TOTAL PRODUCTIVE MAINTENANCE (TPM) PRACTICES AND MANUFACTURING PERFORMANCE: THE MODERATING EFFECT OF TYPES OF PRODUCTION PROCESSES

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by

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DEDICATION

If it were not for the encouragement that given by parents in my early years to continue school I would have never succeeded. Their total supports simply outstanding. This work is dedicated to my mother, Chek binti Saleh, without whose caring support it would not have been possible, and to the memory of my father, Mad Lazim bin Mat Aroff, who passed on a love of reading and respect for education.

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AMS	Advanced manufacturing system
CBM	Condition-based maintenance
CFT	Cross functional team
CMMS	Computerised maintenance management system
DEA	Data envelopment analysis
DS	Discreet semiconductor
DV	Dependent variable
EPU	The Economic Planning Unit
FMM	Federation of Malaysian Manufacturers
FMS	Flexible manufacturing system
GDP	Gross domestic product
HRM	Human resource management
IMMS	International Manufacturing Strategy Survey
IV	Independent variable
JIPM	Japan Institute of Plant Maintenance
JIT	Just in time
KMO	Kaiser-Meyer-Olkin
MIDA	Malaysian Industrial Development Authority
MQFD	Maintenance quality function deployment
MRA	Moderated regression analysis
MRP	Material Requirement Planning
OEE	Overall equipment effectiveness
PM	Preventive maintenance
QFD	Quality function deployment
RBV	Resource-based view
RCM	Reliability centred maintenance
RM	Ringgit Malaysia
SEM	Structural equation modelling
SME	Small medium enterprises
SMI	Small medium industry
SPSS	Statistical Package for Social Sciences
TPM	Total Productive Maintenance
TQM	Total quality management
UK	United Kingdom
US	United States

AMALAN-AMALAN PENYELENGGARAAN PRODUKTIF MENYELURUH (PPM) DAN PRESTASI PEMBUATAN: SUATU KESAN PENYEDERHANAAN OLEH JENIS-JENIS PROSES PENGELUARAN

ABSTRAK

Kepentingan penyelenggaraan telah menjadi fokus utama dalam persekitaran pembuatan. Teknologi terkini dan kemajuan dalam industri pembuatan memacu banyak syarikat untuk melaksanakan program penyelenggaraan yang boleh dipercayai demi mengelakkan terjadinya pemberhentian dan gangguan peralatan dalam operasi seharian. Penyelenggaraan Produktif Menyeluruh (PPM), suatu pendekatan yang berasaskan sumber mengubah paradigma penyelenggaraan dengan memberi tumpuan kepada penglibatan pekerja secara menyeluruh dalam aktiviti-aktiviti penyelenggaraan. Semua operator dan pekerja seharusnya secara aktif terlibat dalam program penyelenggaraan yang mana mampu untuk mengelakkan sebarang gangguan, kerosakan, pemberhentian, kegagalan dan sebagainya terhadap peralatan dalam meningkatkan prestasi pembuatan. Oleh itu, dalam industri pembuatan yang sangat kompetitif, keupayaan dan kebolehpercayaan peralatan yang diselenggara dengan baik adalah begitu penting untuk mencapai prestasi pembuatan yang diingini seperti pengurangan kos, produk berkualiti, penghantaran menepati masa dan kebolehanjalan. Tambahan lagi, terdapat beberapa kajian dalam ulasan karya yang menegaskan kajian lanjutan adalah perlu dalam bidang penyelenggaraan dan pengurusan operasi. Sesungguhnya, dalam keperluan untuk memenuhi keperluan ini, kajian ini mengkaji sejauh manakah amalan PPM dalam syarikat pembuatan di Malaysia, menyelidiki perhubungan di antara amalan PPM dan prestasi pembuatan, dan untuk menyiasat

kesan penyederhanaan jenis proses pengeluaran dalam perhubungan di antara amalan-amalan PPM dan prestasi pembuatan. Kajian ini menggunakan data yang dikutip daripada 106 syarikat pembuatan daripada pelbagai jenis industri. Persoalan kajian pertama telah dijawab bagi mengkaji sejauh manakah amalan-amalan PPM di kalangan syarikat-syarikat sektor pembuatan di Malaysia menggunakan anlisis deskriptif. Keputusan telah menunjukkan strategi PPM dan penyelenggaraan berautonomi merupakan amalan-amalan yang paling tinggi diamalkan dalam syarikat-syarikat pembuatan di Malaysia. Dalam pada itu, penghantaran menepati masa dan produk berkualiti tinggi menjadi keutamaan bagi syarikat-syarikat pembuatan di Malaysia. Secara keseluruhannya, semua syarikat yang turut serta dalam kajian ini bersetuju bahawa semua amalan PPM dan prestasi pembuatan adalah penting. Satu model telah dihipotesiskan dan dianalisis menggunakan REGRESI berhiraki untuk menjawab persoalan kajian kedua dan ketiga. Keputusan analisis menunjukkan amalan PPM secara positif dan signifikan meningkatkan prestasi pembuatan. Sebagai contoh strategi PPM adalah secara positif dan signifikan berkaitan dengan kos, kualiti, penghantaran, dan keanjalan. Hasil dapatan kajian menunjukkan beberapa keputusan yang signifikan kesan pembolehubah penyederhanaan jenis proses pengeluaran dengan perhubungan antara beberapa amalan PPM dan prestasi pembuatan. Keputusan ini menunjukkan kadar perubahan yang berbeza ke atas amalan-amalan PPM dan prestasi pembuatan bagi jenis proses pengeluaran kumpulan, pemasangan (besar-besaran) dan pengeluaran berterusan. Sumbangan dan kekangan kajian turut dibincangkan.

