the correlation between TPM elements emphasis and manufacturing performance dimension was determined. The study found that TPM elements – top management leadership, planned maintenance management, focused improvement, autonomous maintenance and education and training have significant contribution towards manufacturing performance such as lower cost, higher quality, strong delivery and increased productivity. These five elements could be used as a guideline for companies wanting to implement TPM as well as evidence to convince management of the importance of TPM towards the organization. Besides that, this study also found no significant differences of TPM element practices between electrical and electronic industry while only some elements are significant between small medium industry (SME) and large companies. In addition, the longer TPM is practiced, the more improvement resulted in manufacturing performance.*

**Keywords:** *TPM elements/strategies, manufacturing performance, Malaysia, electrical and electronic industry*

### **1.0 INTRODUCTION**

In today's competitive and mature economic environment, many manufacturing plants worldwide face many challenges to achieve world-class manufacturing standards in operations. In addition, market forces are demanding more emphasis on customization, quick delivery and superb quality (Raouf and Ben-Daya, 1995). These pressures demand excellent maintenance practices in such a way that machines and processes are available whenever needed and produce the desired products with the required quality level (Yamashita, 1994). Reliable equipment, operating at the lowest possible cost is also an essential enabler of profits (Williamson, 2006). One approach to improve the performance of maintenance activities is to implement total productive maintenance

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(TPM) system. In fact, the only proven work culture that promotes and sustains reliable equipment at lower costs is through Total Productive Maintenance (Williamson, 2006).

There are a large number of frameworks which has been proposed by authors and consultants in the literature of Total Productive Maintenance (TPM). However, most of them are based on studies done in countries such as Japan, Italy, USA, China and India (Bamber et al., 1999; Ahuja et al., 2004; Tsang and Chan, 2000; Ireland and Dale, 2001). TPM methods and techniques were first successfully implemented in Japan and later followed and adapted to other countries in the world. Despite following a structured approach in developing the framework, each country has their own emphasis on TPM elements or strategies. In other words, the environmental-country factor explains a significant portion of variation in TPM implementation (Kathleen et al., 1999).

Due to the lack of comprehensive studies on TPM strategies or elements in Malaysia, this paper aims to evaluate TPM element or strategies emphasis in Malaysian electrical and electronics industry. Analysis will be done to determine the effect of these TPM initiatives towards the core competencies or benefits to the manufacturing organization. Difference of TPM strategies or elements practice between electrical and electronic industry, as well as between small medium industry (SME) and large companies will also be explored. The effect of TPM implementation time period on manufacturing performance will also be covered.

## **2.0 LITERATURE REVIEW**

TPM represents a radical change in the way maintenance is being look at. It is a methodology and philosophy of strategic equipment management focused on the goal of building product quality by maximizing equipment effectiveness. Originally introduced as a set of practices and methodologies focused on manufacturing equipment performance improvement, TPM has matured into a comprehensive equipment-centric effort to optimize manufacturing productivity (Ahuja and Pankaj, 2009). The goal of TPM or also known as Total Productive Manufacturing is to continuously improve all operational conditions of a production system by stimulating daily awareness of all employees (Nakajima, 1989).

### **2.1 TPM Basic Concepts**

TPM seeks to maximize equipment effectiveness throughout the lifetime of the equipment. It strives to maintain the equipment in optimum condition in order to prevent unexpected breakdown, speed losses and quality defects occurring from process activities. Thus the three ultimate goals of TPM are zero defects, zero accident and zero breakdowns (Nakajima, 1989; Willmott, 1994). Among the principles embraced by TPM to achieve these goals are total employee involvement, autonomous maintenance by operators, small group activities to improve equipment reliability, maintainability and productivity and continuous improvement (kaizen) (Ahuja and Khamba, 2008). Maier et al. (1998) on the other hand, considers preventive maintenance, teamwork shop floor employee competencies, measurement and information availability work environment, work documentation and extent of operator involvement in maintenance activities as factors reflecting TPM implementation. According to Wireman (1991), there is no single right method for implementation of a TPM program. There has been a complexity and divergence of TPM programs adopted throughout the industry as stated by Bamber et al. (1999). It is clear that a structured implementation process is an identified success factor and a key element of TPM programs. These basic practices or programs of TPM are often called “pillars” of TPM.

#### **2.1.1 Pillars of TPM**

The entire edifice of TPM is built and stands on eight pillars (Sangameshwran and

Jagannathan, 2002) which are focused improvement; autonomous maintenance; planned maintenance; training and education; early-phase management; quality maintenance; office TPM; and safety, health, and environment. TPM paves way for excellent planning, organizing, monitoring and controlling practices through its unique eight pillar methodology. These eight pillar implementation plan which is proposed by JIPM results in an increased in labor productivity through controlled maintenance, reduction in maintenance costs and reduced production stoppages and downtimes (Ahuja and Khamba, 2007). The eight pillars of TPM are shown in Figure 1.

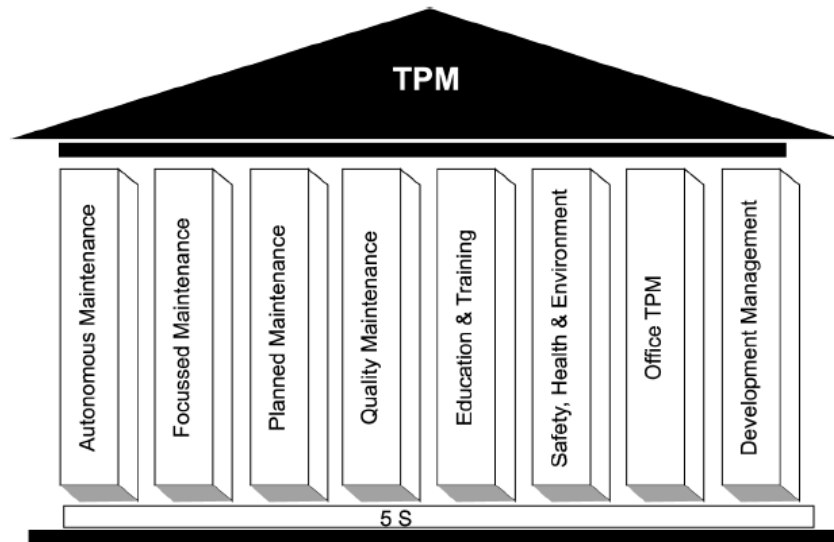


Figure 1: Eight pillars of TPM implementation

Most organizations have since closely followed the JIPM recommended eight pillars of TPM and the various TPM consultants that adherently follow this are TPM Club India, Imants BVBA Consulting and Services, Australian Die Casting Association, Advanced Productive Solutions, Promaint Inc. and Shekhar Jitkar (Mishra et al., 2008). For example, the Australian Die Casting Association (ADCA) has developed a framework which is adopted by a company named Nissan Casting in Australia. This framework has eight pillars which are similar to that of the JIPM framework but the names of many of the major pillars of JIPM are changed to avoid confusion caused by the literal Japanese translation (Luxford, 1998).

