THE FIT BETWEEN ADVANCED MANUFACTURING TECHNOLOGY (AMT) AND MANUFACTURING STRATEGY: IMPLICATIONS FOR MANUFACTURING PERFORMANCE

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Thesis Summary

Researchers posit that maximum benefit will accrue if there is a fit between the firm's strategies and its Advanced Manufacturing Technology (AMT) diffusion. The existing literature discusses how the investment of AMT should be consistent with manufacturing strategy, however little attention has been given to an empirical examination of the link between manufacturing strategy and AMT, and the implications of the fit between these two on manufacturing performance. This thesis addresses that gap in the literature and thus seeks to examine the link between manufacturing strategy and AMT, and how the alignment between these two variables can affect the manufacturing performance.

The findings are based on questionnaire responses from a total of 262 manufacturing companies in the United Kingdom that produce discrete products. The results confirm that there is a link between the integration and the investment of AMT and manufacturing strategy and that companies emphasising a differentiation strategy generally invest and integrate their AMT to a higher degree than companies that follow a cost leadership strategy. However, the former do not excessively invest or integrate much of their assembly and machining technologies as suggested in the extant literature. The study also confirms that companies with a cost leadership strategy are more selective and invest less than other companies, however, the type of AMT's investment and integration are contrasting with the literature, i.e. assembly and machining technologies and material handing technologies.

The study also finds that the most practical and feasible approach to defining fit is 'fit as moderation'. The study reveals that companies adopting a differentiation strategy which invest and integrate highly in Production Planning Technology (PPT), Assembly and Machinery Technology (AsMT) and Integrated Manufacturing Technology (IMT) will significantly achieve higher differentiation performance. Also that, companies adopting a high cost leadership strategy need to invest and integrate highly in Material Handling Technology (MHT) to achieve higher cost leadership performance.

Keywords: advanced manufacturing technology (AMT), manufacturing strategy, manufacturing performance, fit, contingency theory.

DEDICATION

To my wonderful children: **Joshwey, Joshmyn and Joshlee.**

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LIST OF ABREVIATIONS

AGV	Automated guided vehicles
AMT	Advanced manufacturing technology
AsMTs	Assembly and machining technologies
ASRS	Automated storage and retrieval systems
BERR	Department for Business, Enterprise and Regulatory Reform
CAD	Computer-aided design
CAE	Computer-aided engineering
CAM	Computer-aided manufacturing
CAQC	Computer-aided quality control
CIM	Computer integrated manufacturing
CNC	Numerical controlled machines
DNC	Direct numerical controlled
DTI	Department of Trade and Industry, UK.
EDI	Electronic Data Interchange
EEF	Engineering Employers' Federation.
ERP	Enterprise resources planning
FMC	Flexible manufacturing cells
FMS	Flexible manufacturing systems
GDP	Gross Domestic Product
GT	Group technology
IET	Information exchange technology
IT	information technology
IMTs	Integrated manufacturing technologies
JIT	Just-in-time
LAN	Local area network
LPT	Logistics and Planning technology
MHTs	Material handling technologies
MRP	Material requirement planning
MRP II	Manufacturing requirement planning
NC	Numerical controlled
ONS	Office for National Statistics
PDETs	Product design and engineering technologies
PDT	Product design technology
PPTs	Production planning technologies
PT	Process technology
SCM	Supply chain management
SIC	Standard Industrial Classification

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CHAPTER 1

INTRODUCTION

1.1 Background

The way in which manufacturing companies are competing in the market is changing. The market is increasingly unpredictable, dynamic and fiercely competitive. One of the main ways the market has changed has been the rapid expansion of manufacturing capabilities, which at least in part has been due to the increasingly advanced and inexpensive microelectronics-based technologies (Cook and Cook, 1994) which collectively are often referred to as Advanced Manufacturing Technology (AMT).

In particular, AMT relates to the use of computer-controlled, programmable machines that are able to process, and hence add value, to a large variety of differing parts and components, without incurring major changeover or setup cost. This type of flexible automation can span vast functions in manufacturing firms, such as product design, production planning, process planning, material handling, production, and inspection and testing (Saraph and Sebastian, 1992).

According to Porter (1985), a manufacturing company can choose to compete primarily in one of two ways, either on cost leadership, i.e. attempting to produce similar goods at lower prices, or by product differentiation, i.e. producing a good that in some way differs from that of its competitors. It is argued that by investing in AMTs, manufacturers are able to enhance their competitiveness irrespective of which competitive strategy they are following, in other words AMT can allow for increased product differentiation while at the same time, reduce overall production costs (see for example Jelinek and Goldhar, 1984; Skinner, 1985; Pine, 1993; Cook and Cook, 1994; Markland et al., 1998, Small, 2006).

AMT has thus become widely used across manufacturing environments to increase competitiveness. Indeed, in order to stay competitive within the global marketplace, many would argue that investment in advanced technologies is no longer an optional luxury and has become essential for survival (Manetti, 2001). The recent increase in the volume of literature on the capabilities of AMTs further shows the growing importance of AMT for the modern manufacturing company (Koc and Bozdag, 2009; Lagace and Bourgault, 2003).

However, although the use of AMT has become increasingly widespread, results of empirical studies indicate that, while most firms achieve some benefits (see for example, Jaikumar 1986; Upton, 1998; King and Ramamurthy, 1992; Small, 1999; Gordon and Sohal, 2001) many firms are failing to fully exploit the potential benefits of AMT (Voss, 1986; Saraph and Sebastian, 1992; Udo and Ehie, 1996). Perhaps this should not be a surprise, for as is pointed out by Upton (1998), mere installation of these technologies in itself, is not enough to guarantee the competitive success of those adopting firms. The success or failure of any AMT is a much more complicated issue.

Thus although the technical capabilities of AMT are well proven, capturing the full benefits of such processes has been shown to depend on the appropriateness of the AMT selected, the way it is implemented, and the general infrastructure of the company introducing the technology. For example, researchers have identified the lack of strategic alignment between the technology and the business or manufacturing strategy, as a major barrier to exploiting the full benefits of these technologies (Hill, 1994; Small and Yasin, 1997; Cil and Evren, 1998; Kotha and Swamidass, 2002). It is suggested that in order to be fully exploited, the technology chosen needs to be aligned and be part of the company's overall long term strategy (see for example Grant et al, 1991; Small and Yasin, 1997; Cil and Evren, 1998; Kathuria et. al., 1999; Das and Narasimhan, 2001; Mellor and Hyland, 2004; Small, 2006).

The importance of this alignment between AMT and a company's strategy has received much attention in the AMT literature (other examples include Voss, 1986; Meredith, 1987; Boyer et al., 1996; Dean and Snell, 1996; Kathuria and Igbaria, 1997; Kotha and Swamidass, 2000; Heijltjes, 2000; Mellor and Hyland, 2004, Raymond and Croteau, 2009) with the researchers suggesting that maximum benefit will accrue if there is a fit between the firm's strategies and its AMT diffusion. Hill (1994) suggests that the overall business will suffer if the basic link between these two is not made, i.e. the lack of fit results in diminished performance. Therefore it is essential that companies consider these factors and devise manufacturing strategies consistent with the AMT investment and vice versa

The AMT literature is thus replete with studies, both conceptual and empirical, suggesting that there are critical factors for successful AMT implementation, and argue that AMT should be consistent with manufacturing strategy. However, little attention has been given to an empirical examination of exactly what the specific link between manufacturing strategy and AMT is, what type of AMT should be implemented and what implications the fit between these two has on manufacturing performance.

The thesis thus aims to address this knowledge gap in the AMT literature by providing an examination of the link between manufacturing strategy and AMT, and how the alignment between these two variables can affect the manufacturing performance. Informed by data from a unique questionnaire of UK manufacturing firms, it first investigates the link between manufacturing strategy, the types of AMT adopted and their level of integration, and subsequently studies whether the variation in fit among manufacturing strategy and AMT adoption explains the cross-sectional performance amongst the companies sampled. This is guided by the many different definitions of fit suggested by strategic literature, and as such an added contribution of the study is to explore the most appropriate way to measure the fit between AMT and strategy.

1.2 Why UK Manufacturers?

The manufacturing sector plays a vital part of the economy in almost any country in the world, and certainly for all developed countries. A study in 2004 by EEF, one of the UK's leading manufacturers' organisations, showed that countries with larger manufacturing sectors tended to be more prosperous. This was based not only on advanced European economies but also on developing nations in East Asia and Latin America. Manufacturing companies are thus of significance importance within a country's economy.

It is true that the UK manufacturing sector has in general been in decline in recent decades. Figures from the Office for National Statistics (ONS) show that in 1960 the UK manufacturing accounted for 35% of the nation's GDP but by the turn of the century this had fallen to under 19%. Employment levels too have declined within the manufacturing sector, in 1978 ONS figures showed over 7.1 million people were employed in manufacturing related companies, but by 2008 this had fallen by over 50% down to just 3.1 million. Similarly, the importance of exports has declined with manufacturing exports, as a percentage of all exports down to 49.7% in 2007, compared to over 60% in the 1990s (BERR, 2008).

However, with over 50% of exports, and 3 million employees, the UK manufacturing sector remains a significant proportion of the UK economy and in recent years has been shown to be resilient to the increasingly competitive global environment. In 2007, output, investment and productivity of the manufacturing sector had all increased relative to the previous two years (BERR, 2008). Indeed, beyond the direct workforce, many more people are employed indirectly through supply chain and service industries, as such manufacturing remains a major contributor to economic activity and employment in almost every region of the UK (DTI, 2004). In fact, it is the industry most invested in by the UK government and the UK remains one of the world's top manufacturing nations. Thus, the success of UK manufacturing companies remains crucial to the prosperity and success of the whole country. Of course the UK manufacturing sector itself is transforming. The shift of the global economy to low-wage-countries such as China, India and the former Eastern bloc, means that UK manufacturers are often less able to compete effectively based on cost, instead their competitive priorities have changed to other niche dimensions such as quality. This has resulted in a restructuring of UK manufacturing toward higher value-added knowledge-intensive areas and in recent years, growth in high-technology manufacturing has far outstripped growth in the low-technology sectors (BERR, 2006). Thus, advances in science and technology are essential for UK manufacturers to provide opportunities for global competition.

Such changes are consistent with the Government's Manufacturing Strategy Framework (DTI, 2002) that states that in order for high-cost economies such as the UK to sustain and compete in the global market, the activities that are likely to thrive are those that by their nature are complex and high value adding. The DTI Framework encourages manufacturers to focus on support for technological innovation and Research and Development (R&D), in order to help build a successful, knowledge intensive, highly skilled manufacturing sector.

Thus, the study of UK manufacturers is timely to examine their current practice on AMT implementations in order to provide a view of the current state of UK manufacturers in enhancing their technological capabilities in order to achieve their intended competitive advantages. Indeed it is hoped that ideas and suggestions based on the findings from this study can be made in order to help enhance the effectiveness of UK manufacturing companies and allow them to successfully pursue their changing priorities, and thus maximize their contribution to the UK economy.