TOTAL PRODUCTIVE MAINTENANCE (TPM) PRACTICES AND MANUFACTURING PERFORMANCE: THE MODERATING EFFECT OF TYPES OF PRODUCTION PROCESSES

ABSTRACT

The importance of maintenance has become the main focus in the manufacturing environment. New technologies and advancements in the manufacturing industry have driven many companies to implement reliable maintenance program in order to avoid stoppages and disruptions of equipment from occurring in their daily operations. Total productive maintenance (TPM), a resource-emphasized approach moves the paradigm of maintenance by putting emphasis on total employee involvement in the maintenance activities. Operators and all employees should be actively involved in a maintenance programme that enable to avoid any disruptions, breakdowns, stoppages, failures, and so forth in order to improve manufacturing performance. Therefore, in the highly competitive manufacturing industries, the ability and reliability of equipment that well-maintained is very important in order to achieve desired manufacturing performance namely cost reduction, high quality products, on-time delivery, and flexibility. Furthermore, several studies in the literature argue that further research is required in the area of maintenance and operations management. In order to address this need, the study investigates the extent of TPM practices in the Malaysian manufacturing companies, to investigate the relationship between TPM practices and manufacturing performance and to investigate the moderating effect of type of production process in the TPM practices and manufacturing performance relationships. The study uses data collected from 106 manufacturing companies from

various types of industries. The first research question was answered in order to examine the extent of TPM practices in the Malaysian manufacturing companies using the descriptive analysis. The result shows that TPM strategy and autonomous maintenance were the most TPM practices found in the Malaysian manufacturing companies. Meanwhile, on time delivery and high quality product becomes the main concerned in the Malaysian manufacturing companies. Overall, all participating companies were agreed all TPM practices and manufacturing performance were important. A model is hypothesized and analysed by hierarchical regression to answer the second research question and third research question. The results imply that TPM practices positively and significantly improved manufacturing performance. For instance, TPM strategy was positively and significantly related to cost, quality, delivery and flexibility. The significant moderating effects of type of production process were also found on the certain TPM practices and manufacturing performance relationships. The results imply that the rates of change on the TPM practices and manufacturing performance relationship were differed for batch, mass and continuous production processes. Contributions and limitations of the study also discussed accordingly.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Advances in technology coupled with globalisation have propelled manufacturing companies to change fast and be able to suit customers' demands at all times. In manufacturing companies the pressure to ensure equipment operates without breakdowns, stoppages, failures and so forth has become a major concern for maintenance staff (Carannante, Haigh & Morris, 1996). Disruptions and breakdowns of equipment certainly affect the achieving of this, and can be considered to be a critical maintenance issue. The environment of maintenance work has changed significantly in recent years, especially in manufacturing companies. Indeed, Moubray (1997) argues that this is due to the increasing number and variety of physical assets that need to be maintained. Increasing automation and its complexity; new maintenance techniques and changing views on maintenance organisation and responsibilities are also important factors affecting the maintenance work environment.

Traditionally, maintenance has been considered to be a support function, non-productive and not a core function hence adding little value to the business (Bamber, Sharp & Hides, 1999). According to Cooke (2003), maintenance workers may be under pressure to ensure there are no stoppages or breakdowns of the equipment. Any breakdown of any piece of equipment may cause further stoppages upstream or downstream. This happens especially in plants where machines are interlinked and operate continuously. These stoppages and breakdowns can directly or indirectly affect manufacturing performance.

Manufacturing performance can be achieved in many ways and one of them is through the implementation of Total Productive Maintenance (TPM). TPM can be considered as a comprehensive maintenance strategy. TPM focuses on a total system of maintenance prevention, preventive maintenance and maintainability improvement (Nakajima, 1989). In fact, TPM fills a gap in Preventive Maintenance (PM) that focuses only on economic efficiency. Moreover, TPM emphasises three important features (Nakajima, 1989):

1) pursuit of economic efficiency
2) total preventive maintenance: including maintenance prevention activities to improve maintainability as well as preventive maintenance.
3) total employee participation through autonomous maintenance and small group activities and teamwork.