However, some TPM consultants and practitioners have simplified the Nakajima model by eliminating some pillars. One of them is Yeomans and Millington (1997) who has developed their model based on the theory of classic Japanese TPM approach, which is built on five strategic pillars which are focused improvement, training, maintenance prevention, preventive maintenance and autonomous maintenance. Other models have only few pillars that differ from the JIPM model and pillars that cover only the basic definition of TPM like Strategic Work Systems, Society for Maintenance and Reliability Professionals and Society of Manufacturing Engineers (Mishra et al., 2008). However, there are also few models that are totally different from JIPM such as Aramis Management System, Volvo Cars Gent, Centre for TPM Australasia and Phillips 66. One example is the implementation of TPM at Volvo Cars Gent (VCG) which is based upon 13 committees or development pillars. Some of the unique pillars in this framework are: customer-ordered production, early product management, logistics, supplier support and integration in society (Volvo Cars Gent, 1998). The information obtained from the review will be used in developing a questionnaire to be used in the survey carried out.

### 3.0 METHODOLOGY

A questionnaire was developed based on the information from the above review in order to accomplish the aims of the study. The questionnaire consists of 3 sections viz. Section A: General information, Section B: Various TPM strategies/ elements and Section C: Contribution of TPM strategies/element emphasis towards manufacturing performance. Further details of Section B and C are described in the Section 3.1. The questionnaire is then validated through peer review from supervisor, academicians, consultants and practitioners from the industry. Before sending out of questionnaires, it will be pre-tested on a representative sample from the industry in order to ensure it is relevant to the objective of the study. One of the comments obtained from the pilot survey is that the questionnaire was too long and this would discourage respondents from answering the survey. Therefore, efforts were made to reduce further the length of the survey. The TPM questionnaires were then sent to a sample of 240 companies randomly selected from the Directory of the Federation of Malaysian Manufacturers (FMM) which is a subset of over 1240 electrical and electronics companies in Malaysia (MIDA, 2004). The final response rate is 12.5 % based on 30 valid responses. This is considered reasonable because of similar response rate of surveys done in Malaysia by Jusoh et al. (2008) and Ahmad and Hassan (2003) which obtain 12.3% and 11.5% respectively. The responses were then analyzed using SPSS (PASW) Version 18 statistical package and are tabulated in Section 4.0.

#### 3.1 TPM Model

This section will identify the components of the elements or strategies of TPM and manufacturing performance dimension. Each component will be studied in details together with the theory that supports it. The relationship between these TPM elements and manufacturing performance will be analysed to develop an understanding of contribution of TPM implementation element emphasis on manufacturing performance dimension. Figure 2 shows the proposed model for evaluating the relationship between TPM elements/strategies and manufacturing performance.

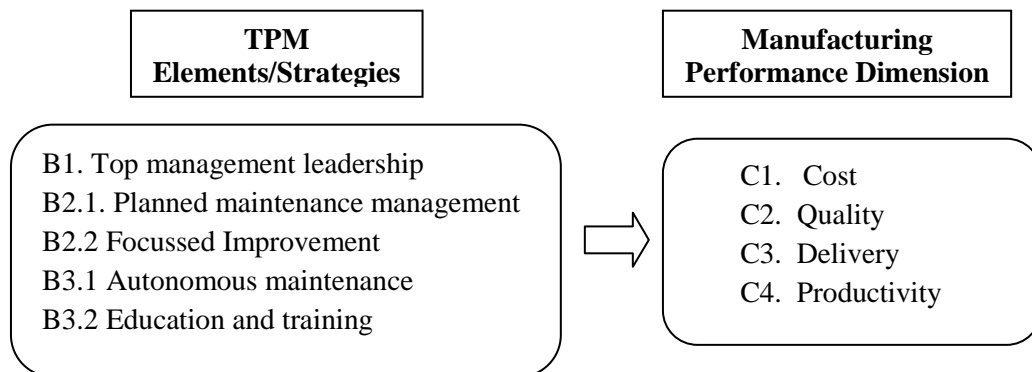


Figure 2: TPM Model

##### 3.1.1 TPM elements/strategies

According to Bamber et al. (1999), there is a complexity and divergence of TPM programs adopted throughout history. In Japan, early TPM programs follows a strict implementation process by Japan Institute of Plant Maintenance (JIPM) which led to many plants winning TPM awards (Nakajima, 1988). From then on, many literatures can be found on TPM framework model such as Kathleen et al. (2001) who have investigated the relationship between TPM and manufacturing performance through structural equation modeling and Ireland and Dale (2001) who has elaborate implication of TPM in

various manufacturing organization. TPM Club India has also produce frameworks of TPM elements which only differ in naming from Nakajima's framework (TPM Club India, 2003). Wiremen (1999), on the other hand, places importance on maintenance prevention in his framework and also emphasis on training to improve the skills of the people involved in TPM. From this exhaustive literature review, five important TPM elements or strategies have been derived in this present study. These five elements play a significant role in contributing towards manufacturing performance of an organization and are listed as follows:

- i. Top management leadership (B1)
- ii. Planned maintenance management (B2.1)
- iii. Focused improvement (B2.2)
- iv. Autonomous maintenance (B3.1)
- v. Training approach (B3.2)

The five TPM elements are core elements that are also found in Nakajima's eight pillars of TPM (Nakajima, 1989) but more closely resembles Yeomans and Millington (1997)'s five strategic pillars; the only difference is the replacement of maintenance prevention element (more focus towards design activities during planning and constructing of new equipment and many companies lack the data to pursue this goal (Wiremen, 1991)) with the top management leadership element.

Top management commitment and leadership (B1) are crucial to the success of effective TPM implementation. Senior management must show its commitment to TPM by devoting time and allocating resources to create and sustain the required cultural change and also to educate its employees (Tsang and Chan, 2000). Tsang and Chan (2000) also mentioned that the pursuit of sustainable TPM requires a change of employees' attitude and values, which takes time to accomplish. Thus, thorough planning and preparation by management are required for successful implementation of TPM (Lycke, 2000). Besides that, top management must also be supportive, understanding and committed towards various kind of TPM activities in order to successfully implement TPM (Patterson, 1996). Bamber et al. (1999) wrote that the major obstacle in implementing TPM in UK was the lack of top management commitment to follow through which resulted in many organizations having to struggle when attempting to implementing TPM.