1.3 Research Problems and Contributions

This section will look at the research problems and issues in terms of the theory underlying the study to derive the research objectives, and outline the expected contributions that the study might have to the manufacturing industry in the UK and to the general AMT literature.

1.3.1 The Research Problems

The underlying premise under investigation in this thesis is the notion that a strategy-AMT fit, leads to superior performance. The study however is guided by contingency theory, which asserts that there is no universal right or wrong answer to a given situation. The right answer always depends on other environmental issues such as size, strategy etc. (Schroeder and Flynn, 2001). The theory argues that applying universal principles without due regard to firm specific variables and a firm's specific strategic orientation can lead to poorer results (Andrews, 1971).

A fundamental assumption of the study is that firms strive to perform at their best, which in line with the recommendations of the Company Law Review Steering Group (2001), is taken to mean that firms aim to maximise shareholder wealth. Thus the research proposition is that manufacturing strategy will seek to configure resource investments in manufacturing technology in such a way so as to maximise manufacturing performance and ultimately its contribution to shareholder wealth creation. Alignment or lack thereof, between manufacturing strategy and technology investments is hypothesised to be a determinant of manufacturing performance. It can also be argued that the technology investments of those firms that achieve superior manufacturing performance, exhibit a high degree of fit with the manufacturing strategy.

As such the fit between the manufacturing strategy and AMT has the potential to have a significant influence on the overall manufacturing performance. What needs to be determined therefore, is what is the best portfolio of AMT to invest in under each possible strategy, given the difference in each firm's underlying position, priorities and competitive advantage.

There are of course some fundamental issues such as the variability of the fit, and indeed the definition of the term "fit" itself within the AMT literature As relatively little attention has been given to conceptualisation of goodness of fit in the AMT literature, and the resulting lack of a specific definition in the operations management field, this study will adopt an holistic approach in defining fit, i.e. it will explore the six perspectives of fit pioneered by strategic management expert, Venkatraman (1989).

Thus, the two main research questions addressed in this thesis are as follows:

(1) Does the type of AMT invested and integrated into the firm, differ according to the type of manufacturing strategy that a manufacturing company is adopting? and

(2) Does a better fit between the levels of integration and investment of AMT and the manufacturing strategy of a particular company, increase that firm's manufacturing performance?

1.3.2 Contributions

The study will provide contributions to both the academic literature and practitioners in manufacturing companies in how to determine the form of AMT to be invested in and how such AMT can and should be integrated into the firm's manufacturing strategy in order to maximize manufacturing performance. Using a contingency theory approach, this study emphasises the internal consistency between manufacturing strategy and AMT. By identifying companies that are high achievers in terms of their manufacturing performance, along with the type of AMT they invested in, and how such AMT was integrated, the study will shed light on exactly what constitutes a good AMT-Strategy fit.

The study will also offer an analytical approach to the selection of manufacturing technology based on the intended manufacturing strategy. Later chapters will develop a technology selection portfolio which supports the particular manufacturing strategy, i.e. the type of AMT which should be utilized based on the competitive priorities of the manufacturing company. It will provide a logical, practical and effective way to make the technology selection that maximises the manufacturing performance, which will be of major benefit to manufacturing corporations.

On an empirical front, the study will provide statistical justification of the appropriate measurement of fit between AMT and the manufacturing strategy and its implication on the manufacturing performance in the UK. It examines the various perspectives of the definition of fit, and proposes a justified and appropriate method to measure the 'alignment' between AMT and strategy, and hence contribute to the contingency theory of fit in the strategic management literature, in the context of AMT implementations. Since AMT implementations are concerned above all with increasing manufacturing performance, these are important contributions.

1.4 Definitions

Definitions adopted by researchers are often not uniform, and ambiguity of terms and notation often leads to unnecessary and unintended controversy in research. Accordingly this section establishes the position and meaning of the fundamental terms as used by this researcher in this thesis. These definitions underlie the data collection procedures and so put boundaries around the findings. Further definitions relating to the core constructs and measurement are provided later in the thesis as appropriate, but the following three terms are fundamental to the whole study and as such definitions are provided below:

(a) ***Advanced Manufacturing Technology (AMT)*** – As defined by Small and Yasin (1997), AMT is "a wide variety of modern computer-based systems devoted to the improvement of manufacturing operations and thereby enhancement of firm competitiveness". Thus, it relates to the use of computer-controlled, programmable machines that are able to process, and hence add value, to a large variety of differing parts and components, without incurring major changeover or setup cost. This type of flexible automation can span vast functions in manufacturing firms, such as product design, production planning, process planning, material handling, production, and inspection and testing. The application of AMT in the manufacturing function has contributed to the achievement of the companies' competitive advantages (Dean and Snell, 1991; Udo and Ehie 1996; Sum and Yang, 1993; Gupta and Somers 1992).

This study adopts a holistic technology perspective, which investigates the whole range of AMT, which can be categorised into five distinctive groups based on their functionality, each of which is then further subdivided. The divisions are as follows:

(1) **Product design and engineering technologies** (PDETs): These can be further subdivided into four subgroups:

i. Computer-aided design (CAD)
ii. Computer-aided engineering (CAE)
iii. Group technology (GT)
iv. Computer-aided manufacturing (CAM).

(2) **Production planning technologies** (PPTs): These production technologies can be subdivided into three subgroups

i. Material requirement planning (MRP)
ii. Manufacturing requirement planning (MRP II)
iii. Enterprise resources planning (ERP).

(3) **Material handling technologies** (MHTs): This group can be split into the two subgroups of:

i. Automated storage and retrieval systems (ASRS)
ii. Automated guided vehicles (AGV).

(4) **Assembly and machining technologies** (AsMTs): These assembly technologies are generally of two types:

i. Computer-aided quality control (CAQC)
ii. Robotics
iii. Numerical controlled machines (NC/CNC/DNC).

(5) **Integrated manufacturing technologies** (IMTs): This final group can be split into two subgroups:

i. Flexible manufacturing cells or systems (FMC/FMS)
ii. Computer integrated manufacturing (CIM).

Hence, in total there are 14 subgroups of technologies that investigated in this study (See Appendix 1: Definition of AMT investigated, for more information). The list is adopted from Small and Yasin (1997) and Small and Chen (1997), and is consistent with the forms of AMT commonly used in manufacturing companies as defined by the existing literature. Note, the popular Just-In-Time is not included as a form of technology investigated, as this is regarded as a management or strategic philosophy that may exploit one of the above technologies, rather than being a form of AMT in its own right.

(b) ***Manufacturing Strategy*** – In order to survive, a company needs to maintain its competiveness, i.e. to ensure that customers choose its products or services instead of, and ahead of its competitor's alternatives. The reason why customers choose one competing product or service over another are based on the competitive advantage of the firm, and one means of achieving a competitive advantage is trough the manufacturing function (Schlie and Goldhar, 1995). Thus, this study focuses on the manufacturing function or production processes that produce the goods.

The manufacturing function can involve a wide variety of activities ranging from product design and development, production planning, logistics and material planning etc. For manufacturing companies, these processes are fundamental to the organisations wellbeing (Slack et al., 1995). Manufacturing strategy is relates to the ways and means a company aims to maintain or create a competitive advantage through its manufacturing functions (Porter, 1980)

There are a number of dimensions to the way a company may choose to compete, which are often termed competitive priorities (Muhamad, 1997). Competitive priorities are thus the elements that make up the overall manufacturing strategy, for example, price, quality, delivery, flexibility, innovativeness are all possible elements within an overall manufacturing strategy (Corbett and Wassenhove, 1993; Slack et al., 1995).

This study adopts the generic strategies as suggested by Porter (1985), i.e. cost leadership and differentiation strategy. A firm pursuing a pure cost leadership strategy aims to gain a competitive advantage by becoming the lowest-cost producer in an industry. It aims to market its products at the lowest price in the industry. In contrast, a firm pursuing a differentiation strategy aims to gain a competitive advantage by offering a unique product or service. Differentiation can be on the basis of quality, flexibility and delivery or any other non-price factor.

(c) ***Manufacturing Performance*** – Studies on the effectiveness of AMT implementation utilise various performance measurements. One of the most common measurements used is overall company performance, though this in itself can be measured in myriad of ways (See for example: Swamidass and Newell, 1987; Kotha and Swamidass, 2000; Das and Narasimhan, 2001). These studies thus measure the AMT performance on strategic variables such as corporate longevity, revenue enhancement, improvement in corporative position, after-tax return on total assets, after-tax return on total sales, net profit position, market share gains relative to competition, sales growth position relative to competitors etc.

However, these measures have been criticised due to the fact that they focus only on the economic dimensions of performance, neglecting other important goals of the firm (Robinson and Pearce, 1983); besides the data are often unavailable or unreliable as companies are often reluctant to provide these kinds of performance data (Swamidass and Newell, 1987; Porth et. al., 1998).

The manufacturing or technical performance, on the other hand, measures the effectiveness of AMT against manufacturing bases such as manufacturing cost reduction, quality improvement, delivery speed and reliability, customisation responsiveness, new product introduction time etc which are the claimed to be the direct technical/manufacturing benefits of implementing AMT (Miller and Roth, 1994; Dean and Snell, 1996).

As AMT is used to improve manufacturing directly rather than business performance, the only pure measure of a technology's effectiveness may be its ability to improve manufacturing function (Small and Yasin, 1997). Besides, the failure to meet the technical/manufacturing benefits will almost invariably result in failure on the other performance bases. In fact, an early assessment of the technical/manufacturing performance of AMT can provide an early signal of technology incompatibility or technology implementation problems and be warning of potential future declines in overall performance (Chen and Small, 1994; Muhamad, 1997; Small and Yasin, 1997; Small, 1999; Das and Narasimhan, 2001)

Based on the above arguments, the performance of AMT in this study is measured against the technical or manufacturing performance of manufacturing companies. As the study is to examine the implications of the fit between AMT and the manufacturing strategy on the manufacturing performance, thus the performance measurements used are to reflect the manufacturing strategy under investigation, i.e. cost leadership, quality, flexibility and delivery.

1.5 Methodology

The study set its boundaries around AMT implementation and its relation to the manufacturing strategy and manufacturing performance. As the majority of the AMT usage is by manufacturers producing discrete products, this study focussed on UK manufacturers that are classified under the Standard Industrial Classification (SIC) system as having codes from 27-35 (See Appendix 2). The sample of 2000 companies, along with company details (addresses, etc) was provided by Dun and Bradstreet (UK) and was drawn randomly from all UK manufacturing companies listed under the SIC 27-35 codes.

The study tests the hypotheses developed in the discussion of the literature with regards to the link between the AMT and the type of manufacturing strategy and as such involves a quantitative approach. In order to gather the data for a statistical analysis, a survey was undertaken as the necessary data was not available from any secondary source.