Therefore, TPM has established itself in maintenance activities that focus on an organisation's internal resources. Furthermore, TPM integrates preventive maintenance, condition-based maintenance and predictive maintenance activities as well. Basically, predictive maintenance plays a significant role in TPM by utilising advanced and modern monitoring techniques to diagnose the signs of deterioration of equipment. Furthermore, equipment deterioration and failure can be identified during operation (Nakajima, 1989). In fact, in TPM, periodic maintenance favours predictive maintenance, which can detect any equipment deterioration and failure more effectively using new embedded technology and condition-based inspection technology such as vibration, spectroscopy and thermography among others (Parida & Kumar, 2006).

Moreover, Schonberger (1987) as well as Cheng and Podolski (1996) also highlight TPM as an important move for companies seeking world class manufacturing status. There are many widely accepted manufacturing performance indicators such as quality, cost, delivery and flexibility (McKone, Schroeder & Cua, 2001; Schroeder, 1993; Ward, Duray, Leong & Sum, 1995; and Wheelwright, 1984). According to Mobley (1990), an average of 28% of the total cost of finished goods can be attributed to maintenance activities in the factory.

Meanwhile, in a study carried out by Mitchell, Robson and Prabhu (2002), levels of maintenance practices were found to be strongly associated with business performance (i.e. cash flow, return on net assets, capital investment, market share, customer satisfaction and employee morale) and operational performance (i.e. process capability, cycle time, deliveries and internal defects). Additionally, Blanchard (1997) has suggested that with the ongoing addition of new technologies, robotics, automation and the increasing use of computer-aided devices and so forth, maintenance costs are likely to be even higher in the future with the continuation of existing practices. Meyer (2004) found that TPM managed to reduce lost capacity by 90%, exceeded 90% of overall equipment effectiveness (OEE), improved the delivery of painted products to assembly areas and reduced the costs significantly.

More importantly, Koelsch (1993) asserts that according to Constance Dyer, (Director of Research and TPM Product Development, Productivity Inc.), companies that adopt TPM are seeing 50% reductions in breakdown labour rates, 70% reductions in lost production, 50% to 90% reductions in set-ups, 25% to 40% increases in capacity, 50% increases in labour productivity and 60% reductions in costs per maintenance unit. TPM helps to improve organisations' capabilities by

enhancing the problem-solving skills of individuals and enabling learning across various functional areas (McKone, Schonberger & Cua, 1999).

In Malaysia, Choy (2006) has reported that Infineon Technologies in Melaka has managed to increase the production capacity of its Discrete Semiconductor (DS) line by more than 100 million production volumes through TPM implementation. Moreover, a study by Ahmed, Masjuki and Taha (2005) shows that TPM implementation improves equipment efficiency and effectiveness, reduces cycle time, inventory and customer complaints, creates small group autonomous teams, increases the skills and confidence of individuals and enhances total productivity.

The manufacturing sector in Malaysia makes a great contribution to the national gross domestic product (GDP). For example, it was reported that the manufacturing sector contributed 31.4% to the GDP, 80.5% to total export and 28.7% to total employment in 2005 (EPU, 2006). Moreover, many manufacturing companies in Malaysia are exporting their products to international markets. For instance, the manufacturing sector had recorded a sound sales value that in June 2006 expanded by 7.6% or RM2.9 billion to RM41.4 billion compared to the RM38.5 billion that was attained in June 2005. This sector also posted an increase in sales value of 0.6% or RM0.2 billion as against RM41.2 billion reported for the previous month (Monthly Manufacturing Statistics, 2006).

In addition, the role of top management commitment in supporting TPM implementation in manufacturing companies is very important (Ramayah, Jantan & Hassan, 2002). Top management commitment enables change management application towards TPM implementation.

On the other hand, a study carried out by Ahmed, Masjuki and Taha (2004) shows that the level of maintenance practices in small and medium enterprises (SMEs)

in the manufacturing sector in Malaysia is still a low priority. Small and medium enterprises (SMEs) contribute about 29% of total manufacturing output and 44% of employment (EPU, 2006, p.114). This certainly exposes a gap in understandings of the importance of equipment maintenance as it is becoming the major contributor to the performance and profitability of manufacturing system (Kutucuoglo, Hamali, Irani & Sharp, 2001).

TPM is a maintenance system that covers the lifespan of equipment and involves total employee participation (Nakajima, 1988). In fact, Chan et al. (2005) describe TPM as a synergistic relationship among various departments for continuous improvements of product quality, operational efficiency, capacity assurance as well as safety aspects. As TPM can have an effect on manufacturing performance, investigating particular TPM practices, namely TPM strategy and TPM team and focussing on TPM processes can provide insights into performance.

1.2 Research problem

In order to survive and succeed in the current manufacturing environment, manufacturing companies must be supported by effective, efficient and reliable maintenance practices and procedures (En-Chi, 2004). Given the complexity of the manufacturing environment, there are differences and varieties of maintenance programmes implemented. One approach to improve manufacturing performance is through the use of TPM practices which require total participation from all employees. More importantly, there should be active participation from operators to maintain equipment and work closely with maintenance staff. The total cost of finished goods can be attributed to maintenance activities in the factory (Mobley, 1990). In addition,

cost is one of the measures of manufacturing performance. The other measures of manufacturing performance that can contribute significantly to competitiveness are quality, delivery, productivity and flexibility. However, there are researchers who put emphasis on manufacturing performance (McKone et al., 2001, Schroeder, 1993; Ward et al., 1995).

