

Change Management and Implementation of Total Productive Maintenance: An Exploratory Study of Malaysian Manufacturing Companies

T. Ramayah
Muhamad Jantan
Mohd Mustapha Hassan

This study examines the effects of change management towards the implementation of productivity and quality improvement programs through the concept of Total Productive Maintenance (TPM), in manufacturing firms in Malaysia. The factors measured are management commitment, training and education, employee empowerment, team culture and company policies and goals for change management. Autonomous maintenance and planned maintenance factors were used to measure TPM. The findings of the study provide empirical evidence that change management factors significantly enhances the extent of TPM implementation.

Keywords: Total Productive Maintenance, planned maintenance, autonomous maintenance, change management, overall equipment efficiency

Kata Kunci: Penyelenggaraan Produktif Menyeluruh, penyelenggaraan terancang, penyelenggaraan sendiri, pengurusan perubahan, kecekapan kelengkapan menyeluruh

Introduction

Although total quality management (TQM) is widely adopted by many firms in their effort to increase organizational capabilities, the payoffs from this program have often been limited because of unreliable or inflexible equipment (Tajiri & Gotoh, 1992). Therefore, it is important to include the maintenance management into the totality concept. Typically, managers perceive maintenance as a low status activity, and treat maintenance as a cost generator. They do not realize the great potential of a well performing maintenance (Ollila & Malmipuro, 1999). A lot of studies and researches conducted by academicians and practitioners, has shown that maintenance has a direct impact on productivity and quality (Nakajima, 1988; Tsuchiya, 1992).

Change Management

Total Productive Maintenance (TPM)

In the old-fashioned maintenance (American-style) it was the "I operate, you fix" concept, where operators merely operate the machine and maintenance is the domain of the maintenance department. Although the United States was the pioneer in the development of preventive and productive maintenance, but due to the determination of the Japanese manufacturers to compete in the world market after the World War II, they imported these ideas to improve their equipment maintenance.

The "I operate-you fix" concept prevailed until the TPM or total productive maintenance was first developed at Nippondenso (one of the automobile part supplier for Toyota) in Japan in 1969 with total employees participation (Nakajima, 1989). The word "total" in "total productive maintenance" has three meanings related to three important features of TPM (Nakajima, 1989). The first will be the "total effectiveness" in the pursuit of economic efficiency or profitability. Second, "total preventive maintenance" to improve maintainability as well as preventive maintenance. Finally the total also means "total participation" where machine operators are involved in the autonomous maintenance and the activities of small groups in every department and at every level.

TPM represents a major shift in the way an organization approaches the maintenance function; from being the responsibility of the maintenance department to being everyone's responsibility. TPM is designed to maximize equipment effectiveness by establishing a comprehensive productive maintenance system covering the entire life of the equipment, spanning all equipment-related fields and with participation of all employees from the top management to the shop-floor workers, to promote productive maintenance through motivation management or voluntary small group activities (Tsuchiya, 1992). In maximizing the equipment effectiveness, the following six big losses of equipment effectiveness has to be eliminated or reduced. They are:

- Breakdowns due to equipment failure,
- Setup and adjustment,
- Idling and minor stoppages,
- Reduced speed (than actual speed),
- Defects in process and rework, and
- Reduced yield between machine startup and stable production.

To eliminate these six big losses, it is important that first, attitudes of people have to be changed through motivation, training and also by creating a work environment that is conducive to TPM implementation.

In implementing TPM, a master plan is needed and this has to be formulated, prior to embarking on the program. This master plan needs to be broken down into distinct stages in order to progress. TPM contains short-term and long-term elements, where the short-term elements focus

on the autonomous maintenance for the production department, a planned maintenance program for the maintenance department, followed by skill development for operations and maintenance personnel. The focus of the long-term elements will be is on new equipment design and the elimination of sources of lost equipment time. By properly adhering to the foci, TPM should result into what the Japanese philosophers termed as zero defect, zero downtime, zero accident, and zero waste (Stephens, 1994). This study focuses on short-term maintenance efforts that could be found at the plant level of the organization.

