AMT, MANUFACTURING PERFORMANCE AND FIRM PERFORMANCE

by

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ABSTRAK

Dalam dunia era teknologi canggih, organisasi perindustrian menghadapi pelbagai cabaran mengimbangi penyerapan teknologi dengan pencapaian. Teknologi Perindustrian atau dikenali sebagai AMT merangkumi penyatuan sistem komputer berintegrasi seperti robotik, CAD/CAM, FMS, kumpulan teknologi, ERP adalah sebahagian besar pelbagai teknologi yang digunakan untuk mempertingkatkan mutu rekaan, pentadbiran, operasi perindustrian serta mencapai keupayaan unggul. Objektif penyelidikan ini ialah untuk mengkaji hubungan di antara tahap penggunaan teknologi dengan pencapaian organisasi dan sama ada saiz dan umur mempengaruhi hubungan tersebut. Seterus, ia mengkaji tentang perhubungan pencapaian perkilangan dan pencapaian organisasi. Oleh demikian, populasi penyelidikan ini merangkumi organisasi-organisasi dalam Persekutuan Pekilang-pekilang Malaysia 2002 edisi ke 33. Sampel telah dipilih secara rambang dan unit analisis ialah pekilang dari pelbagai jenis industri dan saiz. Penemuan menunjukkan bahawa penggunaan AMT mempunyai hubungan signifikan dengan pencapaian perkilangan. Penyelidikan ini telah mengenalpasti bahawa penggunaan AMT mempunyai hubungan dengan pencapaian organisasi. Akan tetapi, saiz dan umur organisasi didapati tidak mempengaruhi hubungan di antara kedua-dua unsur tersebut. Tidak juga terdapat sebarang hubungan kuat di antara pencapaian operasi perindustrian dengan pencapaian organisasi secara keseluruhan. Penyelidikan ini telah menyediakan suatu pemahaman yang lebih mendalam mengenai penggunaan AMT di Malaysia serta memperkukuhkan kenyataan bahawa pengunaan AMT dapat meningkatkan pencapaian perkilangan. Informasi mengenai perhubungan penggunaan AMT dengan pencapaian perkilangan dapat membantu organisasi menyelaraskan keputusan strategik.

ABSTRACT

In a world of advanced technology era, manufacturing organizations face challenges to balance adoption of technology and performance. Advanced Manufacturing Technology (AMT) includes a group of integrated hardware and software based technologies such as robotics, CAD/CAM, FMS, group technology, MRP or ERP, represents a wide variety of modern advanced technologies devoted to enhance design, administration, manufacturing operations and gain competitive capabilities. The objective of this research is to examine the relationship between technology level used and the manufacturing performance. This study also would like to look whether size and age moderate the relationship between AMT and manufacturing performance. Further, it looks at how manufacturing performance relates to organizational performance. Hence, the targeted population was the manufacturing organization in Malaysia from those listed in Federation of Malaysian Manufacturer Directory of Malaysian Industries 2002. Samples were randomly selected and the unit of analysis is a manufacturing firm of all types and sizes. The study found that intensity of AMT has a significant relationship with manufacturing performance. However, both size and age of organization does not moderate the relationship between these two variables. There was also no significant relationship between manufacturing and firm performance. This study provides a better understanding on AMT in Malaysia and it has substantiated the notion that the intensity of AMT can increase manufacturing performance. Information on relationship between intensity of AMT and manufacturing performance enables organization to make strategic decisions.

Chapter 1

INTRODUCTION

1.1 Problem Statement

There have been waves of technological development since the industrial revolution in the 18th century. The first wave was mechanization, use of machines to replace labor. The second wave was mass product automation. The third wave is the integration of automization by use of IT and robotics. In addition to providing information on level of Advanced Manufacturing Technologies (AMT) in relation to manufacturing performance, this research is also aimed to be a source of information for business organizations.

There are levels of technology being applied in an industry such as state of the art, first generation back or second generation back etc. Management will always want state of the art technology. However, state of the art technology incurs high cost. Therefore, what is the trade-off between level of technology and competitiveness of a firm?. According to Stainer, as cited by Chan, Chan, Lau and Ip, (2001) some industrialists and economists believe that AMT has great potential to offer manufacturing companies, with many tangible and intangible benefits. However, the extent of its benefits within manufacturing organizations in Malaysia have not realized as expected. This research focuses on the extent of performance achieved by Malaysian organizations in relation to the intensity of AMT in their firms.