The cost of manufacturing can be very high especially in terms of equipment and machinery. New technology and more sophisticated equipment also require more training for operators and technical staff. On the other hand, the costs of poor quality can contribute to more problematic issues. The costs of non-conformance are also due to processes, materials, human factors and machines for instance and are a drag on the profits of manufacturing companies. The six big losses, i.e. those incurred by breakdowns, set-up and adjustments, idling and minor stoppages, speed reduction, quality defects and reworks and start-up losses can stop equipment from being operated to its full potential (Nakajima, 1989), thus increasing overall costs as well. According to Al-Najjar and Alsyouf (2003), maintenance function has been more challenging in order to maintain and improve product quality, safety requirements, and plant cost effectiveness. In addition, maintenance cost is an essential part of the operating budget for manufacturing companies (Al-Najjar & Alsyouf, 2003).

Moreover, Brown, Collins, and McCombs (2006) postulate that cost is a significant aspect of lean performance measurement. They suggest three indicators to show the highlights of cost, namely productivity, scrap and work in progress. More importantly, companies are looking for ways of reducing their manufacturing costs effectively. Moreover, reducing operating costs i.e. production and marketing, is very important, especially for world-class manufacturing (WCM) companies (Salaheldin & Eid, 2007). In addition, Gulbro, Shonesy, and Dreypus (2000) assert that in order to

compete, firms must improve performance by simultaneously decreasing costs and increasing quality as well as delivery performance.

The quality of products produced can be affected as a result of incorrect setting of the machines, insufficient training of operators handling the machines, mechanical failures of the machines and so forth. Therefore, this certainly will affect the products which will be delivered to customers. Machine or equipment failure not only affects quality but also delivery and flexibility. There are several aspects of TPM practice that can be explored to investigate its effects on manufacturing performance such as quality, cost, delivery and flexibility (McKone et al., 2001, Schroeder, 1993; Ward et al., 1995). However, in this study, more emphasis has been placed upon TPM practices, namely TPM strategy, TPM team and the TPM process focus (Brah & Chong, 2004) to improve the manufacturing performance.

More importantly, these TPM practices are strongly related to the resources of the manufacturing companies. The authors of resource-based studies such as Barney (1991); Wernerfelt (1984) and Fahy (2000) give ideas on how to look into the internal resources of the firm; resources that can be explored to study the effects of TPM practices on manufacturing performance. Consequently, the TPM practices can help to increase the manufacturing performance. The increasing cost of manufacturing therefore needs to be considered as a hindrance to achieving competitiveness in the industry. Therefore, through the TPM practices, the costs can be reduced and a lean manufacturing system can be established eventually.

Moreover, the types of production processes can also affect the relationship of TPM practices and manufacturing performance (Cua, McKone & Schroeder, 2001; De Toni & Tonchia, 1996; Schroeder, 1993; White, Pearson & Wilson, 1999). TPM practices are extensively used to improve efficiency (Katayama & Bennet, 1996).

Therefore, this study tries to identify the role of TPM practices, namely TPM strategy, TPM team and TPM process focuses on the manufacturing performance of manufacturing companies in Malaysia. No study has been carried out for the particular case of Malaysia that has sought to investigate the moderating effect of types of production processes on TPM practices and manufacturing performance, an opportunity therefore exists to engage in this research.

Introducing TPM in Malaysian manufacturing is still considered a major challenge due to several non-conducive environments in the adoption and implementation process. With varieties of types of production processes applied in the production floor, the challenge will be greater. Types of production processes have been regarded as important contributor to the TPM practices and manufacturing performance relationships. The fit between the TPM practices and manufacturing performance relationships can be examined in order to show the moderating effect of types of production processes.

Moreover, the manufacturing sector especially involved in mass production processes, i.e. electrical and electronic products, was the main contributor for Malaysian major exports and was valued at more than RM 266 billion in 2007 (Department of Statistics, 2008). Overall manufacturing sales for the period January – May 2008 show a sales value of more than RM 235 billion and significantly justify the importance of the manufacturing sector to the Malaysian economy.

The need for reliable maintenance techniques to be applied in order to avoid breakdowns and failures occurring affects manufacturing performance. Previous studies have been conducted without considering types of production processes as a moderating variable. More importantly, previous studies have only looked at types of industries, for instance Jonsson (1997); Ireland and Dale (2001); and Cooke (2003),

but have not directly focussed on types of production process. Types of production process are constituted of various activities, cost structures, technology, resources, skills, production volume and so forth.