A questionnaire was developed from the relevant literature and refined through discussions with both academics and practitioners. The questionnaire was then sent to all 2000 sample firms in the first week of March, 2005, a copy of which is included in Appendix 3. A reminder was sent in the third week of March to companies who had not responded to the first mail out. A total of 276 questionnaires were received from the mailing exercises (a response rate of 13.8%), the majority of which had been completed by informants from top level management.

The statistical analyses involved the testing of the hypotheses and an analysis of the fit between the manufacturing strategy, the type of AMTs, and its implication on the manufacturing performance. The testing of the hypotheses is conducted by examining bivariate correlations of manufacturing strategies and AMT. Whilst the fit testing is conducted using the multiple fit definition as proposed by Venkatraman's (1989), namely: fit as moderation, fit as mediation, fit as matching, fit as profile deviation, fit as gestalts and fit as covariation.

1.6 Outline of the Thesis

The thesis is organised into eight chapters. As an overview to the whole thesis a brief outline of each chapter is provided below:

Chapter 1: Introduction

This chapter has provided a brief background to the topic of AMT and the motivation for the study, including an initial identification of the gap in the extant literature and the justification for the study. The researcher has provided an overview of the research problem and the objectives that are to be achieved from the study.

In order to provide a better understanding of the scope of the study, the definition of each fundamental variable under investigation, i.e. AMT, manufacturing strategy and manufacturing performance were included here. A brief summary of the research design and methodology, and chapter outlines was also included, to provide a description of the steps and procedures involved in carrying out this study.

Chapter 2: Literature Review - Terminology

This chapter explores in detail the terminology to be used within the thesis, i.e. AMT, manufacturing strategy and manufacturing performance. Terms used by the researcher are carefully defined, in order to establish clear operational definition of variables used in the thesis. As stated by Furlong et al. (2000), an operational definition is a "precise description of the exact procedures or operations used to measure some behaviour of to produce some phenomenon".

Thus this chapter builds a foundation of variables used in the thesis in order to set the boundaries of the study. The chapter defines each of the variables based on an examination of the common definitions found in the literature. It also provides the rationale for selecting one particular measurement form or definition over another.

Chapter 3: Literature Review – Research Framework

Chapter 3 examines previous seminal works in the multiple literatures that are relevant to this thesis, i.e. AMT implementation, strategic management, contingency theory, information technology and production operations management. It demonstrates the conceptual complexity between strategy, AMT and performance.

The chapter achieves two important objectives: (1) to review the extant literature in order to develop the hypotheses for testing, and (2) to outline the theoretical positioning of the contingency theory of fit in understanding the relationship between AMT, strategy and performance. In doing so, it is then able to propose the measurements of fit that are to be used to study the impact of the alignment between AMT and manufacturing strategy on manufacturing performance.

Chapter 4: Methodology

This chapter discusses the research approach taken, i.e. the research method, and the rationale behind its choice as opposed to other possible modes of study that could have been followed. Research design explains the step by step approach taken to achieve the research objectives, which normally involves the following stages: theoretical foundation, research method, data collection, actual research work, data analysis and finally reporting the findings.

It discusses the development of the research instrument, i.e. the questionnaire which was sent to selected companies, the sampling procedure involved in selecting the UK sample and the statistical methods used in analysing the hypotheses, including an analysis of the various ways the "fit" between AMT and strategy can be measured.

Chapter 5: Descriptive Analyses

Chapter 5 presents the descriptive statistics of the companies who participated in this study. This provides essential information on the companies, such as their demographic characteristics, extent of AMT adoption, their manufacturing strategy and the manufacturing performance of these companies. This information is fundamental to understanding the overall nature of the sampled firms and the usage of AMT.

In terms of demographic characteristics, it describes information such as the type of manufacturing business (based on SIC codes), year of establishment, ownership, etc. The chapter moves on to give full coverage of the respondents' adoption of manufacturing strategy, their levels of AMT investment and integration, and their company performance in regards to their manufacturing capabilities. These variables are all analysed by type of industry, age, type of ownership, etc, in order to provide a thorough understanding of the distribution of the sample.

Chapter 6: Hypotheses Testing and Measurement of Fit

This chapter further explores the survey data and analyses the relationship between manufacturing strategy, AMT and manufacturing performance and as such provides answers to the two main research questions of the study. That is, it examines whether the type of manufacturing strategy determines the levels of the investment and integration of AMT by the company, and explores the implications of fit between the AMT and the manufacturing strategy on the manufacturing performance.

The chapter provides detailed results of the statistical procedures involved in conducting the hypotheses testing, and provides results based on multiple approaches to the measurement of fit, e.g. fit as moderation, fit as mediation, fit as gestalts, etc.

Chapter 7: Discussion of Findings

The penultimate chapter begins with a brief recap of the surveyed companies' profiles. It then discusses the findings presented in Chapters 5 and 6, and their consistency or otherwise with the empirical literature discussed in Chapters 2 and 3.

The discussion of findings consists of two major parts: the first part is focused on the findings of the practices of the surveyed companies in relation to their manufacturing strategy orientations, their attitude towards AMT investment and integration, and their perceived manufacturing performance. The second part of the findings is concentrated on the statistical approach in defining fit between the manufacturing strategy and AMT and its implication on the manufacturing performance.

Chapter 8: Conclusions and Implications

This final chapter highlights the conclusions and implications of the research. It reviews the research issues and research problem and provides a summary of the findings of the research. It also discusses the implications for research, policy and practice, which includes suggestions to the top management team, government bodies and other professional bodies. It reviews the implications for theory and highlights the contributions to knowledge that it has made.

The chapter concludes with a discussion of the limitations of the study and provides suggestions for future research, ending with some final thoughts on the contribution of the thesis as a whole.

1.7 Conclusions

The researcher undertook this study in order to address the issue of the fit between manufacturing strategy and AMT in manufacturing companies. This chapter has shown the importance of the manufacturing sector in the UK economy, and argued that a lack of understanding of the link between AMT and manufacturing strategy, and the implication of the fit between them on manufacturing performance is an important issue that has been overlooked by the existing literature.

In addition this chapter has laid the foundations for the remainder of the thesis. It highlighted the research problem and drew the boundaries for the study by presenting definitions, and briefly describing the research design. It also provided a brief outline of the thesis as a whole. The following chapter then will begin a detailed discussion of the extant literature and relevant theories that can be applied to AMT.

CHAPTER 2

LITERATURE REVIEW I - TERMINOLOGY

2.1 Introduction

Having discussed the rationale for, and the background to this thesis in Chapter 1, the following two chapters provide a comprehensive review of the extant literature of Advanced Manufacturing Technology (AMT), manufacturing strategy, and the fit between the two. This is necessary in order to establish the scope of previous research as well as to identify the shortcomings and gaps in the current literature that this research seeks to address.

The review is split into two chapters; Chapter Three, will concentrate specifically on the measurement of fit and the link between manufacturing strategy and AMT. This chapter will concentrate on the development and discussion of the three core concepts used in this study, namely, Advanced Manufacturing Technology (AMT), manufacturing strategy, and manufacturing performance, each of which has been briefly discussed in the preceding pages. The chapter will review in detail, explanations of each as well as provide explanations of activities and manufacturing technologies that will be used in later chapters.

The literature review chapters also provide a means of setting the boundaries and scope of the current research. Only by reviewing the individual meaning of these terms as is understood in the existing literature, can the subsequent chapters investigate unambiguously the link between the three concepts. As such this chapter is fundamental to the thesis as a whole.

2.2 Advanced Manufacturing Technology (AMT)

This section looks at the common definitions of AMT used in the literature in order to draw a specific definition of AMT for this study. An understanding of the development of AMTs in the manufacturing industry is also included in order to have a clear picture of what constitutes AMT. It also provides an overview of AMT constructs and the common measurements used in the AMT literature. The ultimate goal of this section is to provide a list of AMTs which are then subsequently investigated in this study.

2.2.1 Definition of AMT

The root of AMT, according to Small and Chen (1997), is the application of the silicon microchip in manufacturing processes. This is reflected in the widely used definition of AMT as 'a wide variety of modern computer-based technologies' (Majchrzak, 1988; Dean et al. 1992; Small and Chen, 1997; Small and Yasin, 1997; Parker and Wall, 1998). For example, Small and Yasin (1997) define AMT as 'a wide variety of modern computer-based systems devoted to the improvement of manufacturing operations and thereby enhancement of firm competitiveness'. There are also a number of common terms with regard to manufacturing applications, that are often used interchangeable with AMT, phrases such as 'microelectronic-based manufacturing technology', 'new manufacturing technology' or 'computer-aided manufacturing' are among the most common that have been used in the literature.

Some studies on AMT adopt much wider definitions and define AMT as a collection of hard machines and soft practices in a manufacturing setting (Burgess and Guler, 1998,; Clark, 1996; Dean and Snell, 1996; Roth and Giffi, 1995; McCutcheon et al. 1994; Tranfield et al., 1991). In this regard, 'hard machines' refers to physical technologies such as robotics, computers and plant lines, whilst the 'soft practices' refers to systems such as kanban, just-in-time production or set-up time reduction techniques.

Importantly, this study adopts the narrower form of AMT as used by Small and Chen (1997) and thus regards AMT as a wide variety of modern computer-based technologies in the manufacturing environment and hence defines the boundaries of the thesis. According to Small and Chen, these technologies, when properly implemented, monitored and evaluated, can improve the operating efficiency and effectiveness of the adopting firms, and it is this concept that is further explored within this study..

2.2.2 What is AMT?

The use of AMT is often claimed to achieve higher quality levels, greater flexibility, reducing manufacturing cycle times, and lowering costs, since it permits the integration of the full spectrum of production functions and manufacturing processes with computer technologies (Cook and Cook, 1994).

With the use of computer technology, AMT makes the data storing and manipulation possible - data held electronically can be changed and distributed easily and cheaply between these technologies. Companies adopt these technologies for a wide range of activities, ranging from scheduling to quality inspection. For example, there is no physical adjusting on machinery setting when it involves product changes. It can almost always capture data about the processes. Managers can then use the information derived from these technologies to monitor production more accurately and better understand the resources they control (Beaumont and Schroder, 1997).

The existence of AMT in manufacturing industry can be traced back to the late 1940s and during the 1950s, with the development of numerical controlled (NC) machine tools. Through a series of instructions coded on to a paper tape, the United States Air Force was able to control the machine tools electronically, and hence improve upon quality and consistency in the making of complex parts for modern weapon systems (Wall and Kemp, 1987). The NC machine tool replaced the human operator with a mechanism which would always operate the machine tool in exactly the same way in order to achieve greater consistency of product.

In the 1970s, with the advent of cheap and reliable microprocessors, these paper-taped NC controllers were replaced by computer-based control devices, and the result was the computer numerically controlled (CNC) machine tool. Besides allowing a whole range of programs to be stored and edited directly, the controller also enables the communication with other computers and computer-based control devices. This opens up the possibility for developing multi-machine production systems.