This study focuses on the implementation issues, in particular it will address the question of how managing the change can influence the extent of TPM implementation.

Literature Review

In this competitive age, firms are striving to improve customer's satisfaction and minimize production costs. Traditionally, production costs are minimized by increasing the meantime between failures of the production equipment on the one hand and minimizing maintenance costs on the other (Raouf, 1994). Cutting maintenance costs alone will not help to minimize the production cost, but may lead to ineffectiveness of the production equipment. As such the basic underlying approach of TPM is to maximize production equipment effectiveness, which is typically measured by the OEE (Overall Equipment Effectiveness). An OEE rating may be used to compare different sites within an individual business group, and may influence strategic investment and other important decisions (Mileham et al., 1997). If a company has an OEE of 85% or above, then it is considered to be a world-class company.

Elements of TPM

As mentioned earlier, in this study only the short-term maintenance efforts are considered, as they would normally be found at the plant level of the organization. The short-term maintenance efforts include both autonomous and planned maintenance activities. Short-term maintenance activities were chosen over the long term ones, because the latter, usually focus more on new equipment design and elimination of sources of lost equipment time (McKone et al., 1999) and has to be tracked longitudinally, whereas short-term TPM efforts are focused on the existing equipment maintenance.

Autonomous Maintenance

Maintenance performed by equipment operators is called autonomous maintenance (AM). AM is defined by Nakajima (1989) as deterioration prevention. McKone et al. (1999) defined autonomous maintenance by considering the following four main goals of TPM program.

Change Management

1. Formation of teams – production and maintenance,
2. Joint improvement of the overall health of the equipment by production and maintenance people,
3. Guidance and assistance from the maintenance for the production people on common equipment problems, and
4. Operators involvement.

Planned Maintenance (PM)

Planned maintenance (PM) consists of regular intensive servicing carried out periodically and it could be also regarded as ongoing equipment improvement aimed at eliminating failures and defects (Tsuchiya, 1992). PM involves the work of highly skilled maintenance technicians and is aimed to:

1. Correct minor flaws and abnormalities,
2. Perform periodic measurement and diagnosis,
3. Exchange parts periodically to avoid over exhaustion,
4. Disassemble, inspect and overhaul periodically,
5. Implement improvement,
6. Perform inspection, and
7. Educate (operators and also other technicians).

Change Management

Introducing TPM can be viewed from the perspective of introducing change. Most of the organizational change is triggered by the need to respond to new challenges or opportunities due to external environment, or anticipation of the need to cope with potential future problem. Mullins (1996) described a wide range of forces acting upon organizations and they can be summarized under five broad headings; changing technology, knowledge explosion, rapid product obsolescence, changing nature of the workforce, and quality of work life. Rapid changes of technology shorten the life cycle of the product as well as changes in customer preferences. Changes in family lifestyles and higher education opportunities will definitely have an impact on the nature of the workforce. And finally the change in quality of working life is becoming increasingly important to all as it determines the satisfaction of people's need and expectations at work.

Change management is the process of continually renewing the organization's direction, structure, and capabilities to serve the ever-changing needs of the marketplace, the organization, and employees (Moran & Avergun, 1997). As such management of change will include the creation of an environment where people who are involved and affected by the change can open themselves up to new ideas and concepts, challenge old assumptions, attack new assumptions, and overcome their hostility and resistance to change. Introducing TPM programs in an organization will bring about great changes to the normal way of operation. To successfully implement the change the following must

happen (Moran & Avergun, 1997): people must clearly understand the purpose of the change required, new performance requirements must be clearly stated and understood by the employees, roles and responsibilities must be updated to reflect new performance demands, the organization must have a constant supply of timely and useful information, core processes must be aligned with organizational goals, leaders and employees must have the requisite skills in leadership, creativity, problem solving, continuous improvement, team effectiveness and customer service and the organization's culture must be reshaped in ways that motivate all employees. Thus, managing change must begin with the top management, as many of the above are within the realm of top management responsibilities.