Prominent authors in the field of operations management, for instance Slack and Lewis (2002); Schroeder (1993); Russell and Taylor (2003, 2009); Stevenson (2002); Davis and Heineke (2005) etc, have elaborated in detail the characteristics of types of production processes. The moderating effects of types of production process cause the TPM practices–manufacturing performance relationship to change; however, this depends on the value of the moderator variable (Hair et al., 1998). Moreover, without the moderator effect, we might assume that TPM practices will have a 'constant' effect on manufacturing performance. However, the interaction term will tell us that this relationship changes, depending on the types of production processes used.

As further noted by Hair et al. (1998):

> '…the effect of independent variable and moderator variable by themselves are unimportant, but instead the interaction term complements their explanation of dependent variable' (p.171).

The interaction of TPM team and types of production processes, for instance, will complement the explanation of cost, quality, delivery and flexibility performances. Therefore, this is something new in terms of contributions to the knowledge. Furthermore, it is useful to investigate the moderating effects of types of production processes in the relationship between TPM practices and manufacturing performance. As highlighted earlier, not only the cost of manufacturing will be the main priority for manufacturing companies in order to sustain the competitive advantage but also quality, delivery and flexibility.

1.3 Research objectives

Three primary research objectives motivate this research and the main aim of this research is to investigate the relationship between TPM practices and manufacturing performance. Given the current literature on TPM in the manufacturing environment, the extent of TPM practices in Malaysian manufacturing companies is worth investigating. The relationships to be studied include direct TPM practices and the moderating effects of types of production process on manufacturing performance. The second objective is to provide empirical evidence to support a model that establishes a relationship between TPM practices and manufacturing performance. The third objective is to offer empirical evidence to support the model that states that the moderating variable changes the strength of the TPM practice–manufacturing performance relationship. To summarise then, the three primary research objectives that motivate this study are as listed below:

a. to examine the extent of TPM practices in manufacturing companies in Malaysia
b. to examine the relationship between TPM practices namely TPM strategy, TPM team and TPM process focus, and manufacturing performance
c. to analyse the moderating effect of types of production processes in the relationship between TPM practices and manufacturing performance.

1.4 Research questions

This study will examine the TPM practices and link them to the manufacturing performance of manufacturing companies in Malaysia. As such, the research questions posed are as follows:

a. To what extent are TPM practices implemented in Malaysian manufacturing companies?
b. What is the relationship between TPM practices and manufacturing performance?
c. Do the types of production processes used moderate the relationship between Total Productive Maintenance (TPM) practices and manufacturing performance?

1.5 Significance of study

The significance of this study can be divided into two aspects - theoretical and practical contributions.

1.5.1 Theoretical contribution

This study will look into aspects of TPM practices in the context of manufacturing companies in Malaysia. In addition, the present study intends to fill the gaps in the body of literature concerning the impact of TPM practices on manufacturing performance. In TPM research, few attempts have been made to investigate the effects of TPM practices on performance. Moreover, a lack of consideration of moderating variables has been observed. The literature contains ample research on TPM and performance in various settings in studies such as Brah and Chong (2004); McKone et al. (1999, 2001); Seth and Tripathi (2004, 2005); Tsarouhas (2007) and so forth. However, few studies attempt to link TPM with world class manufacturing practices and performance (McKone et al. 1999, 2001; Bonavia and Marin, 2006), and to provide a bigger picture about how TPM works effectively. These gaps in the research may exist because manufacturing

companies operating various types of production processes and thus TPM practices and performance relationship may be affected accordingly.

The role of types of production process in the manufacturing companies has been sidelined in the previous research, understood as an important moderating role between TPM practices and manufacturing performance. Brah and Chong (2004), for instance, look into TPM practices and the performance relationship without considering the moderating variable effect. Meanwhile, McKone et al., (1999) investigate specific contextual variable differences on TPM implementation but not generalisable, wider scale differences that affect TPM implementation and effectiveness. There are other studies that have investigated TPM practices and performance in various settings, which do not include types of production processes as a moderating variable; for instance, Seth and Tripathi (2005); Ahuja and Khamba (2007, 2008a); Bamber et al., (1999); and so forth.

The research conducted in relation to the body of knowledge on TPM has looked at practices or activities related to TPM. This particular study will look into and highlight the importance of TPM practice issues and will attempt to prove that these practices are related when it comes to ensuring better manufacturing performance and thus, the achieving of a significant competitive advantage. This study hopes to contribute to the theoretical body of knowledge in the process of examining the effects of TPM practices by looking into a resource-based view (RBV) to signify the importance of human capital resources and organisational resources (Barney, 1991) towards achieving performance. It is essential for a firm to organise its business process efficiently and effectively, including manufacturing companies. Moreover, as Barney and Wright (1998) agree, it is

certainly very important for firms to recognise the maximum competitive potential of their resources and capabilities.