With the common control technology, CNC is the natural building block in a progression towards computer integrated manufacturing (CIM) or the factory of the future. These CNC machines can be organised into a cell, and controlled by a central computer which downloads the required programs to individual machines. When automated materials handling (e.g. robots) and transportation devices (conveyors, AGVs, etc) are added and co-ordinated through centralised control, then the system becomes a Flexible Manufacturing System (FMS). Finally, when all the above technologies are integrated with system-wide production control, inventory and other systems, full computer-integrated manufacturing (CIM) is achieved.

Computer-based technologies are also found in other areas of manufacturing firms. For example, computer-aided design (CAD) is a contemporary approach to product and process design. It uses computers to interactively design products and prepare engineering documents. The speed and ease with which sophisticated designs can be manipulated, analysed, and modified with CAD makes review of numerous options possible before final commitments are made (Heizer and Render, 2004). Computer-aided manufacturing (CAM) refers to the use of specialised computer programs to direct and control manufacturing equipment. When CAD information is translated into instructions for CAM, the result of these two technologies is called CAD/CAM (Liker et. al. 1992).

The nature of manufacturing firms that deal with a variety of products and the type of processes involved, demand the technology advancement in material requirements planning. MRP, or Material Requirements Planning, is software developed to determine material requirements for manufacturing firms. The extension of MRP, which is referred to as Manufacturing Resource Planning (MRP II), allows inventory data to be augmented by other resource variables, such as labour hours, material cost (rather than material quantity), or capital cost. In this case, MRP II is integrated with other computer files that provide data to the MRP system. An enterprise-wide resource planning tool, which is called Enterprise Resource Planning (ERP), is an information system for identifying and planning the enterprise-wide resources needed to take, make, ship and account for customer orders, which is the extension of MRP and MRPII (Heizer and Render, 2004).

Automated materials handling (AMH) systems improve the efficiency of transportation, storage, and retrieval of materials in and from warehouses. Automated storage and retrieval systems (AS/RS) provide for the automatic placement and withdrawal of parts and products into and from designated places. AMH can take the form of monorails, computerised conveyors, robots, or automated guided vehicles (AGVs). AGVs use embedded floor wires to direct driverless vehicles to various locations in the plant, delivering materials (Chase and Aquilano, 1995).

Industrial robots are substitutes for many repetitive manual activities (Chase and Aquilano, 1995). A robot is a reprogrammable mechanical device that may have a few electronic impulses stored on semiconductor chips that will activate motors and switches. Robots are used to perform repetitive tasks such as picking and placing devices, spot welding, and painting. Robots or automation are widely used to carry out quality inspection on incoming or final products.

In general the history of AMT is one of a progression from the automation of individual machine tools (NC, CNC), through integration among such machines (DNC), towards much higher levels of integration involving large-scale monitoring and controlling systems (FMS, CIM) (Canada and Sullivan, 2000). As the complexity and extensiveness of the inventories and orders involved in the production environment increases, the development and the adoption of MRP, or MRP II or ERP is inevitable. Manufacturing firms use CAD and CAM to facilitate the design activities and the control of machinery. ASRS and AGVs are used to move incoming materials and parts, work in progress, and final product. Robots are used to perform repetitive tasks in order to achieve consistency, accuracy, speed and strength, while computer-aided quality control inspection systems ensure the quality standards of incoming materials and final products. These computer-based technologies provide manufacturing firms with a new capability for manufacturing – made possible due to the development of a generic, robust, and cheap core information technology.

Given the wide range of computer-based technologies that can be found in manufacturing firms, the holistic technology perspective, which covers the whole range of AMT, is believed to be the AMT research wave of the future, which is in line with the focus of this study. The list of AMTs used in this study is similar to that put forward by Small and Yasin (1997) and Small and Chen (1997). However, the management practice element – JIT, is excluded due to the fact that it is not a technology, but instead more of a practice.

The list of AMT investigated in this study, together with its definition is presented in Table 2.1 as follow:

Table 2.1: List of AMTs: Definitions

Type of Technology	Definition
Computer-aided design (CAD)	CAD is used to design and develop products, these can be goods used by end consumers or intermediate goods used in other products. CAD is also extensively used in the design of tools and machinery used in the manufacture of components. CAD is used throughout the engineering process from conceptual design and layout, through detailed engineering and analysis of components to definition of manufacturing methods (Kotha and Swamidass, 2000). It consists of the following component parts: CAD computer, computer peripherals, operations software, and user software. When CAD is integrated with CAE: Use of computers for drawing and designing parts or products and for analysis and testing of designed parts or products. It assists in the design and drawing process - new products or modifies existing products. It includes the direct graphic-interactive generation of two- or three-dimensional data models with subsequent graphic output, supporting activities such as calculations (e.g. the finite-element method) or simulations (see Maier, 1985).
Computer-aided engineering (CAE)	CAE software assists the engineer while examining and testing design from a structural or engineering point of view. This package is very similar to CAD software (Skinner, 1984).
Group technology (GT)	GT assists in designing and testing a product, from a structural or engineering point, controlling of manufacturing machinery, and also for part classifications and coding systems (Slack et al, 1995).
Computer-aided manufacturing (CAM)	Computer-aided manufacturing (CAM) refers to the use of specialised computer programs to direct and control manufacturing equipment. When CAD information is translated into instructions for CAM, the result of these two technologies is called CAD/CAM (Harrison, 1990). It encompasses the software to control manufacturing machinery. It produces the information required to determine the process of manufacture. For example, if the product is to be processed on a CNC, CAM will determine the movements of the tooling, cutting speeds, etc.

Type of Technology	Definition
Manufacturing Resource Planning (MRP, MRPII)	The application of computer aided systems in the planning and control of contract filling and manufacture as regards disposal and organisation, including determination and management of material needs, dates, and capacities; that is, the administration of bills of materials, operations scheduling, materials, and time as well as the recording of operating data, the planning of production and/or the management of customer orders (Harrison, 1990). It controls the entire manufacturing system from order entry through scheduling, inventory control, finance, accounting, accounts payable and so on (Harrison, 1990; Slack et al., 1995). **Material Requirement Planning (MRP)** – uses to determine and manage material needs, dates, and capacities by using bills of materials, operations scheduling, materials, and time as well as the recording of operating data. A useful tool for the planning of production and/or the management of customer orders (Harrison, 1990; Slack et al., 1995). When MRP is extended to other areas of the business to include the other various resources, it is called **Manufacturing Resource Planning (MRP II)** – planning of all the resources of a manufacturing company, i.e. manufacturing, marketing, finance and engineering. It is based on one integrated system containing a database which is accessed and used by the whole company according to individual functional requirements (Harrison, 1990; Slack et al., 1995).
Enterprise Resource Planning (ERP)	ERP is an extension of MRP II. ERP integrates business processes by using a centralised database. It contains modules to allow efficient reporting and decision making throughout the company, process data interactively and to be available in real time, and it also allows easier global integration (Slack et al, 1995).
Automated material handling (AMH) – Automated storage and or retrieval system (ASRS)	Automated materials handling system which use computers to direct automatic loaders to pick and place items. Storage automation is mostly effected by means of (elevated) shelf storages which are operated by automatic high-lift trucks. It can also include automatic identification of items and interfacing with automatic guided vehicles (AGV) (Slack et al, 1995).

Type of Technology	Definition
Automated Guided Vehicles (AGV)	Transport automation is in most cases undertaken by driverless transport systems, such as automated guided vehicles (AGVs) or rail-guided vehicles, also by suspended conveyors and roller conveyers or conveyor belts. AGVs are small independently powered vehicles which move materials to and from value-adding operations. They are usually guided by cables buried in the floor of the operation and receive instructions from a central computer. Variations on this arrangement include AGVs which have their own on-board computers or optical guidance systems (Harrison, 1990).
Computer-aided quality control	Computer-aided quality control systems - Automatic inspecting and testing performed on incoming materials and/or final product which carry out quality inspections performed by automation or robotics (Slack et al, 1995).
Robotics: simple pick and place robots or more complex robots	Robotics was first introduced for industrial applications in the early 1960s. It often has the appearance of one or several arms ending in a wrist. Its control unit uses a memorizing device and sometimes it can use sensing and adaptation appliances that take account of the environment and circumstances (Slack et al, 1995; Harrison, 1990). These multi-purpose machines are generally designed to carry out repetitive functions and can be adapted to other functions without permanent alteration of the equipment. The movement of robots is controlled in a similar manner to NC machine tools but most robots have many degrees of freedom. Robots can be classified based on their application as handling robots, process robots and assembly robots.
Computer Numerically Controlled machines (CNC) or numerical controlled machines (NC)	Machining tool which is directly linked to a computer that controls it. The information can either be stored on disk/ computer (CNC), or in a form of a punched paper tape (NC). This information controls the movements of its tools and the speed of the machine throughout the processing operation. The set of coded instructions and the computers attached to the machine have taken the place of the operator who would previously have controlled the machine by hand. Today, CNC controls are mostly applied for turning machines, boring and milling machines, horizontal boring machines, and machining centres. Other machining work holds a share of over 20% in NC/CNC machines, the principal share being held by grinding and erosion machines; but CNC controls exist for almost types of machining (Slack et al, 1995).

Type of Technology	Definition
Flexible manufacturing cells (FMC) or systems (FMS)	Consists of two or more NC/CNC machines which are interconnected by handling devices (such as robots) and transport system. A FMS can work on more than one different work piece simultaneously. It allows varying machining operations on different workpieces to be performed within a given area (Lindburg, 1992). The NC workstations perform the machining operations, robots which move parts to and from the work stations, transport/ material handling facilities which move the parts between work stations, and operated under the guidance of a central computer system. FMC – capable of single path acceptance of raw materials and single path delivery of a finished product; FMS- capable of multiple paths. May also be comprised of 2 or more FMCs linked in series or parallel.
Computer Integrated Manufacturing (CIM)	Incorporate CAD, CAM and also the control of FMS. It integrates all elements in the manufacturing process from product design to distribution (CAD/CAM, CNC, robots, AGV, production planning, logistics). It links beyond company departments by integrating computer systems, thus islands of computer application in the firms are integrated (Lay, 1990; Udo and Ehie, 1996). A variety of single elements are designed in a specific way to link already installed systems. With CIM, an uninterrupted digital information flow is created between all computer assisted technical and administrative departments of a plant; avoiding multi-programming and multi-keeping of the same data in the memories of the computer systems in different departments (Boaden and Dale, 1986).