As cited by Burcher and Lee (2000), Swamidass and Waller (1991) stated that the potential benefits which can accrue from investments in advanced manufacturing technologies (AMT), have become increasingly evident to UK companies, faced with growing global competition. However, they also cited that Boer (1990) viewed that often substantial investments in the form of equipment, systems, software and hardware, aimed at improving manufacturing, have not resulted in the immediate tangible improvements in performance intimated by suppliers or indeed anticipated by those within companies championing such investments. Burcher and Lee (2000) also cited that King and Ramamurthy (1992) stated that similar experiences have been echoed in other parts of the world and many reasons have been offered to account for such disappointments. This research hopes to provide some answers to the manufacturing organization on the relationship between AMT deployment and manufacturing performance and how manufacturing performance relates to organizational performance.

1.2 Research Objectives and Questions

One of the research objectives is to study the relationship between the intensity of advanced manufacturing technology (IAMT) and manufacturing performance and how manufacturing performance further relates to firm performance. Next, is to study whether size and age moderates the relationship between IAMT and manufacturing performance. Several researches have been done in the areas of AMT usage and performance (Gupta & Whitehouse, 2001; Small & Yasin, 2000; Co, Patuwo & Hu, 1998). Research on the level of AMT in Malaysia and the relationship between AMT and manufacturing performance have been conducted in the past but was based on certain industries in Malaysia. However, this research is based on all types and sizes of industries throughout Malaysia.

Specifically, the research aims at answering these research questions.

1. What is the AMT level among Malaysian manufacturing firms?
2. Is there a relationship between IAMT and manufacturing performance?
3. Is there a relationship between manufacturing performance and firm performance?
4. Does size and age moderate the relationship between IAMT and manufacturing performance?

1.3 Significance of the Study

Facing intensifying global competition and rapid advancement of manufacturing, the need for successful adoption of technology is critical for organizations' sustenance, competence and survival. Increasing realization that technology changes rapidly, the outcome of dominant role of innovation have brought about various studies on transformation of technology but the focus of this study is to examine the link between technology used and performance. The objective is to develop a better understanding of how IAMT will affect manufacturing performance and hence, firm performance.

It also looks at whether size and age moderates the relationship between IAMT and manufacturing performance. Thus, the researcher would like to know whether size and age are moderators or predictors. According to Chen and Macmillan (1992) there exist a relationship between organization size and performance when size is measured in terms of number of employees and performance is measured by growth measures such as profits, there exist a positive relationship between the two. Goss and Vozikis (1994) found that there is no statistically significant relationship between size and level of technology.

1.4 Organization of Dissertation

This study is organized as follows. The first chapter is Introduction which discussed on problem statement, research objectives and significance of the study. Next chapter is Literature Review which included related literatures, theoretical framework and hypotheses. For chapter three, this section is on the research methodology which explains about population, sampling, measurement of variables, questionnaire design and data analysis technique. The following chapter, chapter four discussed on the findings of this research and the last chapter is the discussion on implication, recommendations, limitations, suggestions for future research and conclusion.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Advanced Manufacturing Technology (AMT) is a wide variety of modern computer technologies consisting of integrated hardware and software to carry out automated production system consisting of people, machines and tools for planning and control of production processes. Usage of AMT in manufacturing industries has increased over the years and some companies have achieved manufacturing performance and firm performance. Japan, for example, has succeeded in world markets by focusing its attention on the importance of superior manufacturing systems and techniques. Thus, manufacturing may be the "sleeping giant" within firms and prove to be a formidable competitive weapon in the global marketplace (Mechling, Pearce & Busbin, 1995). One way that firms can achieve competitive advantage in manufacturing is through the deployment of AMT (Mechling, Pearce & Busbin, 1995). However the level of AMT applied and used varies from one organization to another.

2.2 Overview and classification scheme for AMT

Evolutionary technological choice depends on the prevailing technological development in the industry and adoption by firms to achieve competitive capabilities in the areas of product design, manufacturing, and testing. AMT is a wide variety of modern computer technologies consisting of integrated hardware and software to carry out automated production system consisting of people, machines and tools for planning and control of production processes. Modern technologies such as robotics, computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), flexible manufacturing systems (FMSs), computer integrated manufacturing (CIM), etc., known collectively as advanced manufacturing technology (AMT), offer the promise of enhancing the competitive position in global markets (Chen & Small, 1996).