Research taking a resource-based view involves many areas of study including strategic management (e.g. Barney and Wright, 1998; Barney, 1991); manufacturing settings (e.g. Prahalad and Hamel, 1990; Karami, Analoui and Cusworth, 2004); logistics setting (e.g. Miller & Ross, 2003) and service industry settings (e.g. Ray, Barney, and Muhanna, 2004). In a service industry, for instance, Ray et al. (2004) suggest that business process, i.e. customer service in an insurance company, relies on the exploitation of several different resources and capabilities. Therefore, TPM practices are considered to be important business process that can lead to world class manufacturing status (Cheng & Podolsky, 1996; Schonberger, 1987) as well as contribute to lean production (Bonavia & Marin, 2006; Cua et al., 2001; Dale, 1994; Flynn & Sakakibara, 1995; Ohno, 1988).

The underpinning theory to support the importance of human resources and organisational capabilities relies on a comprehensive theory to explain the significance of internal organisational resources as a source of competitive advantage as highlighted by Barney (1986); Barney (1991); Fahy (2000); and Wernerfelt (1984). From an empirical perspective, investigating TPM practices in manufacturing companies and evaluating their relationship with manufacturing performance will enlarge the understanding of managerial challenges especially when dealing with limited resources in an organisation.

There are many managerial challenges that relate to the internal resources of the organisations. Lack of manpower, limited skills, culture and norms, tight budget allocation, support from top management (Cooke, 2000), communication

barriers, employee involvement, managing the TPM team and improvements, collection and tracking of data on performance (Smith, 2000), and so forth are, for instance, some of the common managerial challenges and they are becoming more apparent in the global stiff competition environment. The present study's contributions on human capital resources are as important as contributions on physical capital resources and organisational resources. Since maintenance is involved in any operational strategy which focuses on issues related to resources, processes, people and so forth (Johnson & Scholes, 2005), therefore it is clearly an essential element of RBV.

Moreover, the so-called intangible resources and capabilities (Fahy, 2000) are very important, especially in dealing with various types of production processes. In project processes, for instance, highly skilled workers are required although the demand volume is very low. Various types of production processes require different sets of intangible resources and capabilities. Furthermore, Barney (1991), Barney and Wright (1998); Fahy (2000) and Slack and Lewis (2002) agree that resources and capabilities include knowledge, experience, skills, relationships, teamwork, judgements, intelligence, firm's formal and informal planning, controlling and coordinating systems.

1.5.2 Practical contribution

The findings of the present research may benefit not only manufacturing companies but also government related organisations, the service sector and last but not least organisations dealing with academics. The results of this study will provide ideas and practical suggestions which can be implemented in TPM in order to improve manufacturing performance and competitive advantage. The

findings of this study are also intended for other relevant maintenance support teams (from all departments in an organisation) to achieve the desired manufacturing performance, i.e. cost, quality, delivery and flexibility. In autonomous maintenance, for instance, cleaning and workplace management (5'S), which are **Seiri:** sorting**, Seiton:** straighten or set in order**, Seisō:** cleanliness, **Seiketsu** standardizing: **Shitsuke:** sustaining the discipline; will expose areas of contamination and hidden defects (Nakajima, 1988). This will allow the elimination of sources of contamination and highlight inaccessible areas for improvement and hence eliminate environmental causes of deterioration such as dirt and dust.

This study can also have managerial and practical implications. Considering that managers have limited discretionary time and often have to work within a constrained set of physical, intellectual and financial assets (including machines, equipment, tools etc.), understanding the resource-related aspects in the total productive maintenance is needed; i.e. knowledge, experience, skills, relationships, teamwork, judgements, intelligence, firm's formal and informal planning, controlling, and coordinating systems and so forth (Barney, 1991; Barney & Wright, 1998; Fahy, 2000; Slack & Lewis, 2002) In addition, this study will enhance the understanding of TPM in manufacturing companies and the effect of effective maintenance management on manufacturing performance.

The moderating effect of types of production processes were observed in the TPM practices and manufacturing performance relationships. Batch and mass production processes were mostly moderated by the relationship between TPM practices and manufacturing performance. Therefore, the managers of manufacturing companies should be aware of the moderating effect of the

production processes. The technical complexity of the production processes are important as more automated and mechanised equipment is becoming used in both batch and mass production processes. Efforts to strengthen TPM strategy, for instance, should be increased and closely monitored as it shows a positive relationship with all manufacturing performance. Additionally, types of production processes have been moderated on the basis of the relationship between TPM strategy and manufacturing performance, for instance cost, quality and flexibility.

Additionally, perhaps, this study will be of benefit to the government. The Malaysian government has spent billions of 'Malaysian ringgit (MYR)' on repairing public buildings and amenities due to a poor maintenance culture (Wong, 2006). In order to minimise the consequences of escalating maintenance costs, government related organisations, for instance, could also utilise the results of this study. For instance, government related agencies could practice TPM team and autonomous maintenance that strongly emphasises total employee participation to eliminate sources of equipment deterioration and reduce overall costs as well. Properly arranged training and education sessions should be introduced to all staff combined with strong support from top management. Therefore, based on this study, the TPM practices such as TPM strategy, TPM team, autonomous maintenance and planned maintenance, for instance, can be introduced in order to avoid problems such as an unnecessarily large amount of money being spent on maintenance. Basically, the corrective maintenance approach taken by government agencies could be significantly replaced by TPM.