2.2.3 What Constitutes AMT?

There is no specific list of what constitute AMT. From the AMT literature, studies on AMT can investigate an individual technology (Burcher, et al. (1999) on CNC machine); technologies related to specific function, such as Pagell, et al. (2000) investigate two types of process technology: FMS and CNC; or cover the whole range of technologies from production planning to distribution (Rosenthal, 1984; Warner, 1987; Adler, 1988; Dean and Snell, 1996; Small, 1999; Heijltjes, 2000; Swamidass and Kotha, 1998; Boyer et al; 1996). Some of the AMT studies include other general information technology applications, such as local area network (LAN) (see in Kotha (1991), and Kotha and Swamidass (2000), or some management philosophies, such as just in time (JIT) (Small, 1999); total quality management (TQM); or administrative applications such as decision support systems, EDI etc (Boyer et al, 1996).

Some studies treat AMT as a uni-dimensional construct, which treats each technology as an individual technology, whilst some studies use a multidimensional construct which divides AMT into categories of technologies based on their attributes or functions. In this case, AMTs are grouped into smaller and more manageable subgroups. Some of these emerging multidimensional views on AMT are not necessarily tested and established by empirical data, but they are useful guides for conducting empirical studies, and they are useful inputs to the development of future conceptual schemes.

Several conceptual schemes have been offered to grapple with the flexible nature of AMT (Goldhar and Jelinek, 1985; Adler, 1988; Swamidass, 1988; Dean and Snell, 1991, 1996; Dean et al., 1992; Gerwin, 1993; Gerwin and Kolodny, 1992; Parthasarthy and Sethi, 1992). These schemes make valuable contributions to understanding AMTs.

Kotha and Swamidass (2000) have called on the future study on AMT to consider AMT as a multidimensional construct. As the study is to understand the AMT-strategy-performance configurational synergy in organisations, the use of a multidimensional construct is appropriate to conceptualise and understand in greater detail the often subtle relationships among these constructs (Kotha and Swamidass, 2000). Besides, this broader view of AMTs facilitates the study because it permits the many dimensions of AMTs to be matched against several possible manufacturing functional strategies while studying the notion of fit and its implications for firm performance. Therefore, this conceptual classification of AMT forms the basis for the operationalisation of AMT in this study.

A search on the AMT literature found that more and more studies on AMT are taking on a multidimensional view of AMT. The multidimensional view of AMT takes many forms. Heijltjes (2000) classified 9 types of technologies into three broad group based on its usage:

(1) Methods for design – such as CAD, and CAE.
(2) Methods for flexible manufacturing – such as CAM, CNC machines, Robotics and FMS
(3) Methods for computerised planning and control – such as MRP, ERP, Supply Chain Management (SCM).

Small (1999) also divides the technologies into three categories, but this time based on the benefits associated with each classification.

(1) Integrated process and information/logistic technologies which comprises of CAD, NC/CNC/DNC, MRP, MRPII, JIT, FMS, CIM, ROBOTS;
(2) Integrated information/logistic technologies which comprises of CAD, NC/CNC/DNC, MRP, MRPII, JIT; and
(3) Non-integrated technologies which comprises of CAD, NC/CNC/DNC.

Boyer et al. (1996) empirically derived 3 separate dimensions of AMT: Design, manufacturing and administrative. Design included a mix of design and process technologies such as CAD, CAE, CAM, computer-aided process planning, and the use of CNC equipment. Manufacturing covered technology elements such as FMS, real time process control systems and robotics, while the administrative dimension included MRPII, EDI, and knowledge and decision support systems.

Kotha (1991) groups the various AMTs into 4 groups on the basis of the imbedded information processing capabilities: (1) product design technologies (PDT): CAD, CAE, and automated drafting technologies that focus primarily on product definition, and design-related information processing functions; (2)Process technologies (PT): FMS, NC, and programmable controllers that focus on the process aspects of manufacturing, thus these technologies control manufacturing processes and generate process related information on the factory floor; (3) Logistics/ planning technologies (LPT): focus on controlling and monitoring the material flow from the acquisition of raw materials to the delivery of finished products, and related counter flows of logistical information. It includes production scheduling systems, shop floor control systems and MRP systems; (4) information exchange technologies (IET): help facilitate the storage and exchange of information among process, product, and logistics technologies identified above. Technologies such as common databases, system translators, data transfer protocols, and intra- and inter-factory networks belong to this group.

Das and Narasimhan (2001) treat AMT as a multi-dimensional construct, encompassing initiatives in manufacturing design, manufacturing technology, manufacturing infrastructure, and human resource management practices.

Swamidass and Kotha (1998) developed 4 dimensions: information exchange and planning technologies (MRPII, EDI etc), and product design technology (CAD/CAE), and distinguished between high volume automation technology (robotics, manufacturing automation, computer-aided inspection etc) and low-volume automation technology (CNC, CAD, CAM, FMS).

Small and Yasin (1997) and Small and Chen (1997) divide AMT into three categories based on the level of integration: (1) Stand-alone systems: Design and Engineering (CAD, CAE, Group Technology (GT) and CAM); machining/ fabricating (CNC, robots); (2) Intermediate systems: Material handling (ASRS, AGV); inspection/ testing (CAQC), (3) Integrated: FMS, CIM and logistic-related systems (MRP, MRP II, ERP).

A careful examination of these conceptualisations reveals it is possible to divide those 14 AMT investigated into five clear AMT domains: (1) a design and planning domain, i.e. Product Design and Engineering Technologies (PDET): concerned largely with design and engineering technologies, such as CAD, CAE, GT and CAM; (2) a production planning and logistics-related domain i.e. Production Planning Technologies (PPT): concerned with production and logistic planning, such as MRP, MRP II and ERP; (3) a materials handling domain i.e. Material Handling Technologies (MHT): which concerned with handling and transporting of materials, such as ASRS and AGVs; (4) a manufacturing domain i.e. Assembly and Machining Technologies (AsMT) – concerned with repetitive production technologies such as CAQCS, robotics and numerical control machine (NC/CNC/DNC); (5) an integrated manufacturing domain, i.e. Integrated Manufacturing Technologies: comprises of integrated and flexible manufacturing technologies such as FMS and CIM. Thus, this study classifies AMT based on its functions.

The level of integration was not included in this dimensional classification, however, as each individual type of AMT is capable and possible to be integrated with any other type of AMT, thus, we will discuss the integration measurement of AMT in the next section.

Table 2.2: Comparison of Multidimensional Views of AMT

Classification	Authors and year of publication
1. Computer-aided design group 2. CAD/CAM group 3. Computer-aided manufacturing group 4. Factory management and control group	Rosenthal (1984)
1. Shop floor technologies with intelligence 2. Product oriented technologies 3. Information and control technologies	Warner (1987)
1. Design automation 2. Manufacturing automation 3. Administrative/ control technologies	Adler (1988)
1. Information exchange and planning technologies (MRPII, EDI, computers for production planning etc), combined the logistic and planning technologies (LPT) and Information Exchange Technology (IET) from Kotha (1991) 2. Product design technology (CAD/CAE, automated drafting technologies), 3. High volume automation technology (robotics, manufacturing automation, computer-aided quality control etc) (split the Process Technology (PT) in Kotha (1991). 4. Low-volume automation technology (CNC, CAD/ CAM, FMS).	Swamidass and Kotha (1998)
1. Product design technologies (PDT): CAD, CAE, and automated drafting technologies 2. Process technologies (PT): FMS, NC, and programmable controllers; 3. Logistics/ planning technologies (LPT): includes production scheduling systems, shop floor control systems and MRP systems; 4. Information exchange technologies (IET): such as common databases, system translators, data transfer protocols, and intra- and inter-factory networks.	Kotha (1991)

Classification	Authors and year of publication
1. Stand alone systems • (a) Design and engineering technologies: CAD, CAE. • (b) Machining, fabricating and assembly technologies: NC/CNC/DNC, robotics, lasers. 2. Intermediate systems • (c) automatic material handling technologies: ASRS. • (d) automated inspection and testing equipment: computer-aided quality control 3. Integrated systems • (e) FMS • (f) CIM • (g) logistic-related technologies/ or management/information technologies: JIT, MRP, MRPII.	Small and Chen (1997), Small and Yasin (1997).
1. Integrated process and information/ logistic technologies: CAD, NC/CNC/DNC, MRP, MRPII, JIT, FMS, CIM, robots 2. Integrated information/ logistic technologies: CAD, NC/CNC/DNC, MRP, MRPII, JIT; and 3. Non-integrated technologies which comprises of CAD, NC/CNC/DNC	Small (1999)
1. Design: included design and process technologies such as CAD, CAE, CAM, computer-aided process planning, and the use of CNC equipment. 2. Manufacturing: FMS, real time process control systems and robotics, 3. Administrative: MRPII, EDI, and knowledge and decision support systems.	Boyer et al. (1996)
1. Methods for design: CAD, and CAE. 2. Methods for flexible manufacturing: CAM, CNC machines, Robotics and FMS; 3. Methods for computerised planning and control: MRP, ERP, SCM.	Heijltjes (2000)
1. Hardware-based technologies 2. Software-based technologies	Udo and Ehie (1996)

2.2.4 The Measurement of AMT

AMT is often measured using the extent of use, or the level of investment. However, there is still lacking any study that uses the level of integration to measure the extensiveness of AMT usage in companies. Studies have, in the past, classified AMTs into integrated or non-integrated technologies, or intermediate technologies or stand alone technologies (see Small and Yasin, 1997; Small and Chen, 1997; and Small, 1999). It is indeed not entirely true as mentioned by Maier (1985), CAD, which often regarded as a non-integrated technology, can be directly linked to the manufacturing function, through coupling with CAM systems.

According to Wall and Kemp (1987), most of the AMT are commonly found as 'stand-alone' technologies. However, with a common information processing base, they have the potential to be combined into more comprehensive production systems. It uses an array of flexible resources that are monitored by extensive information systems (Doll and Vonderembse, 1991). Thus, this study explores the possibility of adopting another measurement which is the level of integration. Integration has become synonymous with a utilitarian goal of greater efficiency, effectiveness and competitiveness in organizations (Wainwright and Waring, 2004).

The rationale of assessing the level of integration of AMT is due to the fact that the major strength of AMT is its ability to facilitate enterprise-wide integration, as compared to other manufacturing systems like dedicated manufacturing systems (DMS) (Cook and Cook, 1994). Manufacturers employing AMT are often more flexible than their traditional counterparts since AMT permits the integration of product design and production processes (Cook and Cook, 1994). It allows more rapid product development with fewer flaws and at lower costs.

Manufacturing 'policy' has evolved from task specialisation to mechanization to automation to integration, where human intelligence is being replaced by machine intelligence and integrated with physical machine processes (Schlie and Goldhar, 1995). Thus, manufacturers no longer emphasise the passive supportive role of production, but rather its ability to facilitate enterprise-wide integration. This integration of computer-based control systems and manufacturing processes creates production systems that are more flexible, reliable and productive. The integration, not only within the manufacturing function, but rather the entire organisation, creates competitive advantages (Cook and Cook, 1994).