As for Woodward (1965) cited by Ghani and Jayabalan (2000), he classified manufacturing technology as unit or batch, mass, continuous production based on the type of production. Ghani and Jayabalan (2000) also cited that currently, according to Meredith and Hill (1987), Snell and Dean (1992), based on the automation and integration of manufacturing activities, AMT has been classified into four levels. Level 1 is stand-alone machine tools or equipment, where as level 2 is the manufacturing cells based on grouping of machines to perform a variety of parts to perform family parts. For level 3, the cells in level 2 are connected to form linked islands through computerized information network and at level 4, all the manufacturing activities including marketing of products are integrated through information network. Technologies are categorized using a scheme that attempts to combine technologies that require similar levels of organizational integration and are conducive to similar implementation approaches.

Wiarda (1987) as cited by Ariss, Raghunathan and Kunnathar (2000) suggested various subgroups of technologies within AMT consisting of systems, devices, stations (SDS) and integrated and managerial systems (IMS) which performs integrative and managerial functions. Several authors have structured the AMT field into three classifications. Jonsson (2000) cited that Kaplinsky (1984); Lei and Goldhar (1991) used the dimensions design, manufacture and integration.

For design, the dimension of AMT includes computer-assisted drafting, design and engineering which focuses on the design of products and processes. As for manufacturing, it includes computer-controlled processes in the fabrication/ assembly industries; automatic materials handling; automatic storage and retrieval systems. Here, the focus of AMTs is on the actual manufacturing and physical transformation of the products. The administrative dimension includes computerized accounting, inventory control systems and shop-floor tracking systems focusing on tracking operations.

Voss (1986) viewed a continuum of advanced manufacturing technology, ranging from NC machines at one end to CIM at the other. One dimension of this continuum is measured in terms of the level of integration, with NC machines requiring no integration and CIM requiring extensive integration. Suresh and Meredith (1985) grouped all other AMTs together as "integrated systems," but Small and Yasin (1997) noted that a differentiation needs to be made between FMS and CIM, and still grouped them together as integrated systems. CIM is a technology that involves enterprise-wide integration which includes the functionality oriented integrative technologies of CAM and FMS besides combining automation.

AMT in this research consisted of the categories based on Small and Yasin (2000), where technologies are classified as stand-alone systems, intermediate systems, and integrated systems and further divided into seven technology subgroups. The subgroup classification attempts to combine technologies that offer similar organizational benefits and are conducive to similar planning and installation approaches. Stand-alone systems are individual machine tools or equipment controlled by self-contained computers. Intermediate systems are at the level between the stand-alone and the integrated that handles storage, material or inspection. Integrated systems is the level of AMT which offers production facility that integrates two or more cells to achieve competitive advantage such as generation of new products rapidly and enter new markets.

The deployment of AMT and assessing business organization's opinion on the relationship between AMT and performance will involve research in levels of AMT usage, AMT and manufacturing performance, the impact of size and age on AMT and manufacturing performance, measurement of performance and relationship between manufacturing and firm performance. The list of the subgroup classifications, and their constituent technologies according to Small and Yasin (2000) are presented below:

<u>Stand-alone systems</u>

A. Design and engineering technologies:

(1) Computer-aided Design (CAD)

(2) Computer-aided process planning (CAPP)

B. Machining, fabricating and assembly technologies:

(3) NC/CNC or DNC Machines

(4) Pick-and-place robots

(5) Other robots

(6) Materials working lasers

Intermediate systems

C. Automated material handling technologies:

(7) Automatic storage and retrieval systems (AS/RS)

(8) Automated material-handling systems (AMHS)

D. Automated inspection and testing technologies:

(9) Automated inspection and testing equipment (AITE)

Integrated systems

E. Flexible manufacturing systems:

(10) Flexible manufacturing cells/systems (FMC/FMS)

F. Computer-integrated manufacturing :

(11) Computer Integrated Manufacturing (CIM)

G. Logistic-related technologies:

(12) Just-in-time (JIT)

(13) Material requirements planning (MRP)

(14) Manufacturing resources planning (MRPII)

(15) Enterprise resource planning (ERP)

2.3 Definition of Terms

The AMT terms are as per below:

CAD *(Computer aided design)* – any design activity that involves the effective use of the computer to create or document an engineering design.