The ability of an organization to perform basic maintenance activities or planned maintenance (B2.1) effectively in an organized and efficient way determines the success of implementing TPM programs (Ahuja and Khamba, 2008). Planned maintenance management aims to make the equipment reliable with zero failures and quality defects and to do so efficiently, at a minimum cost (Shingo, 2007). It consists of maintenance practices and approaches like preventive maintenance (PM), time-based maintenance (TBM), condition-based maintenance (CBM) and corrective maintenance (CM). Preventive maintenance is a kind of physical check up on the equipment to prevent equipment breakdown and prolonged equipment service. PM comprises of maintenance activities that are undertaken after a specified period of time of machine used (Herbaty, 1990). During this phase, the maintenance function is established and time based maintenance (TBM) activities are generally accepted (Pai, 1997). The preventive work undertaken may include equipment lubrication, cleaning, parts replacement, tightening, and adjustment. The production equipment may also be inspected for signs of deterioration during preventive maintenance work (Telang, 1998).

Planned maintenance (B2.1) typically requires discipline planning process for maintenance task, good information tracking systems to capture data for problem solving and schedule compliance as an indicator of the health of the planned maintenance management system (Kathleen et al., 2001). The key to effective planned maintenance is

to have a PM plan for every tool. The PM plan is based on the history and analysis of failure modes to determine preventive practices. The PM plan consists of five elements which are as follows (Leflar, 1999):

1. A set of checklists for PM execution.
2. A schedule for every PM cycle.
3. Specification for every PM cycle.
4. Procedure for every checklist item.
5. Maintenance and parts logs (equipment maintenance history) for every machine

Focused improvement (B2.2) complements this by using why-why and P-M analyses to eliminate losses and improve equipment reliability (Shingo, 2007). Focused improvement includes all activities that maximize the overall effectiveness of equipment, processes, and plants through uncompromising elimination of losses and improvement of performance (Suzuki, 1994). The driving concept of Focused Improvement is Zero Losses. Maximizing equipment effectiveness requires the complete elimination of failures, defects and other negative phenomena – in other words, the wastes and losses incurred in equipment operation (Nakajima, 1989). Focused Improvement has been, and still is, the primary methodology for productivity improvement in the fabrication process and the key metric for Focused Improvement is Overall Equipment Effectiveness (OEE).

Autonomous maintenance (AM) goals are to develop equipment competent operators and also to empower operators to look after their own equipment (Shingo, 2007). TPM through AM (B3.1) enables operator to learn more on their equipment function, identify common problems and how to prevent them through early detection and treating of abnormal conditions (Kathleen et al., 2001). TPM also embraces empowerment to production operators, establishing a sense of ownership in their daily operating equipment. This sense of ownership is an important factor that underpins TPM to its continual success with every operator being responsible to ensure their machine is clean and maintained (Tsang and Chan, 2000). AM enables operators to perform basic maintenance task such as housekeeping task which includes cleaning and inspection, lubrication, precision check and other light maintenance task. It can be broken down into five S's – seiri (organization), seiton (tidiness), seiso (sweeping), seiketsu (sanitizing) and shitsuke (self-discipline) (Nakajima, 1988).

The final TPM element that would be covered is Education and training (B3.2) which involve not only transforming organization culture and redefining roles but also skills and technical upgrade for everyone in operation, maintenance and support group (Tsang and Chan, 2000). According to Tsang and Chan (2000), training should be provided even before TPM is implemented on the shop floor. Training and educational issues has become one of the critical factors to establish successful TPM implementation, where proper education begins as early as during TPM introduction and initial preparation stage (Blanchard, 1997). Training and education provide the necessary skill, knowledge and the ability to make it happen (Saylor, 1992). Wiremen (1991) also emphasized on training to improve the skills of the people involved in TPM and have classified it into two major components. One is soft skill training, such as how to work as teams, diversity training and communication skills. The second is technical training, which ensures that the employees have the technical knowledge to make improvements to the equipments (Wiremen, 1991).

In order to evaluate the extent of TPM implementation elements in electrical and electronics industries in Malaysia, a five point Likert scale will be used in this study (Rating mechanism: 1 – no emphasis at all, 2 – very little emphasis, 3- some emphasis, 4 – reasonable emphasis, 5 – extensive emphasis).

### **3.1.2 Manufacturing Performance Dimensions**

The success of a TPM implementation program does not only depend on a formal implementation of various TPM initiatives in the organization but also requires ensuring the laid out programs are moving in the right direction and quantifiable benefits and results can be derived as result of the implementation of TPM (Ahuja and Khamba, 2008). Shingo (2007) said that people's attitude and behavior (regarding TPM) will not change until they see the results and benefits of TPM implementation. When people's thinking change, defects and breakdowns starts to be seen as something to be ashamed of and when people's behavior change, they strive to make improvements and manage their work more carefully (Shingo, 2007). In this paper, the four basic dimensions of plant manufacturing performance that are going to be studied are as follows (Skinner, 1969; Schroeder, 1993; Ward et al., 1995):

- i. Cost (C1)
- ii. Quality (C2)
- iii. Delivery (C3)
- iv. Productivity (C4)

Cost is indicated by manufacturing cost like unit costs, material and overhead cost and also inventory cost. Manufacturing cost is measured by the manufacturing cost of goods sold as a percentage of sales. The measurement of inventory cost include inventory turnover ratio where a high turnover ratio indicates a low cost position. Quality is measured as a percentage of good products that are produced according to specifications. Manufacturing quality priority can also be measured by degree of emphasis on activities to reduce defect rates, improve vendor quality, improve product performance and reliability, or activities related to achieving an international quality standard, such as, ISO 9000. Delivery performance measures include emphasis on activities intended to increase either delivery reliability or delivery speed or percentage of orders delivered on time. Finally, productivity measures include improved machine efficiency, availability and reliability; reducing inputs such as capital and material while increasing output of finished goods produced.

In order to evaluate the manufacturing performance dimensions accrued as a result of effective emphasis of TPM implementation, a five point Likert scale will be used in this study (Rating mechanism: 1 – no correlation at all, 2 – nominal impact, 3- some impact, 4 – reasonable impact, 5 – extensive impact/correlation).