Management Commitment

To Moran and Avergun (1997), change is top-down and bottom-up. It must be top-down to provide vision and create structure; and it must be bottom-up to encourage participation and generate support. Ultimately, leading change is a shared responsibility of everyone in an organization, from top to bottom. To bring in changes, the top management or the change leaders have to prepare themselves to the changes before asking their employees to adopt the changes. Top management or the change champions must be able to create an environment that effectively reduces or eliminate the fear for change. The management also must provide their employees with proper tools, techniques and other facilities to allow people to synthesize the new concepts, and align themselves to the new way of working. Firms must have top management support, understanding and commitment to embark on the TPM program as it involves a cultural change that cannot happen overnight. Hoffman and Mehra (1999) in their study described that the all four scholars; Deming, Juran, Crosby and Garvin, link top management involvement and commitment to both productivity and quality improvement programs.

The commitment at the top must be total, both in terms of level and extent. It must include the full senior management team of the organization and each manager must be fully committed to any initiative or development program (Heap, 1992). The responsibility of the top management is to actively promote motivation, ability and favorable work environment (Nakajima, 1989). Of these three keys, motivation and ability will be the responsibility of the workers and that the creation of favorable work environment will be the responsibility of the management. The management commitment in implementing any productivity or quality improvement program is to provide necessary training to develop a workforce of capable, motivated, and truly autonomous workers.

The second responsibility of the management is to create a favorable work environment by eliminating the psychological and physical obstacles to workers' autonomy in the environment (Nakajima, 1989). Nakajima (1989) quoted in his writing that Ouichi (1981) discovered that a mixture of American and Japanese style of management has led to success in many

Change Management

leading companies in the United States. The distinctive characteristics of the Japanese management techniques are the management commitment to employees, which provided the foundation of mutual trust, concern, and egalitarianism.

Training and Education

Maggard and Rhyne (1992) stated that training and education is crucial to the success of TPM. Training and education is necessary to create a clear understanding of the changes required, the purpose of the change as well as the benefits to be gained out of it. Further, they argued that management must be educated thoroughly because excellence in equipment effectiveness depends on total management commitment for the long term. Training and education also include maintenance personnel training operators to perform routine preventive maintenance tasks, operators training on the mechanics of their equipment, problem skills, and team building.

The importance of training is further highlighted by Turbide (1995) and Moore (1997), who stressed that TPM calls for training people to improve their job skills especially training for the equipment operators. Nakajima (1989), mentioned that, to carry out the TPM activities, a company needs personnel with strong maintenance and equipment-related skills. This is because one of the important goals of TPM is to raise workers' skill levels and this would be only can be done if there is thorough and continuous training.

Employee Empowerment

As organizations undertake change such TQM, JIT (Just In Time) and other radically different programs of excellence, employees must step forward and accept responsibility for every facet of production. As such, the management has to get employees to accept this responsibility by giving the employees the authority to act.

Empowering the employees is one of the elements necessary to ensure success in TPM implementation. Patterson et al. (1995), stated that TPM requires employee empowerment and the attitude that TPM is not a maintenance department's program but it's everyone's program. Under TPM, production workers assume ownership of their work area and become responsible for routine maintenance of machines and equipment. In some organizations, the managers do not trust operators to make any repairs and adjustments on the machine because they feel that the expensive equipment will be damaged. In such cases, the organizations are not ready to implement TPM programs (Patterson et al., 1995).

Team Culture

Patterson et al. (1995), suggested that management must promote and establish a team culture and use these teams to implement the TPM

programs. According to Nakajima (1989), the formed groups should function at every level and across the divisions to accomplish company objectives. These groups must be integrated into the organizational structure. These groups are able to set goals compatible with the higher goals set by the company and achieve them through group cooperation and teamwork. As workers manages their own work autonomously, the management must play a larger part by keeping the employees motivated. According to Nakajima (1989), there are four factors in motivating small group activities are:

- recognizing the importance of work,
- setting and achieve goals,
- acting on workers' suggestions, and
- rewarding workers' efforts.