One key aspect of successful AMT systems that researchers may have neglected to incorporate under the rubric of AMTs is the level of integration of different AMT. In order to reap the full benefits of AMTs, companies need to use all of the AMT, rather than just few of them (Kotha and Swamidass, 2000). This may be the heart of AMT effectiveness as argued in the extant literature (Meredith, 1987; Dean and Snell, 1996), which denotes that the use of all AMT factors increases the potential for integration.

For the study, integration is referred to any kind of systems inter-relationships, which includes integrated, interfaced, stand-alone and universal (Das, 1992). Thus, the technologies investigated are regarded as integrated regardless of whether one- or two-way communication with other elements, sharing of database, decision making by either or both parties etc. Four types of integration were introduced, i.e. no integration or a stand alone piece of technology; limited integration where integration within the manufacturing department; full integration refers to company-wide integration; and finally, extended integration which encompass the whole enterprise-wide integration, stretched over its supply chain.

2.3 Manufacturing Strategy

This section will look at the common definition of manufacturing strategy in the strategy literature, and its distinction with other common terminologies in the strategy literature, i.e. operations strategy, corporate strategy, competitive advantage, competitive factor, or competitive priority. An understanding of the function of manufacturing strategy in manufacturing companies is also included in order to have a clear picture of its role. Besides providing the definition of manufacturing strategy used for this study, this section will also provide the operationalisation of manufacturing strategy.

2.3.1 Definition of Manufacturing Strategy

Manufacturing strategy is an area of growing concern in most industries. In order to find an appropriate definition of manufacturing strategy for this study, it is useful to review the terms commonly use in the strategy literature. Other terms like operations strategy, competitive advantage, competitive priority, and corporate strategy are worth mentioning for better understanding of the concept.

In practice, different organisations will adopt different organisational structures and define different functions. Manufacturing and operations are the common terms used to refer to the function or department which produces their goods and services. In this study, the term manufacturing will be used to reflect the manufacturing activities in the manufacturing industry. The manufacturing function is central to the organisation because it produces the goods which are its reason for existing (Slack et al, 1995). This function is important to the organisation because it directly affects how well the organisation satisfies its customers.

What are the exact boundaries and responsibilities of the manufacturing function vary between organisations – companies can either adopt a narrow organisational definition of the manufacturing function, which exclude all activities shared with any other functions, or a broad definition which include all activities that had any connection with the production of goods (Slack et al, 1995). This study adopts the somewhat broader definition of manufacturing. Activities which span from product design and development, production planning, logistics and material planning are coming within the sphere of the manufacturing function. This is in line with the types of AMTs being investigated in this study, which are technologies employed to carry out or to assist to carry out these activities.

Before we proceed to the types of manufacturing strategies available to manufacturers, it is perhaps useful to have some understandings of terms common in strategy literature such as competitive strategy, competitive advantage and competitive priority. According to Porter (1980 and 1985), competitive advantage is created but not inherited. It is the general term to judge a firm's strength and position in a market (Porter, 1980 and 1985). It is a generic concept without specifying the means. Companies can achieve competitive advantage through acts of innovation which include both new technologies and ways of doing things (Porter, 1990). Thus, through technology innovation and advancement, competitive advantage is created. According to Porter (1990), it is because technology highlights the critical strength or weakness of a company and it has been evident as the primary force to create competitive advantage dynamically.

Competitive strategy defines its means - a broad formula for how a business is going to compete, what its goal should be, and what policies will be needed to carry out those goals (Porter, 1980). Porter (1980) organises the universe of competitive strategies into three generic types – low-cost leadership, differentiation and focus. Schlie and Goldhar (1995) argue that the focus strategy is more an element of competitive scope than a strategy in and of itself. Thus, Porter's framework of generic strategies is viewed in terms of two generic strategies – cost leadership and differentiation.

Competitive strategies are implemented via 'policies' that direct and govern the functional activities of the firm such as manufacturing, marketing, finance etc. Porter (1985) organises all of the firm's activities in his model of the value chain, and a firm gains competitive advantage by performing value chain activities cheaper or better or differently than its competitors and by managing linkages among its value chain activities or between its value chain activities and those of its suppliers or customers.

Schlie and Goldhar (1995) define competitiveness as the ability to get customers to choose your products or services over competing alternatives on a sustainable basis. The reason why customers choose one competing product or service over others are competitive advantages, and one means of achieving competitive advantage is through the manufacturing function. The application of AMT in the manufacturing function has contributed to the achievement of the companies' competitive advantages (Dean and Snell, 1991; Udo and Ehie 1996; Sum and Yang, 1993; Gupta and Somers 1992; Choobineh 1986; Kerr and Greenhalgh, 1991; Schlie and Goldhar, 1995).

Competitive priorities are the elements making up a set of dimensions in the manufacturing strategy, namely price, quality, delivery, flexibility and innovativeness (Kathuria & Igbaria, 1997). These dimensions are sometimes used as measures of (external) competitiveness and sometimes of (internal) competence (Corbett and Wassenhove, 1993). Thus competitive priorities may be defined as a consistent set of goals for manufacturing, consistent with the corporate or business unit goals (Muhamad, 1997).

Manufacturers seek to satisfy customers through developing their performance objectives. For example, if customers particularly value low-priced products or services, the operation will put emphasis on its cost leadership performance. If customers insist on error-free products or services, the operation will concentrate on its quality performance. These factors which define the customer's requirements are called competitive factors.

Each company has its own manufacturing strategy to guide its manufacturing activities. The ability of a manufacturing company to compete is set by its manufacturing capabilities, which must be planned in total alignment with the firm's goals and strategies (Gudnasson and Riis, 1984; Swamidass, 1986; Hill, 1994). According to Kerr and Greenhalgh (1991), manufacturing strategy can be viewed as the effective use of manufacturing capability for the achievement of business and corporate goals. It dictates how a product is manufactured, how resources are deployed in production, and how the infrastructure necessary to support manufacturing should be organised (Groover, 1987; Hayes and Wheelwright, 1979). It creates and adds value by helping a firm establish and sustain a defensible competitive advantage that is the unique position an organisation develops against its competitors (Zahra and Das, 1993).

In short, manufacturing strategy answers the question of what are the most important aspects of the products and services a company provides. It determines the priority of its performance objectives, i.e. which performance objectives are particularly important to it. Should it concentrate on being particularly good at quality or speed or dependability or flexibility or cost or perhaps some combination of two or more of them?

2.3.2 What is Manufacturing Strategy?

Manufacturing strategy has been viewed from many perspectives in the literature. The various definitions have shown that manufacturing strategy has three generic properties of: (a) supporting the corporate objectives, (b) providing manufacturing objectives of cost, quality, dependability and flexibility, thus offering competitive advantage, and (c) focusing on a consistent pattern of decision making within key manufacturing resources, which include structural items and the appropriate infrastructure to ensure that operations are effective (Muhamad, 1997).

This study adopts Porter's generic definition of manufacturing strategy, i.e. cost leadership and differentiation strategy. These two strategies, i.e. low-cost and differentiation, are commonly accepted 'generic' dimensions of strategy that have successfully withstood many empirical tests in the strategy literature (Robinson and Pearce, 1988; Nayyar, 1993). As such, this study follows the same strategy framework as other AMT-strategy research, for example, Allen et al (2007) also use Porter's generic strategies in their recent study of AMT. They are of the opinion that even though various types of strategies have been identified over the years, Porter's generic strategies remain the most commonly supported and identified in key strategic management textbooks.

According to Porter (1980), a firm pursuing a pure cost leadership strategy aims to gain a competitive advantage by becoming the lowest-cost producer in an industry. Thus the emphasis is on efficiency, high productivity and economies of scale. Companies will pursue rigorously on cost reduction from all possible sources, with the objective of selling their products at the lowest price in the industry. In contrast, a firm pursuing a differentiation strategy aims to gain a competitive advantage by offering a unique product or service. Differentiation can be on the basis of design, quality, reliability, product or any other non-price factor.

Past research that has focussed on manufacturing strategy has at times defined such strategy in terms of the ability of the organisation to achieve low costs, have high flexibility, or superior dependability and quality (Hayes and Wheelwright, 1984; Hill, 1994; Schroeder et. al., 2002). However, such definition of strategy can still be viewed as being consistent with Porter's definition of strategy, i.e. – cost-leadership and differentiation strategy. The competing views of strategy ultimately represent expansions of the two generic strategies.

Based on these notions, this study will focus on the two generic manufacturing strategies, namely cost leadership and differentiation strategy proposed by Porter (1980, 1985). The next section will look at more details of each strategy and their manufacturing characteristics. These strategies are discussed under each strategy heading, such as cost, quality, delivery, and flexibility. The study is adopting the approach of treating manufacturing strategy as its operational strategy dimensions of cost, quality, delivery and flexibility (See Muhamad, 1997).

2.3.2.1 Cost Leadership Strategy

A cost leadership strategy, or merely cost strategy, emphasises high volume production and efficiency (Clark, 1996). It emphasises on efficiency and cost reduction from all possible sources (Kotha and Swamidass, 2000). Companies with a cost leadership strategy have the tendency to place a great reliance on standardisation and simplification through low product variety and high volume production (Porter, 1985)

Measurements of cost leadership strategy vary. Kotha and Swamidass (2000) adopt measurements from Dess and Davis (1984) and Robinson and Pearce (1988). Kotha and Swamidass emphasise on the continuing concern for cost reduction in all possible sources. Muhamad (1997) defines cost as the overall cost of the product, which is basically the sum of the costs incurred at each of the functional areas of design and engineering, procurement, manufacturing, marketing and sales, as well as those associated with the general administration of the company. Thus, companies positioning such a strategy would compete on the basis of lowest cost involved in operations, which in turn is capable to offer the cheapest price in the market.

2.3.2.2 Differentiation Strategy

Differentiation aims for low market share and thrives on a perception of exclusivity (Porter, 1980). The perception of exclusivity can take form in terms of quality of product, speed of delivery, dependability of delivery (reliable delivery), or flexibility (Slack et al, 1995)

Companies with a differentiation strategy will select one or more attributes that consumers perceive as important and position themselves to meet those needs, and seek reward for its uniqueness by charging a premium price (Porter, 1985). They normally have lower volume of production, and emphasis on flexibility and adaptiveness toward the marketplace (Kotha and Swamidass, 2000).

2.3.2.2.1 Quality Strategy

'Quality' can be interpreted into many dimensions. Quality is governed by the degree to which technical specifications of the product satisfies the customer demands, some viewed as the percentage rejects and rework that influence the performance (Muhamad, 1997).

A common definition of product quality from a customer's perspective is fitness for use (Juran and Gryna, 1993). As the study is to investigate the manufacturing strategy, the definition of quality is from a manufacturer perspective, which emphasises primarily the quality aspects related to zero defect error products, product reliability, and conformance to specification.