CAM *(Computer aided manufacturing)* – the translation of design data into language which an automated assembly machine or an NC machine can utilize as input to produce a part.

CAPP (*Computer aided process planning*) – expert systems that capture the knowledge of a specific manufacturing environment along with generic manufacturing principles and apply this knowledge to create a plan for the physical manufacture of a part.

CNC (*Computerized numerical control machine tools*) – a numerical control system that uses a dedicated, stored computer program to perform some or all of the basic numerical control functions.

AS/RS (Automatic storage and retrieval systems) – A high density rack inventory storage system with vehicles automatically loading and unloading of racks.

Industrial robots – A machine handling objects, including parts, material or tools, which are both versatile and operate independently of human control.

FMS (Flexible manufacturing systems) – A group numerically controlled machine tools interconnected by a central control system. The various machining cells are interconnected via loading and unloading stations by an automated transport system.

FMC (Flexible manufacturing cells) – asserts that parts which have similar physical configurations or can be partitioned into distinct product families, and which require similar machine operations on similar machines are prime candidates for FMSs.

CIM (Computer integrated manufacturing) – The application of a computer to bridge various computerized systems and connect them into a coherent, integrated whole.

JIT (Just in time) – A manufacturing program with the primary goal of continuously reducing and ultimately eliminating all forms of waste through JIT production and involvement of the work force

MRP (Material requirements planning) – A computer based information system designed to handle ordering and scheduling of dependent-demand inventories like raw materials, component parts and subassemblies.

MRPII (Manufacturing resources planning) – Expanded approach to production resource planning, involving other areas of a firm in the planning process, such as marketing or finance.

ERP (Enterprise resource planning) – Expanded effort to integrate financial, manufacturing and human resources on a single system computer.

2.4 Importance of AMT

Although the importance and research interests in AMT implementation are growing, scholarly materials addressing the planning aspects of AMT remain scattered and disjointed (Chen & Small, 1996). Usage of AMT in industries has shown positive relationship with performance and has managed to achieve diversified objectives.

Among the frequently-cited benefits of AMT include reduced direct labor costs, reduced product development time, reduced inventory, more efficient layout and use of machinery, reduced floor space requirements, better quality, less waste, improved productivity, shorter manufacturing lead time and quicker response to market shifts (Co, Patuwo & Hu, 1998). The operational role of AMT is often seen as an instrument for achieving economies of scale in small batches (Chen & Small, 1996). As cited by Jonsson (2000), Goldhar and Jelinek (1983) stated that, for mass production firms, the greater flexibility and speed provided by AMTs could result in economies of scope. It is believed that improved justification methods will encourage more firms to invest in AMT and to realize the benefits these investments can offer.

2.5 General Overview of AMT and performance

The initial success with AMT is low where most companies still struggle with AMT implementation (Chen & Small, 1996). Nevertheless, investment in capital intensive technology such as AMT has increased over the years and has been receiving attention from academic community (Boyer, Leong, Ward & Krajewski, 1997). Sambasivarao and Deshmukh (1995) cited that Troxler and Blank (1990) provided a comprehensive list of potential strategic effects of AMT, which includes investment, growth, technology position, employee relations, market position, workforce composition, organization structure and operations management. Stated that advanced manufacturing technology is used as the framework for assessing "level of success" and proposed that the success of advanced manufacturing technology can be measured at two levels: technical success and business success.

The lowest level is technical success (level 1) comprised of installing and running a technology without significant downtime. Business success means realizing the potential benefits of a technology. At the lowest level of business success (level 2), firms benefit from advanced manufacturing technology by increasing productivity through, for example, reduced labor inputs; at the next level (level 3), firms achieve non-productivity benefits such as reduced lead times, quality improvements, increased flexibility and customer responsiveness (Voss 1988).

2.5.1 AMT and manufacturing performance

Different levels of AMT usages have recorded different results. Here, the researcher wants to analyze the relationship between IAMT and manufacturing performance. Some companies have realized handsome payoffs from investing in advanced manufacturing planning and control (MPC) techniques such as manufacturing resources planning (MRPII). Co, Patuwo and Hu (1998) cited that Vollmann (1993) found that Tennant company, in a two-year period with its MPC system in place, reduced purchased inventory by 42 percent, increased production rate by 66 per cent and increased delivery promises met from 60 to 90 per cent. Companies can attain significant competitive advantages through AMT such as flexible manufacturing systems (FMS), computer-aided design and robotic systems. A survey of five FMS installations indicated a reduction in lead time by 25 per cent (Meredith, 1987).