Company Policies and Goals

TPM combines "top-down" goal-setting by top management with "bottom-up" small group improvement and maintenance activities on the front line (Nakajima, 1989). TPM should be incorporated into the basic company policy by the management, so that the company will encourage the total involvement of their employees.

Klusman (1995) stated that a clear, well thought-out plan supported by appropriate policies is crucial to the successful implementation of a restructured maintenance program. He further highlighted that a high percentage of programs fail or fall short of desired objectives due to poor planning. Klusman outlined four essential elements that need to be considered into plan and policy development. They are, first, the scope which needs to be defined for any system before the implementation of a program. Second is the factors to address and objectives, where the factors need to be addressed are the internal and external, and the objectives which need to factored in are the management objectives.

Theoretical Framework

This study attempts to investigate the impact of company-wide factors on the extent of TPM implementation in various industries. As shown in Figure 1, the dependent variable is the extent of TPM implementation which is measured using autonomous and planned maintenance, while the independent variables are depicted as management commitment, training and education, employee empowerment, team culture and company policies and goals factors, which relates to factors that need to be considered in managing the change.

Change Management

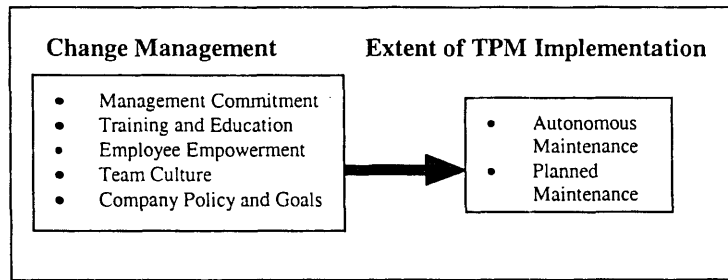


Figure 1: Theoretical Framework

Research Hypotheses

Based on the theoretical framework, the following hypotheses were generated:

- H1: The greater the management commitment in change management, the higher the extent of TPM implementation
- H2: Continuous training and education in change management will lead to higher extent of TPM implementation.
- H3: Employee empowerment in change management will result in higher extent of TPM implementation.
- H4: Creation of team culture in change management will lead to higher extent of TPM implementation.
- H5: Setting new policies and goals in change management will enhance the extent of TPM implementation.

Research Methodology

Measurement of Variables

The dependent variable that is the extent of TPM implementation is measured by the extent of practice in terms of autonomous (Housekeeping – 5S approach, General inspection, Workplace management, Operator involvement) and planned maintenance (Disciplined planning, Information tracking, Schedule compliance). The independent variable (Change Management) is measured by the extent of management commitment, training and education, employee empowerment, team culture, and company policies and goals.

The questions were adapted from previous studies and they are basically of two types; categorical and perceptual. The perceptual questions are measured on five point Likert like scale with 1 (not at all), 2 (to a little extent), 3 (to some extent), 4 (to a great extent) and finally 5 (completely).

Reliability test was carried out using the inter-item internal consistency coefficient (Cronbach α), and these alpha values (tabulated below in Table 1 and 2) were found to exceed 0.7. Thus, this indicates that the measures for the respective measurements are statistically reliable (Nunnally, 1978).

Table 1
Reliability Assessment (Dependent Variable)

| Variables | Total no. of Item | Cronbach α |
|----------------------|-------------------|-------------------|
| Housekeeping | 5 | 0.8462 |
| General Inspection | 5 | 0.8269 |
| Workplace Management | 6 | 0.7953 |
| Discipline Planning | 3 | 0.7733 |
| Information Tracking | 5 | 0.8946 |

Table 2
Reliability Assessment (Independent Variables)

| Variables | Total no. of Item | Cronbach α |
|--------------------------|-------------------|-------------------|
| Management Commitment | 5 | 0.8844 |
| Training & Education | 5 | 0.8937 |
| Employee Empowerment | 4 | 0.8132 |
| Team Culture | 6 | 0.9325 |
| Company Goals & Policies | 5 | 0.9034 |

Population and Sampling

The population consisted of all manufacturing companies in Malaysia, which incorporates both the foreign and local companies located around Sg.Petani and Kulim in Kedah, Bayan Lepas and Prai in Penang, the Klang Valley and also Muar, Johor. A convenience sampling was used, whereby, 200 established organizations were handpicked from a list of about 630 firms throughout the mentioned industrial areas. The firm's addresses were obtained from FMM (Federation of Malaysian Manufacturers) directory of manufacturing companies. Data was collected using mailed questionnaires.