## **4.0 SURVEY RESULTS AND DISCUSSION**

### **4.1 General Profile of Respondent**

The first aspect analyzed is the general profile of the respondents. One of the important information is the breakdown of respondents based on the size of the companies which is shown in Table 1. This is important because the differences in TPM strategies between small and medium industry and large industry in Malaysia will be studied later. A large portion (76.7 %) of the respondents is from large sized companies which comprise of more than 150 employees. Large companies typically consist of two categories (151 to 1000 employees which is about 20 % and companies with more than 1000 employees is 56.7 %). Next, 13.3 % of the respondents comprise of medium size companies having 51 to 150 employees and small companies with less than 50 employees constituted 10 %. Thus, small medium enterprise or also known as SMEs represents 23.3 % of total percentage of respondents while the remaining 76.7 % are large industries. The definition of SME is in accordance with that given by SME Corporation.

Table 1: Breakdown of respondent in terms of their size of industry

Size of company (No of employees)	No of respondent	Percent (%)	Percent (%)
Small (50 or less)	3	10.0	23.3
Medium (51 to 150)	4	13.3	
Large (151 to 1000)	6	20.0	76.7
Large (More than 1000)	17	56.7	
Total	30	100.0	100.0

The second aspect analyzed in this study is the type of industry which comprised of two types; electrical and electronics industry. Table 2 shows the breakdown of respondent based on the type of industry. 63.3 % of the respondents were from the electronics industry while 36.7 % were from the electrical industry.

Table 2 : Breakdown of respondent based on types of industry

Industry	Frequency	Percent (%)
Electronic	19	63.3
Electrical	11	36.7
Total	30	100.0

An important criterion in determining the state of Total Productive Maintenance (TPM) in Malaysian companies is through the number of years of TPM implementation. It also indicates the experience and maturity of the companies in TPM application. 16.7 % of the total respondents have never implemented TPM before while 10 % have implemented TPM but there have been a relapse due to various reasons. 30 % of respondents are in the introductory phase of TPM with less than 3 years of implementation while 6.7 % are in the stabilization phase of TPM between 3 to 5 years of implementation. A large portion (36.7 %) of the respondents has long experiences with TPM having more than 5 years of TPM implementation.

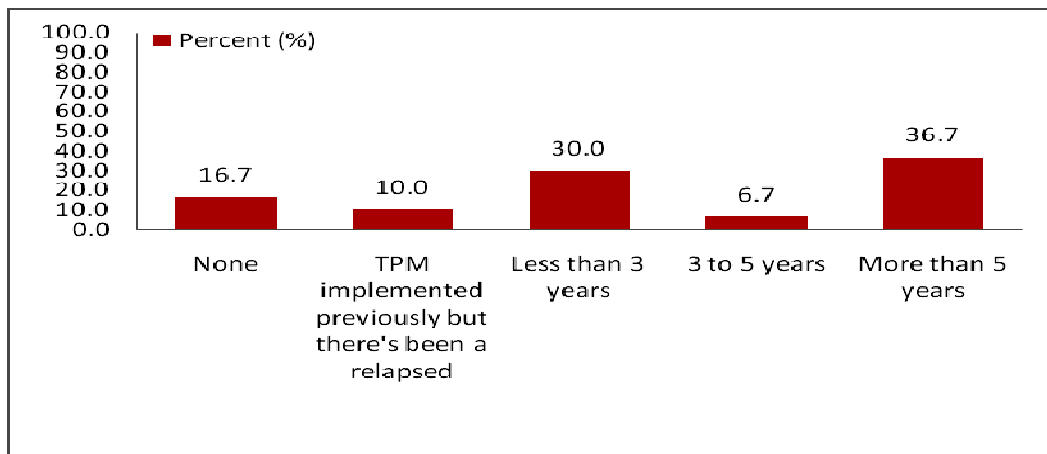


Figure 2 : Number of years of TPM implementation

#### 4.2 Reliability Test

Reliability analysis or also known as internal consistency was performed to assess the reliability of the measurements (nine constructs) depicting the degree to which they



indicate a common latent (unobserved) construct. It relates to the extent to which an experiment, test or any measuring procedure yields the same results on repeated trials (Cramer, 1998). Cronbach's Alpha ( $\alpha$ ) is commonly used for this purpose, where values of alpha range from between 0 and 1.0, with higher values indicating higher reliability. Thus, Cronbach's Alpha values for the various categories of TPM elements/strategies and manufacturing performance dimensions were calculated to ascertain the reliability of the input and output data collected from the survey questionnaire.

The alpha values range from 0.777 to 0.962, which indicates an internal consistency with the alpha value of more than 0.70, so no item was dropped from each variable. These also indicate the significantly high reliability of data for various inputs and output categories and are a reliable measure of construct.

### **4.3 Validity Test**

Construct validity is used to measure that the factor or items in question are really able to measure the underlying construct that it is designed to measure. For this study, the validity of the factors for each TPM elements will be tested using confirmatory factor analysis approach (Bagozzi, 1980). Factor analysis is used for structure detection to examine underlying (or latent) relationship between the variables. The factor analysis test used is the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) which indicates the proportion of variance in the variables that might be caused by underlying factors and for construct validity. For KMO test, high values (close to 1.0) generally indicate that a factor analysis may be useful with the data. If the value is less than 0.50, the results of the factor analysis probably won't be very useful. Kaiser (1974) also recommends either to collect more data or to exclude certain variables if the value is below 0.5. For this study, the KMO values for each factors range from 0.705 to 0.886 which were considered satisfactory.

Principal component analysis was also performed and items that do not load into a single factor will be eliminated and analysis re-performed. The Eigen value of each factor loading is considered satisfactory if they are greater than 1.0 and acceptable if they are greater than 0.5 (Nunnally, 1978). All factor loadings greater than 0.5 is also acceptable (Nunnally, 1978). All the factor's Eigen values were more than 1.0 while the lowest factor loading for all factors is 0.682 which is higher than the minimum acceptable value of 0.5. Thus, both analyses confirmed that the survey instrument has construct validity.

### **4.4 Level of Emphasis of TPM Elements/Strategies**

After studying the background of the respondents and performing analyses on the reliability of the results, the next part analyses the level of emphasis of TPM elements or strategies, which is the core of this survey. To further understand this, a summary of the mean values for each TPM elements were calculated as shown in Table 3, where higher value indicates a higher level of emphasis.

Table 3: The mean of TPM elements/strategies

<b>Factor</b>	<b>TPM elements / strategies</b>	<b>Overall mean</b>	<b>Std Dev</b>	<b>Rank</b>
B1	Top management leadership	2.962	1.205	5
B2.1	Planned maintenance management	3.577	0.968	1
B2.2	Focussed improvement	3.507	1.263	2
B3.1	Autonomous maintenance	3.448	1.157	3
B3.2	Education and training	3.187	1.184	4
Average Mean		3.336		

The mean score for each TPM elements ranges from 2.962 and 3.577 and the variability of each construct is almost similar to one another. From the table, the TPM element which has the most emphasis by manufacturing companies in Malaysia is planned maintenance management with the highest overall mean value of 3.577 while the least emphasis is top management leadership with mean value of 2.962. This is consistent with case studies done by Sim and Yusof (2003), Shamsuddin et al. (2004) and Cheng (2005) which shows that companies in Malaysia have at least a basic traditional planned maintenance schedule and activities. Furthermore, the ability of an organization to conduct basic maintenance activities effectively in an organized and efficient way will determine the success of a TPM implementation program (Ahuja and Khamba, 2008).