The literature that provides ample guidance for managers on how limited resources should be allocated between organisations is, however, still insufficient. Furthermore, very few studies have examined the impact of adopting total

productive maintenance (TPM) in the Malaysian context. These few include: Jantan, Nasurdin, Ramayah and Ghazali (2003), Nasurdin, Jantan, Peng and Ramayah (2005), Seng, Jantan and Ramayah (2005), Ramayah, Jantan and Hassan (2002) and Choy (2006). Moreover, these studies did not include any consideration of the moderating effect of types of production process in the relationship between TPM practices and performance; therefore, this study will fill that gap and examine the moderating effect of types of production processes in the relationship between TPM practices and performance.

1.6 Definition of variables

The definitions of variables used in the study are as follows:

1.6.1 TPM practices

There are many definitions of TPM practices as highlighted by various authors (Bamber et al., 1999; Cooke, 2000; Cua et al., 2001; Nakajima, 1989; Seth & Tripathi, 2005). For instance, Seth and Tripathi (2005) use the term TPM implementation factors as well as TPM practices. Dimensions such as the focus on customer satisfaction, leadership for improvement, strategic planning for improvement, human resource management, education and training, information architecture, performance measurement systems, materials management, equipment management, process management and financial resources management have been given attention in the literature supporting the importance of TPM (Cooke, 2000; Nakajima, 1989; Tajiri & Gotoh, 1992; Takahashi & Osada, 1989; Tsang & Chan, 2000; Yamashina, 1995).

However, in this study, the TPM practices we will focus and conceptualise are as those highlighted by Brah and Chong (2004) which consist of three main activities, namely TPM strategy, TPM team and TPM process focus. The reason to choose and focus on TPM practices as highlighted by Brah and Chong (2004) due to the appropriateness of matching with a resource based view (RBV). The independent variables are consistently related and well-suited to the RBV definition, which includes capabilities, intangible resources, human capital resources and organisational resources (Barney, 1991). Moreover, the Brah and Chong (2004) study which was conducted in Singaporean manufacturing companies also investigated the correlation of general organisational and TPM specific constructs and performance. More importantly, Brah and Chong's (2004) study is likely to be relatable to the Malaysian manufacturing environment as it includes various similar types of industries and production processes.

1. TPM Team

   The TPM team are defined the utilisation and the direction of TPM in the manufacturing company. The quality of leadership, communication standards and problem solving skills of the team to solve problems, lead small group activities and so forth are some of the measurements to be considered (Brah & Chong, 2004).

2. TPM Strategy

   TPM strategy is conceptualised as the conducting of well-planned activities that relate to maximising equipment effectiveness, continuous improvement actions taken to improve quality ('kaizen'), increase safety and reduce costs

and actions to raise the morale of the team that is implementing TPM (Eti, Ogaji & Probert, 2004).

3. TPM Process Focus

TPM process focus will look into processes that directly relate to TPM implementation at a plant level as suggested by McKone et al. (2001). The activities involved are autonomous maintenance and planned maintenance. Autonomous maintenance measurements include total employee participation in TPM, cleaning, inspection, lubrication standards, conduct, general inspection training and development of inspection procedures, the autonomous conducting of general inspections, workplace organisation and housekeeping. Autonomous maintenance helps the operator to regularly inspect the quality of products. However, planned maintenance is conceptualised as being related to these activities, namely disciplined planning, information tracking and schedule compliance (McKone et al., 1999).

1.6.2 Manufacturing performance

The operations management literature, for instance, provides multiple dimensions to evaluate manufacturing performance (McKone et al., 2001; Skinner, 1974; Ward et al., 1995). The most common dimensions in manufacturing performance are quality, cost, flexibility and delivery. Moreover, Skinner (1974) asserts that these dimensions are also competitive priorities. Meanwhile, two studies by Ward et al. (1995 & 1998) categorise manufacturing performance into four dimensions, namely quality, cost, delivery, and flexibility using factor analysis.

Hence, in this study, cost, quality, delivery and flexibility will be referred to as the manufacturing performance dimensions. Manufacturing cost will be increased by maintenance jobs due to breakdowns and equipment failures. Potential causes of such breakdowns, stoppages, and failures due to mechanical or electrical problems, loose bolts and nuts, for instance, may cause the equipment operate in a very vulnerable condition. Due to this problem, the product being produced by the equipment may be off-centred and poor quality performance may result.

The defective products must be reworked in order to rectify the quality deficiency as soon as possible and the root cause of the problems must be identified and solved immediately, especially if it is related to the equipment settings and adjustments, to avoid further quality problems. The reworked products take some time to be re-inspected before delivery to the customer. Hence, due to re-inspection, the product cannot be delivered on time and causes a delay in production lines. More importantly, due to re-inspection, some adjustments may well need to be made in order ensure the product can reach the customer as soon as possible.