Data Collection and Respondent's Profile

A total of 200 questionnaires was mailed as well as distributed personally, of 80 replied and returned the questionnaires. Unfortunately 11 returned questionnaires were rejected due to significant omissions, making the useable response rate at 34.5%.

A majority (76.8%) was foreign owned companies compared to only 20.3% locals. Of the respondents 45.6% were top management who are ranked from department managers to general managers, while 36.2% were Engineers. The remaining 17.4% were others of the same level. Relating

Change Management

to the size of the responding organizations, 62.3% of the companies employ more than 1000 workers, and 21.7% employs 500 or less employees. They have been in operation for quite some time, with 23.8% of companies has been in operation for more than 10 years but less than 20 years, while those above 20 years amounted to about 25.4%.

Findings

Extent of TPM

The dependent variables that comprise of five components namely housekeeping (5S), general inspection, workplace management, discipline planning and information tracking are meant to measure the extent of the TPM implementation. The descriptive analysis is presented in Table 3.

Table 3
Descriptive Statistics of the Variables

| Dependent Variable | Mean | Standard Deviation |
|-----------------------------|--------|--------------------|
| Housekeeping (5S) | 4.1855 | 0.6538 |
| General Inspection | 3.9797 | 0.6473 |
| Workplace Management | 3.5918 | 0.5495 |
| Discipline Planning | 3.6329 | 0.7778 |
| Information Tracking | 3.6087 | 0.9662 |
| Independent Variable | | |
| Management Commitment | 4.0580 | 0.6869 |
| Training and Education | 3.8551 | 0.7467 |
| Employee Empowerment | 3.3406 | 0.7753 |
| Team Culture | 3.9734 | 0.8516 |
| Company Policies and Goals | 3.6696 | 0.8379 |

Out of these five components of the dependent variable, housekeeping (5S) factor showed the highest mean of 4.186 and with a standard deviation of 0.654. This indicates that all the participating companies were concerned about housekeeping of their plant, equipment and machinery by putting it as the first priority. This is followed by the general inspection that resulted in a mean of 3.980 and with a standard deviation of 0.647, thus respondents seem to be putting a lot of emphasis in conducting inspection on their products as well as the machines and equipment through operators (see Table 3).

Whereas for the components of the independent variable, management commitment showed the highest mean (4.05) followed by team culture, training and education, company policies and goals and then by employee empowerment. All the respondents agree that all the components are important.

Testing the Hypothesis

In order to test the hypotheses, Pearson Correlation Coefficient method was applied.

Table 4
Correlation Coefficients

| Independent Dependent | Management Commitment | Training and Education | Employee Empower- ment | Team Culture | Company Goals And Policies |
|---------------------------------|--------------------------|------------------------------|------------------------------|-----------------|----------------------------------|
| Extent of TPM Implementation | 0.642** | 0.658** | 0.694** | 0.618** | 0.701** |

** significant at $\alpha = 0.01$

As shown in Table 4, all the variables are positively correlated with extent of TPM implementation. Thus all the five hypotheses is accepted and we can conclude that all the independent variables significantly enhances the extent of TPM implementation.

Discussion And Conclusion

Although the word TPM might still be new to most of the manufacturing firms in Malaysia, especially among the locals, but it seems that it was not the true picture. The TPM programs are being widely used by both foreign and local firms based on the descriptive analysis.