TPM implementation requires a long term commitment to achieve the benefits of improved equipment effectiveness (Sim and Yusof, 2003). The pursuit of sustainable TPM requires a change of employees' attitude which takes time to accomplish (Tsang and Chan, 2000). This could explain the lower emphasis of top management leadership in Malaysian companies who could perhaps been expecting instant and companywide gains after implementing TPM. This could also account for 10 percent of the respondents who had actually implemented TPM previously but there has been a relapsed in implementation.

Some of the respondents also placed emphasis on other TPM element which is not part of the five construct such as Safety, Health and Environment (SHE). Elements like SHE comes with the implementation of the five TPM elements covered in the survey. Shingo (2007) states that during step 1 of autonomous maintenance (B3.1), safety problems are identified together with other problems. Planned maintenance aims to eliminate unexpected breakdown which indirectly improves safety because equipment problems often lead to accidents, which are often due to operator's lack of experience in dealing with abnormalities or carrying non-routine tasks (Shingo, 2007). Overall, the respondent companies places "moderate to intensive" emphasis on the TPM elements/strategies with an average mean of 3.336

**4.5 Evaluation of TPM Elements and Manufacturing Performance**

**4.5.1 Relationship between Factors**

Based on the responses, an assessment has been made of the relationship between various TPM element emphases and their contribution towards different manufacturing performance dimension. To show this relationship, the bivariate correlation procedure is used to compute Pearson's correlation coefficient between various TPM element emphasis and manufacturing performance dimension as shown in Table 4. It is useful to determine the strength and direction of association between two scale variables. In this case, Pearson correlation is worked out to define significant TPM element contributing towards realisation of different manufacturing performance. Only pairs that are statistically significant at 1 percent level of significance are considered to have strong association with one another.

Table 4 : Pearson's correlation between various TPM elements and manufacturing performance dimension

	<b>C1</b>	<b>C2</b>	<b>C3</b>	<b>C4</b>
<b>B1</b>	0.691**	0.492**	0.302	0.483**
<b>B2.1</b>	0.482**	0.740**	0.408	0.678**
<b>B2.2</b>	0.393	0.769**	0.474**	0.727**
<b>B3.1</b>	0.707**	0.440	0.32	0.372
<b>B3.2</b>	0.648**	0.643**	0.559**	0.619**

Note: \*\*Correlation is significant at 0.01 level (two-tailed)

Where:

B1: Top management leadership	C1: Cost
B2.1: Planned maintenance management	C2: Quality
B2.2: Focused improvement	C3: Delivery
B3.1: Autonomous maintenance	C4: Productivity
B3.2: Education and training	

#### **4.5.2 Relationship between TPM Element Emphasis and Manufacturing Performance**

The Pearson's correlation results show that there exist significant association between various TPM elements and their contribution towards manufacturing performance. Top management leadership, commitment, organization structure and motivational initiatives (B1) is essential towards contributing to manufacturing performance of an organization in terms of overall cost saving (C1), high quality products (C2) and even increased productivity of the plant (C4). Top Management plays a crucial role in supporting the necessary techniques and providing advice and guidance in altering processes (Bosman, 2000). Thus, only commitment by top management can ensure the success of TPM implementation which will lead the organization to reap the benefits that come with it.

Next, the results also show similar pattern with planned maintenance management (B2.1) having significant contribution towards improving manufacturing performance by lowering cost (C1), high levels of quality (C2) and increased productivity (C4). The objective of Planned Maintenance is to establish and maintain optimal equipment and process conditions (Suzuki, 1994). As defined by JIPM, devising a planned maintenance system means raising output (no failures, no defects) which reduces product cost, as well as improved quality of product and increasing plant availability (machine availability) which indirectly affects productivity.

Focused Improvement (B2.2) on the other hand, shows significant relationship with improving quality (C2), strong delivery performance (C3) and high level of productivity (C4). This is due to the objective of Focused Improvement which is zero losses. Maximizing equipment effectiveness requires the complete elimination of failures, defects, and other negative phenomena – in other words, the wastes and losses incurred in equipment operation (Nakajima, 1989). Education and training (B3.2) also shows significant impact on all four manufacturing performance dimension in terms of cost (C1), quality (C2), delivery (C3) and productivity (C4). The objective of Training and Education is to create and sustain skilled operators able to effectively execute the practices and methodologies established within the other TPM pillars (Leflar, 2003). It also enables the upgrading and expanding of employees' technical, problem solving and team working skills (Tsang and Chang, 2003). Only by improving the workforce in the organization, would we see improvement in manufacturing performance of the organization. Training and Education focuses on establishing appropriate and effective training methods, creating the infrastructure for training, and proliferating the learning and knowledge of the other TPM pillars. Training and Education may be the most critical of all TPM pillars for sustaining the TPM program in the long-term. A test of TPM success is to look at organizational learning, TPM is about continual learning (Leflar, 2003).

However, Autonomous Maintenance (B3.1) shows only one significant contribution towards manufacturing performance which is cost (C1). This is to be expected because the benefits of autonomous maintenance are more intangible than tangible. Suzuki (1994) defined some of the intangible results due to autonomous maintenance which include self-management of shop-floor workers, improved confidence of production workers, clean up of production and administrative areas, and improved company image for customers. Autonomous maintenance also brings a higher level of

shop floor employee involvement (team activities) in improvement activity, and greater employee empowerment (Ames, 2003). For example, it is hard to assess the tangible value of 5S activity (an autonomous maintenance tool) even though it is a valuable and critical part of TPM process. This is because the activities are not centred on results, but rather emphasize people's behavioural patterns, such as the elimination of unnecessary items from the work environment or the cleaning and arranging of equipment. Consequently, the activities make quantitative assessment of their effectiveness difficult (Takahashi and Osada, 1990).