2.3.2.2.2 Flexibility Strategy

Firms are placing increasingly an emphasis on the adoption of AMTs that have a proven ability to enhance flexibility (Sambasivarao, 1995; Small and Chen, 1997; Swamidass and Kotha, 1998). Flexibility is made feasible by integrating AMT into other functional areas in the company (Cook, 1990). Through programmed flexibility, these technologies allow a variety of products to be manufactured with minimal change-over and set-up disruption, maximising both flexibility and production (Swamidass and Kotha, 1998; Schroder and Sohal, 1999). Such flexibility permits the production of a wide variety of products at low volumes without added cost or penalty.

Flexibility is the term used to describe the ability to respond effectively to a changing environment. In the strategic context, manufacturing flexibility is the ability of a manufacturing organisation to adapt its resources effectively in response to changing market conditions, significantly epitomised by variability in product demands (Muhamad, 1997). At the strategic level, the flexibility requirement is expressed in terms of product mix changes and volume demand variations. Besides, market flexibility, is the ease with which changes in the market environment can be responded to, and production flexibility, is the universe of part types that can be produced without undergoing major changes such as the addition of major capital equipment (Muhamad, 1997).

Flexibility is considered to have two interdependent dimensions – a time dimension which focuses on the speed of the response to customer needs and a range dimension which is concerned with the ability to meet varying customer customisation and volume requirements in an efficient cost-effective manner (Small and Chen, 1997).

Mix flexibility is the ability to provide wide range or mix of products (Slack et. al, 1995). Companies produce a wide range of products in order to respond to a variety of market needs (Hambrick, 1983). The product flexibility player will strive to have frequent new product development and high product variety (Kotha and Swamidass, 2000). They are able to offer new models into existing products, and also to launch new product lines to new customers. They exhibit greater product innovation and greater dynamism in product mix than cost leaders (Porter, 1980).

2.3.2.2.3 Delivery Strategy

The delivery requirement can be further broken down to the delivery reliability and the delivery speed. Delivery dependability means doing things in time for customers to receive their goods or services when they were promised (Slack et al, 1995)

Speed is referred to as the responsiveness to customer demands, i.e the speed to reach to customer. This can be done by decreasing the manufacturing cycle time (Cook, 1990; Cook and Cook, 1994). For example, CIM systems are capable of moving through products in as quickly as one day, as contrasted with several weeks when using the manual batch-assembly process (McKenna, 1992).

2.3.3 Conclusions

This study adopts the two main generic strategies identified by Michael Porter (1985) – cost leadership and differentiation strategy. The cost leadership strategy involves positioning the organisation as a low cost producer of a standard 'no frills' product for either a broad or a focused market, whilst the differentiation strategy, on the other hand, requires that an organisation's product or service becomes unique on some dimension which is valued by the buyer, thus ensuring a premium price. The basis for a differentiation strategy may be the quality, flexibility or delivery dimension of the product.

2.4 Performance Measurement

This section reviews the current performance literature to derive the appropriate performance measurement for the study. First, we look at the existing approach of studying AMT performance, and the next section justifies the selection of the appropriate approach for performance measurement. The measurement construct for each performance criteria concludes this section.

2.4.1 AMT Performance Measurement

A trawl of the existing AMT literature found that studies on the effectiveness of AMT implementation utilise various AMT performance measurements. The most common AMT performance measurements used are business performance, financial performance, manufacturing or technical performance, or a combination of the above performances. As the study is looking at the fit between AMT and manufacturing strategy, two areas of literature are reviewed in order to find an appropriate way of measuring the performance, i.e. AMT literature and manufacturing strategy literature.

One of the most common used performance measures for empirical studies of the effectiveness of AMT adoption is company performance (Kim and Lee, 1993; Swamidass and Newell, 1987; Robinson and Pearce, 1988; Venkatraman, 1989; Ward and Duray, 2000; Kotha and Swamidass, 2000; Das and Narasimhan, 2001). These studies measure the AMT performance on strategic variables like corporate longevity, revenue enhancement, improvement in corporative position, and other financial performance. For example, Kotha and Swamidass (2000) use six items to study the effectiveness of AMT: after-tax return on total assets, after-tax return on total sales, net profit position, market share gains relative to competition, sales growth position relative to competitors, and overall firm performance/ success.

There are strong conceptual grounds for arguing that each initiative will contribute to company performance, and it is precisely because they should do, that they have proved so attractive to companies. Small (1998) reveals that firms tend to judge their AMT systems on three interdependent bases: technical/manufacturing, organisational development and adaptation, business/competitive. Each technology offers its own basket of differentiated operational, strategic and marketing capabilities (Primrose, 1991; Small and Chen, 1995; Demmel and Askin, 1996; Lefley, 1996). Robb and Xie (2003) point out that a number of manufacturing policies, including those related to hard and soft technology are strongly related to both competitive objectives and the financial performance of the firm. According to Kakati (1997), such business performance should receive top priority while evaluating AMT.

Nevertheless, there are contradicting views of using financial measures to measure AMTs performance. For example, the use of accounting measures have been criticised due to the fact that they focus only on the economic dimensions of performance, neglecting other important goals of the firm; also the data are often unavailable or unreliable (Robinson and Pearce, 1983). Besides, there is often difficulty in obtaining objective financial measures of performance from small business units. Although it is desirable to use objective measures of performance, privately-held companies, which are, coincidently, the majority of the sample studied, are often reluctant to furnish objective performance data (Swamidass and Newell, 1987; Porth et. al., 1998).

Another method of measuring AMT performance is by looking at its manufacturing performance (Chen and Small, 1994; Muhamad, 1997; Small and Yasin, 1997; Small, 1999; Das and Narasimhan, 2001). Small (1999) in his study on AMT implementation, measures the effectiveness of the implementation against technical or manufacturing performance. His rationale of choosing this variable is because the failure to meet the technical/manufacturing benefits will almost invariably result in failure on the other performance bases. Besides, an early assessment of the technical/manufacturing performance of AMT can provide an early signal of technology incompatibility or technology implementation problems.

This is also implied by Small and Yasin (1997), that the only pure measure of a technology's effectiveness may be its ability to improve manufacturing rather than strategic or competitive performance. This measurement is said to reflect the capabilities of the technologies being surveyed. The performance of an AMT system should be judged on its ability to meet the organisational goals for which it was acquired. However, in order to be able to measure its performance, these goals should be converted to specific technical performance measures (Chen and Small, 1994).

Researchers use multiple performance criteria in order to capture the appropriate level of performance (Beaumont and Schroder, 1997). This is been emphasised by Bergeron et al (2001) who suggested future studies on information technology effectiveness to use multiple performance measurement. For example, Das and Narasimhan (2001) measure manufacturing performance along five dimensions: manufacturing cost reduction, quality improvement (conformance), delivery speed and reliability, customisation responsiveness (flexibility), new product introduction time, which was adapted from existing scales from Miller and Roth (1994) and Dean and Snell (1996).

Based on the above discussion, it is justified that manufacturing or technical performance is the most appropriate performance measurement for the study. As the study is to examine the implications of the fit between AMT and the manufacturing strategy on manufacturing performance, the performance measurements used are to reflect the manufacturing strategy under investigation, i.e. cost leadership, quality, flexibility and delivery, as listed in Table 2.3 as follow:-

Table 2.3: Manufacturing Performance Measurement Constructs

Manufacturing Strategy	Performance Variables
Cost Leadership	Ability to offer competitive or lowest prices through efficiency from all possible sources
	Ability to offer competitive or lowest prices through cost reduction from all possible sources
Quality	Ability to offer products that are reliable
	Ability to offer high performance products to our customers
	Ability to deliver zero defect error products
	Ability to provide products of consistent quality
Flexibility	Ability to offer a wide range of product options to our customers
	Ability to provide excellent after-sale service
	Ability to customise products according to customers' specifications and requirements
	Ability to offer new models into our existing products
	Ability to launch new product lines to new customers.
	Ability to change the output volume quickly according to our customers requirements
	Ability to change the output volume quickly to cope with fluctuating demand
	Ability to reschedule manufacturing priorities to reflect to our customers requirements
Delivery	Ability to deliver goods on time
	Ability to provide fast deliveries to our customers

2.5 Conclusions

This chapter provides the fundamental definitions of variables investigated in this study. It is an essential part of the study as it sets the foundation and the boundaries for the study. AMTs are restricted to the 14 types of the computer-based technologies employed in manufacturing companies, and manufacturing strategies are categorised as differentiation strategy and cost leadership strategy. The manufacturing performance looks at the ability of the company in achieving their competitive advantage in terms of the differentiation dimension and cost leadership dimension.

The next chapter will draw the theoretical framework for the study from the relevant literature. It identifies gaps and research issues which are controversial and worth researching.

CHAPTER 3

LITERATURE REVIEW II: RESEARCH FRAMEWORK

3.1 Introduction

In the last chapter, the researcher presented terminologies used in this study. This chapter aims to build a theoretical foundation upon which the study is based by reviewing the relevant literature. Research issues which are worth researching due to their controversies and those that have not been answered by previous researchers will be identified. This chapter proposes research issues on these gaps and provides a focus for the collection of data that will be described in the next chapter.

First of all, this chapter outlines the theoretical positioning of the contingency theory of fit in understanding the relationship between AMT, strategy and its performance. The underlying theory - the contingency theory will be reviewed. It will then be followed by the proposition of appropriate AMTs for each particular type of manufacturing strategy. Finally, the empirical framework for the study is presented, in order to guide the subsequent investigation. To develop this framework, literature from IT, AMT, strategic management and manufacturing management is reviewed. It is hoped that this chapter will draw out the potential contribution of the body of knowledge through an original investigation.

3.2 The Theoretical Rationale

This research is called to investigate the link between the AMT and manufacturing strategy, and the implication of fit between them on the manufacturing performance, based on the projection in the literature that the lack of alignment between them is the major barrier to exploiting the full benefits of AMT (Hill, 1994; Small and Yasin, 1997; Cil and Evren, 1998; Kotha and Swamidass, 2002). Researchers also suggest that the 'fit' could lend a competitive edge (Grant et al, 1991; Cook and Cook, 1994; Small and Yasin, 1997; Cil and Evren, 1998; Kathuria et. al., 1999; Das and Narasimhan, 2001).

Thus, the main focus of the study is the fit between the variables. A trawl of literature in both strategic management and production operations management reveals that the contingency theory of fit has always been the underlying theory when studying 'fit' or 'alignment' between two variables. This has provided an extensive and supportive theoretical literature.

According to Selto et. al. (1995), there is no other theory which directly concerns fit except the contingency theory, and 'despite criticism, the intuition behind the theory continues to be appealing'. Besides, it offers plentiful opportunities for measurement and observations, and explicit linking of organisational characteristics and performance. However, contingency theory has a shortcoming of a lack of a standard measure, which led to ambiguity in the operationalisation of the key construct, fit, and equivocal past empirical results. Thus, it is important for any contingency study to define the fit before embarking on the study.

The next section will look at the definition and past seminal work on contingency theory of fit. The section is concluded by reviewing the work on contingency theory of fit from both the strategic management and operations management fields, and finally proposes the approach to operationalise contingency of fit.