The delay of equipment settings to accommodate any re-inspection process, on the other hand, also causes the flexibility of the operators and equipment to be affected. The above illustration shows that manufacturing performance dimensions such as cost, quality, delivery and flexibility have a crucial relation to equipment maintenance hence total productive maintenance practices must be introduced and implemented accordingly TPM initiatives can have a major positive impact on plant performance such cost, efficiency,

quality performance, fast delivery, on-time delivery, inventory turnover and flexibility (Maier et al., 1998).

1.6.3 Types of production processes

There are three broad types of process structures that very much depend on the extent of the volume of items produced in manufacturing operations such as project processes, intermittent processes and line-flow processes (Davis & Heineke, 2005). Intermittent processes consist of two types of processes called job shop and batch, while line-flow processes include assembly line and continuous processes. However, Russell and Taylor (2003) state that there are four types of production processes: projects, batch production, mass production and continuous production.

Meanwhile, Stevenson (2002) postulates that there are five types of production processes: project, job shop, batch, repetitive/assembly and continuous production. In this study, the types of production processes used will be based on areas suggested by Russell and Taylor (2003, 2009): project, batch, mass/assembly and continuous production. Russell and Taylor (2003, 2009) are one of the main authors in the area of Operations Management and they have categorised clearly types of production processes under several items. For instance, type of product, type of customer, product demand, demand volume, primary type of work, worker skills, costs, work in progress and examples of product produced, are systematically arrayed as depicted in **Table 3.7** in the next section. These four types of production processes can be used to explain the moderating effect involved in the relationship between TPM practices and manufacturing performance.

Lean production has not been included in this study. In fact, lean production practices are total productive maintenance (TPM), just in time (JIT) production system and total quality management (TQM) (Bonavia & Marin, 2006) and human resource management (HRM), therefore they are at same level in the analysis. According to Davis and Heineke (2005), lean production is commonly known as an 'integrated set of activities designed to achieve high-volume flexible production' (p.349) and with the emphasis on waste reduction and the just-in-time or pull-system concept. Nevertheless, flexible manufacturing system (FMS) is a highly integrated manufacturing system, combined with many sub-assemblies and interdependent components (Vineyard, Amoaka-Gyampah & Meredith, 2000) rather than a type of production process.

Additionally, Sharma et al. (2006) mention that:

> 'flexible manufacturing system (FMS) is a highly integrated manufacturing system that consists of many dissimilar components, i.e. mechanical, electronic, hydraulic, software integrated with a computer network' (p.260).

Moreover, Russell and Taylor (2009) illustrate technology primers that consist of product technology, process technology, manufacturing technology and information technology. FMS is one of the manufacturing technologies as well as computer numerical controlled (CNC), robots, computer integrated manufacturing (CIM) and automated guided vehicle (AGV). As a result, this study excludes JIT and FMS as types of production process.

1.7 Organisation of the thesis

The present thesis is organised as follows:

i) In chapter one, introduction and background of the study were discussed. The research problem has been explored through the research questions and research objectives. The summary of the study's contributions has been elaborated as well.

ii) In chapter two, theoretical aspects of overall maintenance management, TPM practices and TPM implementation issues such as barriers, problems and manufacturing performance will be looked into through a discussion. Chapter two presents and defines the concepts that will be used throughout this study. It reviews the relevant literature to define the theoretical constructs needed for the development of a conceptual model linking TPM practices and manufacturing performance with the moderating effect of types of production processes. A theoretical framework will be presented together with the hypotheses of the present study. The constructs will be specified whereby the hypothesised relationships between these constructs will be stated and discussed in detail.

iii) In chapter three, the methodological and research design of the study, which include measures, questionnaire design (the survey instrument), units of analysis, sampling and pilot testing will be discussed. The survey instrument is presented in detail with relevant reference to the literature.

iv) In chapter four, the results of the study, the relationship of TPM practices and manufacturing performance with the moderating effect of types of production processes is presented. The constructs will be validated through research findings and factor assessment leading to the empirical analysis of the theoretical model.

v) In chapter five, the discussion of the finding will be presented. Concluding remarks and avenues of future research will also be presented in this chapter.

CHAPTER 2

LITERATURE REVIEW

2. 1 Introduction

The goal of this chapter is to synthesise the relevant literature into an integrated conceptual model by linking the different interactions in the TPM practices to manufacturing performance. Segments of three large bodies of literature are reviewed critically in this chapter.

The first section presents the literature referring to the underpinning theory of a resource-based view, with the emphasis on its application to maintenance management in general and total productive maintenance specifically.

The second section of this chapter reviews overall maintenance management studies that are mainly associated with manufacturing and operations management, with special attention given to TPM practices and total employee involvement in the TPM.

The third section reviews the segment of literature on maintenance management which pertains to the integration between maintenance staff and production operators. Then, the TPM concepts, with particular attention devoted to the origin of implementation are introduced. The history of the concept of TPM starting from the first maintenance approach is also discussed.

2.2 Resource-based view

The competitive manufacturing environment needs flexible and fast actions to cope with fast changes in customer needs and expectations. Therefore, terms such as flexible manufacturing, lean production and JIT for instance are emerging to