Results have shown the each of the five TPM elements have strong association with the improvement of manufacturing performance such as lower costs, higher quality levels, faster delivery and increased productivity. Some element like autonomous maintenance show more intangible rather than tangible benefits which is also important to the organization as a whole. Thus, all of the five TPM elements have to be emphasized and not neglected in order to reap the benefits of a successful TPM implementation program. Since implementing TPM is a strategic decision and mistakes cannot be made by managers, these five elements can act as a guideline for organization wanting to implement TPM. This will ensure that all important areas are covered and there is a standard structured implementation process during the TPM implementation phase. At the same time, the improvement of manufacturing performance or the benefits of TPM implementation must be recognised by the organization (Robinson and Ginder, 1995; Cooke, 2000). According to Robinson and Ginder (1995), for TPM to be successful, "the improvement process must be recognized as benefiting both the company and the worker" It is important to identify the critical elements of TPM and their impact on manufacturing performance because many companies fail to invest in maintenance programs because they manage maintenance by a budget and fail to see the strategic implication of a strong maintenance program (Kathleen et al., 1999). Thus, this study could act as evidence to convince management the importance of TPM implementation towards the organization.

#### **4.6 Inferences on the Differences in Mean**

##### **4.6.1 Differences of TPM Element Practices between Electrical and Electronic Industry**

The first hypothesis test is done to find out if there are any significant differences of TPM elements practices between electrical and electronics industry. This analysis used a comparison t test to compare the mean between the samples. The first hypotheses are as follows:

$H_0: \mu_{\text{electrical}} = \mu_{\text{electronics}}$ ; i.e. there is no significant difference of each TPM element emphasis between electrical and electronics industry

$H_1: \mu_{\text{electrical}} \neq \mu_{\text{electronics}}$ ; i.e. there is significant difference of each TPM element emphasis between electrical and electronics industry

The null hypothesis assumes the two sets of scores (electrical and electronics) are samples from the same population and therefore the two samples do not differ significantly from each other because the sampling was random. However, the alternative hypothesis states that the two sets of score differ significantly.

The results of the t test can be seen in Table 5 which shows the p value for all TPM elements were more than 0.05. Therefore, the null hypothesis cannot be rejected at 0.05 significant level; indicating that there is no significant differences of TPM element practices between electrical and electronic industry. This is consistent with the study done by Kathleen et al. (1999) that the type of industry studied (electronic, machinery and automobile) did not provide a significant factor in the use of TPM practices. While the

country factor provides some explanation for differences in TPM implementation, there is insufficient evidence to link the adoption of TPM to specific industries (Kathleen et al., 1999).

**4.6.2 Differences of TPM Element Practices between SMEs and Large Companies**

The second hypothesis test aims to compare whether there are significant differences of TPM element practices between SMEs and large companies using the same comparison test. The second hypotheses are as follows:

$H_0: \mu_{SME} = \mu_{Large}$ ; i.e. there is no significant difference between SME practices (on each TPM elements) and those of large companies

$H_1: \mu_{SME} \neq \mu_{Large}$ ; i.e. there is significant difference between SME practices (on each TPM elements) and those of large companies

Table 5 : t test results between electrical and electronic industry

Factor	TPM elements / strategies	$\mu_{electrical}$	$\mu_{electronic}$	p value	Results
B1	Top management leadership	2.818	3.046	0.627	Not Sig.
B2.1	Planned maintenance management	3.425	3.667	0.457	Not Sig.
B2.2	Focussed improvement	3.236	3.663	0.325	Not Sig.
B3.1	Autonomous maintenance	3.208	3.587	0.326	Not Sig.
B3.2	Education and training	2.909	3.347	0.186	Not Sig.

The null hypothesis assumes that the mean scores of SME and large companies do not differ significantly from each other while the alternative hypothesis states the opposite. From the results shown in Table 6, the null hypothesis at significant level of 0.05 cannot be rejected for key factors like planned maintenance management, focused improvement and autonomous maintenance while there is evidence to reject the null hypothesis for factors like top management leadership and education and training. Thus, there are significant differences between SME practices and those of large company in TPM elements such as top management leadership and also education and training. However, in areas like planned maintenance management, focused improvement and autonomous maintenance there is no difference in practice between SME and large companies.

Table 6 : Comparison of TPM element practices between SMEs and large companies

Factor	TPM elements / strategies	$\mu_{SME}$	$\mu_{Large}$	p value	Results
B1	Top management leadership	2.226	3.124	0.005	Sig.
B2.1	Planned maintenance management	3.380	3.639	0.487	Not Sig.
B2.2	Focused improvement	2.829	3.713	0.067	Not Sig.
B3.1	Autonomous maintenance	3.041	3.572	0.225	Not Sig.
B3.2	Education and training	2.457	3.409	0.008	Sig.

TPM elements such as top management leadership and education and training are more advanced in large companies compared to SMEs because of their larger resources and manpower. SMEs have a shortage of necessary learned manpower (Nwankwo, 2000)

and also run under very constrained funding (Gustafsson et al., 2001). Other limitations of SMEs include lack of managerial knowledge and thus lack of clear vision of what training is really required, lack of resources or facilities in carrying out an effective training program or maintaining a training wing in the organization, difficult to afford absence of employees from the workplace for training as there is a poor scope for substitution and lack of space within the organization and shortage of funds to be allocated for adequate training (Shamsuddin et al., 2004).

The results to a certain extent contradict with the results of a study done by Kathleen et al. (1999) where, some of the organizational factors (size of company) were not significant and some were in terms of explaining differences in TPM implementation. Those results suggest that the state of organization's resources may not limit a company's ability to implement TPM and small plants as well as large plant can implement TPM (Kathleen et al., 1999). As Shiba et al. (1993) suggest the real issue is not on the organizational factor but whether or not the workforce is open to making changes that are required by TPM.

**4.7 Effect of TPM Implementation Time Period on Manufacturing Performance Dimension**

In order to study the effect of the time period of TPM implementation on manufacturing performance of the organization, the responses obtained from the survey is divided into three categories depending on the experience each organization has over time period as shown in Table 7.

Table 7 : Classification of responses based on TPM implementation time period

Categories	Time period of TPM implementation	Number of response (N)
Phase 1	Companies in this category consist of those which have not implemented TPM and also companies that have previously implemented TPM but there has been a relapse due to various reasons.	8
Phase 2	Less than three years of TPM implementation. Introductory phase	9
Phase 3	Comprises of those companies who have implemented TPM between three to five years (Stabilization phase) and also those more than five years (Maturity phase)	13

Next, the average mean and standard deviations of various manufacturing performance dimension from effective implementation of TPM is shown in Table 8. From the table, it is observed that the average mean value for manufacturing performance dimension in Phase 2 is higher than those obtained in Phase 1 while the mean value for manufacturing performance dimension in Phase 3 is higher than those in Phase 2. This means that the longer the organization implements TPM, the more benefits in manufacturing performance can be realized. Improvement in manufacturing performance can be observed when TPM is implemented over a long period of TPM implementation.