The research findings by Frohlich and Dixon (1999) shows that adaptations to production planning and control, scheduling, cost accounting, performance measurements and CAD systems were directly related to higher degrees of operational performance. This supports Small and Yasin's(1997) finding that the most integrated AMTs had the highest level of performance (Frohlich & Dixon, 1999). Effective implementation of CAD/CAM systems offers manufacturers a number of benefits such as: cutting design costs, reducing cycle time, reducing matching time and improving information flow. For firms that have already implemented CAD/CAM systems the improvement in their productivity will also coincide with a marked decrease in design and production costs, thus freeing valuable staff time so that they can concentrate on pro-actively managing customers' demands and other value added activities (Soliman, Clegg & Tantoush, 2001). Co, Patuwo and Hu (1998) cited that a study of flexible manufacturing systems (FMS) by Hayes and Jaikumar (1991), out of twenty US firms, it showed that FMS can reduce labor by as much as 88 per cent.

AMT usage has assisted companies to gain manufacturing performance and thus, create an impact on the firm performance. This study looks at whether there is a positive relationship between manufacturing performance and firm performance due to the usage of AMT. According to Voss (1988) the success of AMT can be measured also at business level. At this level, AMT has resulted in firms gaining competitive advantage. At the top level of business success (level 4), benefits represent a competitive gain in the marketplace for a company (Voss, 1988).

Based on the findings on Lessons for Implementing AMT based on some case experiences on CNC in Australia, Britain and Canada, examples of productivity gains that can be quantified, for instance, reductions in lead times, labor costs and minor rework in the Australian case and cost reductions, increased throughput and reductions in work in progress at the British machine tool company. There is also the ability to produce smaller batches economically in the British and the Canadian companies, together with gains in market share for the Canadian company. All three companies also cite quality improvements, as an important benefit from such investments (Burcher, Lee & Sohal, 1999). Co. Patuwo and Hu (1998) cited that Badiru (1990) stated that factory automation tightens process control, simplifies the diagnosis of problems, minimizes human error and automates quality assurance procedures , where by Attaran (1989) viewed that computer aided design enhances process accuracy and repeatability, with a lower defect rate and improved product quality

Voss's (1988) proposed that the success of advanced manufacturing technology can be measured at two levels: technical success and business success. A useful tool that businesses are turning to, in order to build strong capabilities, improve performance, undertake better decision-making, and achieve a competitive advantage is Enterprise Resource Planning (ERP) Software (Al-Mudimigh, Zairi & Al-Mashari, 2001).

2.6 Size, age and performance

This study is also keen to study the moderating effects of size towards the relationship between AMT usage and manufacturing performance. The number of employees, the level of sales, and the value of firm assets are the most appropriate indicators of firm size according to Samiee and Walters (1990). They also stated that generally, there have been no universally accepted criteria for measuring firm size. Gupta and Whitehouse (2001) cited that Reid (1982) took into account the number of product lines, the number of technical and academic employees for measuring size.

Here, the study wants to analyze if there exist a positive effect within AMT towards performance and whether smaller firms achieve better results or vice versa. Based on Gupta and Whitehouse (2001), the results of the study indicate that smaller firms get better performance from technology implementation. The results of the study also indicate that the size of the firm does interact favorably with the AMT strategy. Thus, the successful implementation of AMT could be achieved with careful focus on the organizational size. This study also supports the saying the ``leaner'' organizations perform better and believe that small firms favor an ``entrepreneurial'' mode of behavior and appear to be especially productive in turning R&D expenditures into innovations.

Based on a study by Mechling, Pearce and Busbin (1995), firm size does not appear to have a significant moderating effect on the relationship between a firm's exporting activity and AMT adoption. However, Frohlich and Dixon (1999) cited that restructuring of traditional functional, stove-pipe structure of organizations may be essential for larger plants and organizations, suggesting that size can be considered as an important moderating variable. In this study, the research is to find whether size moderates the relationship between IAMT and manufacturing performance.