As has been shown all the change management factors are positively related to the extent of TPM implementation. This is in line with many other researches. The quality "gurus" namely Deming, Juran, Crosby and Garvin had made a remark that the top management's involvement and commitment are important in implementing both productivity and quality improvement programs (Hoffman & Mehra, 1999). Thus, management commitment is the basic requirement in the TPM implementation. Nakajima (1989) also finds that the responsibility of the top management is to actively promote motivation, ability and favourable work environment to the workers. Heap (1992) also stressed on the commitment by saying the commitment at the top must be total, both in terms of level and extent, and that it must include the full senior management team of the organization and each manager must be fully committed to any initiatives or development programs such as TPM.

Training and education positively influence the extent of TPM implementation, in efforts to improve productivity or quality. Providing training and educating the people involved in the program, furnish them with the requisite information, knowledge as well as skills that are needed by the workers to improve their existing job or to learn something new.

Employee empowerment is also found to be one of the important factors for TPM implementation. Empowering the workers is one of the main criteria in TPM implementation (Patterson et al., 1995). This view is also in line with that of Nakajima's (1989), who found that TPM will not

Change Management

work without empowering the operators or the production workers to carry out the autonomous maintenance. Under TPM, production workers assume ownership of their work area.

On the effect of team culture towards the extent of TPM implementation, there is a significant positive correlation between these two factors as expected. The finding agrees with other previous literature, where most of the TPM implementation activities are executed through team efforts. Joint problem solving in improvement programs have been found to improve sustainability and maintainability of equipment.

Company goals and policies, which is the fifth component of the change management factors, is found to be a highly positive correlated with the extent of TPM implementation. This explains the need for a structured and documented policies that establish concrete goals, known to all the workers directly or indirectly involved in the program, in successfully implementing TPM.

Implications

This study has shown empirically that manufacturing companies that practice change management effectively will help to boost the implementation of TPM programs. TPM seems to be well practiced by most of the Malaysian manufacturing companies in carrying out their productivity and quality improvement programs. This can be clearly seen in descriptive analysis where all the dimensions show high mean values.

As change is a nonlinear process and often it has no clearly defined beginning or end, to promote it would be the toughest challenge to the management. No one person can single-handedly implement organizational change. Change involves "concerted efforts" from all the employees. So the relationship between change management and the implementation of productivity and quality improvement programs should be closely investigated. Perhaps in the future researches, it would be better to consider the effectiveness in practicing change in an organization towards the extent of TPM implementation.

The findings of the research also have important practical implications for TPM implementation. As the practice of change management favoured the extent of TPM implementation, thus the study has provided empirical evidence that management commitment, training and education, team culture, employee empowerment and setting up of new company policies and goals can lead to better TPM implementation.

As such it is important for top management to continuously promote incremental changes in the organization, to reduce resistance to change, should there be a need to implement radical changes. But in doing so, a number of items has to be considered in order to make the initiative a success. Top management has to provide support and enough tools and facilities to the change leaders who are the change agents. Change leaders with the management support and commitment, and through the other practices namely promoting team culture, empowering employees, providing continuous training and education, and incorporating the change

in its company's policies and goals can increase the extent of TPM implementation.

It can be concluded that the study has provided empirical evidence that full management commitment and support, continuous training and education, employee empowerment, promoting team culture and setting up of new policies and goals (in line with productivity or quality improvement programs) from the view of change management significantly enhances the extent of TPM implementation.

It is been proven that in Japan, especially, TPM programs are being practiced thoroughly and it worked because of the change management factors are being well followed (Turbide, 1995). Basically all the Japanese companies that embraced change together with TPM programs achieved high performance through fewer defects, less downtime, less accident and less waste.

This is true in the context of Japanese change strategies such as the famous Japanese Kaizen, a suggestion-based continuous improvement and also the team approach as well as the approach of empowering workers. Top management's support and the inclusion of the productivity and quality improvement programs into company's goals and policies are given priorities by the most of the Japanese and American firms now. This is mainly to enhance further the performance of the companies.

Although this study is confined to the Malaysian context, the results showed very high positive correlation between the change management and TPM level. Thus, it can be concluded that the change and TPM implementation in Malaysia is comparable with other firms around the world.