Table 8 : Results of manufacturing performance dimension over TPM implementation time period

Factor	Manufacturing Performance Dimension	Phase 1		Phase 2		Phase 3	
		N = 8		N = 9		N = 13	
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
C1	Cost	2.792	1.301	3.556	1.182	3.821	1.245
C2	Quality	3.438	0.863	4.167	0.823	4.269	0.854
C3	Delivery	3.500	0.927	2.963	1.171	3.410	1.151
C4	Productivity	3.625	0.937	3.722	0.982	4.231	0.941
	Average mean	3.339		3.602		3.933	

This finding is agreed upon by Robinson and Ginder (1995) who state that TPM is a long-term strategic initiative rather than a short-term tactical fix. It will fail if a ‘program of the month’ mentality exists. The study done by Ahuja and Khamba (2008) also revealed that TPM implementation program does not yield overnight success but takes appropriate planning and focused plan assisted by top management through organizational cultural improvement, over a considerable period of time (usually three to five years) to realize significant results from holistic TPM implementation program. For the most part, TPM is a long-term process, not a quick fix for today’s problems. This seems to be an important attitude to hold, because results are not immediate. To see the full benefits of TPM, it appears that organizations need to make a continued commitment to the possibilities and philosophy espoused by TPM methodology (Horner, 1996). TPM is not a short term fix, but a long, never-ending journey to best in class factory performance through: on-going management commitment, increased employee responsibilities, and continuous improvement to achieve goals of TPM (Max International Engineering Group, 2004).

## 5.0 CONCLUSIONS

This study has presented the results of the survey conducted on Malaysian electrical and electronic industry to evaluate TPM elements/strategies and their contribution towards various manufacturing performance dimensions. From the results and discussion, the TPM element given the most emphasis is planned maintenance management while the least emphasis is top management leadership. Overall, all TPM elements score is between moderate to high in terms of implementation.

This study has investigated the contribution of TPM elements/strategies towards manufacturing performance dimensions in electrical and electronic industry in Malaysia. For this purpose, five TPM elements and four manufacturing performance dimensions have been categorized after exhaustive literature review. The empirical evidence has also been presented to support the relationship between various TPM elements and manufacturing performance. Findings show that these TPM elements are important to manufacturing organization in term of lowering cost, improving quality products, on-time delivery and increased productive levels. Thus, it can be concluded that all five TPM elements which are top management leadership, planned maintenance management, focused improvement, autonomous maintenance and education and training are equally important and need to be placed equal emphasis in order to achieve the benefits in manufacturing performance. These elements can be a sound platform or benchmark for organization that have plans to implement TPM in their plant. In this way, nothing is left out and there would be a structured approach in TPM implementation which is essential for a successful TPM implementation program.

This study also found that there is no difference of TPM elements practices between electrical and electronic industry in Malaysia. Therefore, these TPM elements are generic in nature and may be applied uniformly to different types of industries. However, there are significant difference of some TPM elements practices between SMEs and large companies in areas such as top management leadership and education and training but no differences in other areas like planned maintenance, focused improvement and autonomous maintenance. This might suggest that while resources may not limit TPM implementation and small and large companies could implement TPM, the extend of top management input and education/training may be limited due to limited resources. In addition, TPM implementation must be deployed for a longer period of time between 3 to 5 years and more to see increased improvement in manufacturing performance.

## REFERENCES

1. Ahmed, S.M. & Hassan, M. (2003). Survey and case investigations on application of quality management tools and techniques in SMIs. *International Journal of Quality & Reliability Management*, Vol. 20, No. 7, pp. 795-826
2. Ahuja, I.P.S., Singh, T.P., Sushil and Wadood, A., (2004). "Total productive maintenance implementation at Tata Steel for achieving core competitiveness", *Productivity*, Vol.45 No. 3, pp.426-6.
3. Ahuja, I.P.S. and Khamba, J.S. (2007). "An evaluation of TPM initiatives in Indian industry for enhance manufacturing performance", *Journal in Quality in Maintenance Engineering*, Vol. 13 No. 4, pp 338-52.
4. Ahuja, I.P.S. and Khamba, J.S. (2008). "Justification of total productive maintenance in Indian manufacturing industry for achieving core competitiveness", *Journal in Manufacturing Technology Management*, Vol. 19 No. 5, pp 645-669.
5. Ahuja, I.P.S. and Pankaj Kumar. (2009). A case study of total productive maintenance implementation at precision tube mills, *Journal of Quality in Maintenance*, Vol 15 No.3, pp.241-258.
6. Ames, V. A., (2003). "TPM Interview. T. Pomorski", Austin, Tx.
7. Bamber, C.J., Sharp, J.M and Hides, M.T., (1999) 'Factors affecting successful implementation of Total Productive Maintenance: a UK manufacturing case study perspective', *Journal of Quality in Maintenance Engineering*, Vol. 5, No. 3, pp 162-181.
8. Bargozi, R. P., (1980). *Casual Models in Marketing*. Wiley, New York, NY.
9. Blanchard, B. S. (1997). An enhanced approach for implementing total productive maintenance in a manufacturing environment, *Journal of Quality in Maintenance Engineering*, Vol. 3 No. 2, pp 13-16.
10. Bosman, H. (2000). "TPM Activities Toward Winning the World Class Award." *JIPM TPM* **16**: 4-7.
11. Cheng, Choon Ho .(2005). "Proposal for TPM in a process industry", Call No. TS192 C43 2005, Skudai: University Technology Malaysia
12. Cooke, F. L., (2000) "Implementing TPM in plant maintenance: some organizational barriers", *International Journal of Quality and Reliability Management*, Vol. 17 No. 9, pp. 1003-16.
13. Cramer, D. (1998) "Fundamental Statistics for Social Research" (London, Routledge)
14. Gustafsson, R., Klefsjo, B., Berggren, E. and Granfors-Wellemets, U. (2001), "Experiences from implementing ISO 9000 in small enterprises – a study of Swedish organization", *The Quality Magazine*, Vol. 13 No. 4, pp. 232-46
15. Herbaty, F. (1990), *Handbook of Maintenance Management: Cost Effective Practices*, 2<sup>nd</sup> ed., Noyes Publication, Park Ridge, NJ.



16. Horner, M., (1996) Analysis of Total Productive Manufacturing Teams in Semiconductor Manufacturing Organization, University of North Texas, Denton, TX.
17. Ireland, F and Dale, B.G., (2001). 'A study of total productive maintenance implementation', Journal of Quality in Maintenance Engineering, Vol. 7 No. 3, pp. 183-191
18. Jusoh, A., R. Z., Yusoff and S., Mohtar, (2008). "Determining TQM practices in university R&D activities using factor analysis: Research experience of Malaysian universities" Jurnal Kemanusiaan, 11 (1), pp. 36-54.
19. Kathleen, E. Mc. K., Roger G.S and Kritiy O.C. (1999) 'Total productive maintenance: a contextual view', Journal of Operation Management, Vol 17, pp. 123-144.
20. Kathleen, E. Mc. K., Roger G.S and Kritiy O.C. (2001). The impact of total productive maintenance practices on manufacturing performance, Journal of Operation Management, Vol 19, pp. 39-58.
21. Leflar, J. (1999), TPM at Hewlett-Packard. 10th Total Productive Maintenance Conference, Las Vegas, NV, Productivity, Inc.
22. Leflar, J. (2003). TPM Interview. T. Pomorski. Fort Collins, CO
23. Luxford, G. (1998) 'Measurement of overall equipment effectiveness as a basic for TPM activities', International Journal of Operations and Production Management, Vol. 18, No. 5, pp. 495-507.
24. Lycke, L., (2000). Team development when implementing TPM, Total Quality Management, Vol. 14 No. 2, pp. 205-13.
25. Pai, K. G. (1997), "Maintenance Management", Maintenance Journal, October-December, pp. 8-12
26. Patterson, J. W., Kennedy, W. J and Fredendall, L. D., (1996) "Total productive maintenance is not for this company," Production and Inventory Management Journal, 36 (2), pp. 61-64
27. Maier, F. H., Milling, P. M. and Hasenpusch, J., (1998) "Total Productive Maintenance: An International Analysis of Implementation and Performance."
28. Max International Group. (2004). *Total productive maintenance*. Available online at: <http://www.maxiege.com/operational6.htm>
29. MIDA. (2004). Business opportunities in Malaysia's electronic industry, Published by the Electronics Industry Division and ICT & Electrical Industries Division, Website: <http://www.mida.gov.my>
30. Mishra, R.P., Anand, G. and Kodali, R. (2008). A SWOT analysis of total productive maintenance frameworks, Int. J. Management Practice, Vol. 3, No. 1, pp. 51-81.
31. Nakajima, Seiichi. (1989). *Introduction to TPM*. Cambridge, Mass.: Productivity Press.
32. Nunnally, J. C. (1978). Psychometric theory (2nd ed.). New York: McGraw-Hill.
33. Nwankwo, S. (2000), "Quality assurance in small organizations: myths and realities", International Journal of Quality & Reliability Management, Vol. 17 No. 1, pp. 82-99.
34. Raouf, A. and Ben-Daya, M. (1995) "Total maintenance management: a systematic approach", Journal of Quality in Maintenance Engineering, Vol. 1 No. 1, pp. 6-14.
35. Robinson, C. J. and A. P. Ginder., (1995) "Implementing TPM: The North American Experience", Portland, OR, Productivity Press.
36. Sangameshwaran, P and Jagannathan, R. (2002). Eight Pillars of TPM, Indian Management, Vol. 1, pp. 3-67.
37. Saylor, J.H. (1992). *TQM Field Manuals*, New York, McGraw-Hill
38. Schroeder, R. G., (1993) "Operation management, Decision Making in the

- Operation Function”, 4<sup>th</sup> edn. McGraw-Hill, New York
39. Shamsuddin A., Masjuki, Hj.H, and Zahari, T. (2004) “State of implementation of TPM in SMIs: a survey study in Malaysia’, *Journal of Quality in Maintenance Engineering*. Vol. 10, No. 2, pp. 93-106
  40. Shamsuddin, A., Hassan, M.H. and Taha, Z. (2005) “TPM can go beyond maintenance: expert from a case implementation”, *Journal of Quality in Maintenance Engineering*, Vol. 11 No. 1, pp.19-42.
  41. Shiba, S., Graham, A., Walden, D., (1993). *A New American TQM: Four Practical Revolutions in Management*. Productivity Press, Cambridge, MA
  42. Shingo Nakamura, (2007). *TPM in semiconductor plants*, JIPM-Solutions
  43. Sim, H.K and Shari Mohd Yusof. (2003). Development of TPM implementation plan in switchgear and engineering company, *International Conference on Mechanical Engineering (ICME2003)*, Dhaka, Bangladesh.
  44. Skinner, W., (1969) “Manufacturing – missing link in corporate strategy,” *Harvard Business Review* 47 (3), 136-145
  45. Suzuki, T. (1994). *TPM in Process Industries*, Productivity Press, Portland, OR
  46. Takahashi, Y. and T. Osada. (1990). *TPM: Total Productive Maintenance*. Tokyo, Asian Productivity Organization.
  47. Tajiri, M. and F. Gotoh., (1992). “TPM Implementation - A Japanese Approach”, New York, McGraw Hill.
  48. Takahashi, Y. and T. Osada. (1990). *TPM: Total Productive Maintenance*. Tokyo, Asian Productivity Organization.
  49. Telang, A. D. (1998), “Preventive maintenance”, in Vijaykumar, K. (Ed.), *Proceeding of the National Conference on Maintenance and Condition Monitoring, February 14*, Government Engineering College, Thissur, India, Institution of Engineers, Cochin Local Centre, pp. 160-73
  50. TPM Club India. (2003). The TPM 8 pillars. Available online at: [www.tpmclubindia.org](http://www.tpmclubindia.org)
  51. Tsang, A.H.C. and Chan, P.K. (2000) ‘TPM implementation in China: a case study’, *International Journal of Quality & Reliability Management*, Vol. 17 No. 2, pp. 144-157.
  52. Volvo Cars Gent (1998) *TPM pillars*. Available online at: [http://www.volvocarsgent.be/content\\_en/g/g2.htm](http://www.volvocarsgent.be/content_en/g/g2.htm)
  53. Ward, P.T., Duray, R., Leong, G.K., Sum, C.C. (1995). Business environment, operations strategy and performance: an empirical study of Singapore manufacturers. *Journal of Operations Management* 13, 99–115.
  54. Williamson, Robert, M., (2006) “Total Productive Maintenance: What It Is and What It Is Not”, Strategic Work Systems, Inc. Columbus, NC 28722
  55. Willmott, P., (1994). *Total Productive Maintenance: The Western Way*. Oxford, England, Butterworth- Heinemann, LTD
  56. Wireman, T., (1991) “Total Productive Maintenance - An American Approach”, New York, Industrial Press
  57. Yamashina, H. (2000). Challenge to world-class manufacturing. *International Journal of Quality & Reliability Management*, Vol. 17 No 2, pp. 132-143
  58. Yeomans, M. and Millington, P. (1997) ‘Getting maintenance into TPM’, *Manufacturing Engineer*, Vol. 76, No. 4, pp.170–173