Bibliography

- Guimaraes, T., & Armstrong, C. (1998). Empirically testing the impact of change management effectiveness on company performance, *European Journal of Innovation Management*, 1(2), 74-84.
- Heap, J. (1992). *Productivity Management: A Fresh Approach*, London: Cassell Educational PLC.
- Hoffman, J., & Mehra, S. (1999). Operationalizing productivity improvement programs through total quality management, *International Journal of Quality & Reliability*, 16(1), 72-84.
- Ingram, H., & Desombre, T. (1999). Teamwork: comparing academic and practitioners' perceptions, *Team Performance Management*, 5(1), 16-22.
- Jonsson, P. (1999). Company-wide integration of strategic maintenance: An empirical analysis, *International Journal of Production Economics*, Vol.60-61, 155-164.

Change Management

- Klusman, R. A. (1995). Establishing proactive maintenance management, *Water Engineering & Management*, 142 (1), 16-19.
- Maggard, B. N., & Rhyne, D. M. (1992). Total productive maintenance: A timely integration productivity, *Production and Inventory Management Journal*, 33(4), 6-9.
- McKone, K., Schroeder, R.G., & Cua, K. (1999). Total productive maintenance: A contextual view, *Journal of Operations Management*, 17, 123-144.
- Mileham, A. R., Culley, S. J., McIntosh, R. I., Gest, G. B., & Owen, G.W. (1997). Set-up reduction (SUR) beyond the productive maintenance (TPM), *Proceedings of the I MECH E Part B Journal of Engineering Manufacture*, 18, 211(4), 253-260.
- Moore, R. (1997). Combining TPM and reliability-focused maintenance, *Plant Engineering*, 51(6), 88-90.
- Moran, J. & Avergun, A. (1997). Creating Lasting Change, the *TQM Magazine*, 9(2), 146-151.
- Mullins, L. J. (1996). *Management and Organisational Behaviour*, London: Pitman Publishing.
- Norman, R.M. (1997). Uptime: The true measurement of maintenance productivity, *Modern Casting*, 87(5), 51-53.
- Nakajima, S. (1989). *TPM Development Program*, Oregon: Productivity Press.
- Nakajima, S. (1988). *Introduction to Total Productive Maintenance (TPM)*, Oregon: Productivity Press.
- Nunnally, J. (1978). *Psychometric Theory*, New York: McGraw Hill.
- Ollila, A., & Malmipuro, M. (1999). Maintenance has a role in quality, *The TQM Magazine*, 11(1), 17-21.
- Patterson, W. J., Kennedy, W. J., & Fredendall, L. D. (1995). Total productive maintenance is not for this company, *Production and Inventory Management Journal*, 36(2), 61-64.
- Patterson, W. J., Fredendall, L. D., Kennedy, W. J., & McGee, A. (1996). Adapting total productive maintenance to Asten, Inc., *Production and Inventory Management Journal*, 37(4), 32-37.
- Raouf, A. (1994). Improving Capital Productivity through Maintenance, *International Journal of Operations & Production Management*, 14(7), 44-52.
- Stephens, K. S. (1994). "ISO 9000 and total quality", *Quality Management Journal*, Fall, 57-71.
- Tajiri, M., & Gotoh, E. (1992). *TPM Implementation: A Japanese Approach*, New York: McGraw-Hill.
- Tsang, A. (1998). A strategic approach to managing maintenance performance, *Journal Of Quality in Maintenance Engineering*, 4(2), 87-94.
- Turbide, D. A. (1995). Japan's new advantage: Total Productive Maintenance, *Quality Progress*, 28(3), 121-123.

Tsuchiya, S. (1992), *Quality Maintenance: Zero Defects Through Equipment Management*, Oregon: Productivity Press.

T. Ramayah (ramayah@usm.my) is the Chairman of the Operations Management Department at the School of Management, Universiti Sains Malaysia, Minden 11800 Penang.

Muhamad Jantan (mjantan@usm.my) is a Professor at the School of Management, Universiti Sains Malaysia, Minden 11800 Penang.

Mohd Mustapha Hassan is a post graduate student at the School of Management, Universiti Sains Malaysia, Minden 11800 Penang.