3.2.1 What is Contingency Theory?

The contingency theory is rooted from Burns and Stalker (1961) who believe that there is no one best way to manage an organisation. In the context of an organisation, the notion of contingency is that the application of theory depends on certain contingency factors that guide the choice of the right set of solutions to the right problem (Drejer, 2002). In other words, there is no right or wrong answer or definite answer for each problem – in fact, each problem required a different kind of approach to solve it (Schroeder and Flynn, 2001).

At an organisational level, common synonyms for 'fit' include 'alignment', 'linkage', 'top-down approach', 'congruence', or 'match' (Knoll and Jarvenpaa, 1994). This study adopts the broad definition of fit by Nadler and Tushman (1980), as 'the degree to which the needs, demands, goals, objectives, and/or structure of one component are consistent with the needs, demands, goals, objectives, and/or structure of another component'.

The contingency theory has been applied in various areas of study as the underlying assumption of a great number of research models. It has been the central to both theoretical and empirical research in many disciplines. For example, it is used to explain the interrelationships of essential organisational elements and their interrelationships and effects on performance (Dean and Snell, 1991; Gunnigle and Moore, 1994; Selto et. al., 1995; Kathuria and Igbaria, 1997; Lalla et.al 2003; Congden, 2005).

The central theme of contingency theory is that all components of an organisation must 'fit' well with each other or the organisation will not perform optimally (Perrow, 1986; Hill, 1994). The theory believes that an organisation's ability to achieve its goals is a function of the congruence between selected organisational components and its environment (Perrow, 1967).

The lack of fit in organisational elements caused diminished performance (Perrow, 1967; Van de Ven and Drazin, 1985; Egelhoff, 1982; Joshi et. al., 2003). Van de Ven and Drazin (1985) for instance, contend that each organisation has its own optimal configuration or best fit of context, structure and control. Deviation from that ideal fit (which is misfit) would cause lack of coordination, miscommunication, misunderstanding, poor morale, and poor motivation, which, in turn, should lead to poor performance.

3.2.2 Measurement of Fit

This section looks at the measurement of fit, and the justification of the choice. The definition of fit is important in order to determine the appropriate data analysis for the study. Bergeron et. al. (2001) invoke researchers to specify the type of fit to be examined, and to support their choice before conducting the study. Thus, the classificatory framework helps to draw the appropriate links between the verbalisation of fit-based relationships and the statistical analyses chosen to test these relationships.

The concept of 'fit' has been the central to research in the field of strategic management (Venkatraman, 1989; Van de Ven and Ferry, 1980; Hrebiniak and Joyce, 1984; Van de Ven and Drazin; 1985). Thus for the purpose of selecting the type of fit to be examined in this study, the researcher reviewed the most seminal studies of the concept of fit from the strategic management experts, Van de Ven and Drazin (1985), and Venkatraman (1989).

Van de Ven and Drazin (1985) propose three approaches to classify fit: the natural selection approach, interaction approach and systems approach.

The natural selection approach assumes that organisational fit is the result of an evolutionary process of adaptation; firms that survive have achieved a good fit between the contingency forces in their environment and their organisation. Researchers adopting the natural selection approach usually focus on discovering the patterns of strategy and structure that exist among surviving organisations in different environments. Having accepted the assumptions about survival, researchers study the relationships between the components of the organisation without explicitly testing for any link to performance. Under this approach, fit is defined in terms of predictable correlations between pairs of organisational variables. Anything less or no correlated pairs of variables would lead to 'extinction' in a competitive environment. Such relationships are predicted by the selection approach. It should be noted that explaining performance is not an aim of the selection approach since it is assumed that only good performers survive to be observed. Using the natural selection approach, it is possible to predict that AMTs are correlated with manufacturing strategy since anything less would lead to 'extinction' in a competitive environment. As the performance is not the aim of the approach, the analysis would not involve the performance variable when performing the analyses.

The second approach, interaction, assumes that fit is an interaction effect on performance, between the two organisational variables (example: culture, structure, strategy, reward systems, etc), or between an organisational variable and an environmental condition. In this concept, none of these variables alone would affect performance, but it is the fit among them that affects performance. This approach assumes that variations in organisational performance can be explained by misfits between organisational elements, or between an organisational element and its environment. For a particular organisational context, ideal organisational structures and processes exist; deviations from that configuration would lead to performance deterioration. In short, the interaction approach preaches that the fit among the organisation variables affects performance.

The system approach takes a holistic or gestalt approach and examines the level of internal consistency among a large number of pieces of a puzzle to obtain a complete image. This is the most recent but least-tested form of contingency theory in studying the interdependencies in organisations. In concept, optimal system fit occurs when all organisational elements are congruent. Variations in performance result from variations in this overall systemic fit. The further the elements are from optimal, then the lower the performance should be. Identifying the optimal organisation is the primary drawback to this approach, since it is possible to have many equally effective, feasible sets of organisational elements (equifinality). Defining optimal fit is problematic as well, and is usually defined in a somewhat circular manner: optimal fit is the configuration of the optimally performing organisation. In this approach, congruence among many variables is examined within the context of organisational results. This approach embraces the concept of equifinality – that there are many different equally effective combinations of organisational variables.

Close internal consistency among variables is, however, assumed in any effective design. Van de Ven and Drazin (1985) operationalised deviations from optimal system fit as the difference from the set of characteristics of the top performing workgroup in an organisation. Selto et al. (1995) select the top performer that performed the highest on each outcome measure. That workgroup became the benchmark for each test of cross-sectional outcomes. The system approach suggests that variations in performance result from variations in the overall systemic fit. For example, the further the AMT-strategy is from optimal, then the lower its performance should be. The top performing firms can be the benchmark for each test of cross-sectional outcomes (Van de Ven and Drazin, 1985; Selto et. al., 1995).

Another effort toward definitional clarity of the concept of fit was proposed by Venkatraman (1989). This is in fact quite similar with that proposed by Van de Ven and Drazin. The framework comprises of six different perspectives from which fit can be defined and studied: these are fit as: (a) moderation, (b) mediation, (c) matching, (d) covariation, (e) profile deviation, and (f) gestalts. The following sections will look at each perspective of fit in detail.

3.2.2.1 Fit as Moderation

Fit as moderation is conceptualised as the interaction between two variables. It is popular in organisational research to use the moderation perspective in studying the effect of two interactive variables on the third variable. According to the moderation perspective, the impact that a predictor variable has on a criterion variable is dependent on the level of a third variable, termed here as the moderator.

Researchers invoke this perspective when the underlying theory specifies that the impact of the predictor (e.g., AMT) varies across the different levels of the moderator (e.g. strategy). The moderator affects the direction or the strength of the relation between the predictor variable (e.g. AMT) and a dependent variable (e.g. performance). In this case, it is postulated that the 'interaction' between manufacturing strategy and AMT will have implications on performance. When this perspective of fit is adopted, correlations for various subsamples are the appropriate testing technique.

Figure 3.1: Fit as Moderation: Adapted from Venkatraman (1989)

3.2.2.2 Fit as Mediation

Fit as mediation is viewed as the intervention between two variables. This perspective specifies the existence of an intervening variable (e.g. manufacturing strategy) between an antecedent variable (e.g. AMT) and the consequent variable (e.g. performance). In this case, the existence of manufacturing strategy indirectly affects or mediates the relationship between AMT and manufacturing performance. The appropriate analytical scheme for fit as mediation is carried out within a path analytic framework.

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Figure 3.2: Fit as Mediation: Adapted from Venkatraman (1989)

3.2.2.3 Fit as Matching

Fit as matching is theoretically defined as the match between two variables. The measure of fit between two variables is developed independent of any performance anchor, which is unlike the previous two perspectives. The measure of AMT-strategy fit (0 or 1) can be derived based on the underlying theory without reference to performance. The fit measurements can then be tested with the external criterion of performance. For this study, fit exists when manufacturing strategy matches AMT. Three analytical schemes have been identified for supporting the matching perspective: deviation score analysis, residual analysis, and analysis of variance.

Figure 3.3: Fit as Matching: Adapted from Venkatraman (1989)

3.2.2.4 Fit as Covariation

Fit as covariation refers to fit as a pattern of covariation or internal consistency among a set of underlying theoretically related variables; if fit is defined as covariation, it means that it is the appropriate coalignment of AMT and manufacturing strategy that will influence performance. In this regard, Venkatraman identifies second-order factor analysis as the appropriate analysis technique for testing the propositions.

Figure 3.4: Fit as Covariation: Adapted from Venkatraman (1989)

3.2.2.5 Fit as Profile Deviation

Fit as profile deviation looks at fit as the internal consistency of multiple contingencies, it assumes that an ideal profile exists, and deviations from this ideal profile should result in lower performance. If an ideal AMT profile (e.g. the level of integration deployment along a set of AMT) is specified for a particular manufacturing strategy, a business unit's degree of adherence to such a multidimensional profile will be positively related to performance if it has a high level of strategy-AMT coalignment. Conversely, deviation from this profile implies a weakness in strategy-AMT coalignment resulting in a negative effect on performance. Thus, this perspective allows a researcher to specify an ideal profile and to demonstrate that adherence to such a profile has systematic implications for effectiveness. When adopting this perspective, a subsample of high performers is selected from the larger sample. The AMT profile of these high performers is estimated. Then, the degree of adherence to the ideal profile is obtained by calculating the Euclidean distance in an n-dimensional space.

Figure 3.5: Fit as Profile Deviation: Adapted from Venkatraman (1989)

3.2.2.6 Fit as Gestalts

Fit as gestalts is based on an internal congruence conceptualisation, whereby fit is seen as a pattern. Miller (1981) conceptualises fit as a set of relationships which are in a temporary state of balance. Researchers should try to find frequently recurring clusters of attributes or gestalts, rather than look at a few variables or at linear associations among those variables. Gestalts are often seen as common configurations which may be logically, aesthetically, perceptually, or functionally integrated. In this situation, it is difficult to say 'what determines what'. There is no obvious central feature, merely a tight configuration of parts that are mutually supportive. Fig. 3.6 adapted from Miller illustrates the notion of gestalt, in a three dimensional space. The appropriate statistical technique for developing the profiles is cluster analysis.

Figure 3.6: Fit as Gestalts: Adapted from Miller (1981)

The perspectives brought forward by the two experts in the strategic management domain, as presented above, are very similar, but differ in their classification of different types of fit. Van de Ven and Drazin classified fit from three perspectives: the natural selection approach, interaction approach and systems approach, whilst Venkatraman differentiates fit into six categories of definition: (a) moderation, (b) mediation, (c) matching, (d) covariation, (e) profile deviation, and (f) gestalts.

This study examines fit from the six perspectives as proposed by Venkatraman (1989). The method was selected for two reasons. Firstly, the fit perspectives developed by Venkatraman are considered more comprehensive and detailed, i.e. fit is broken down into six perspectives as opposed to three, allowing for greater analysis of the various elements of fit

More importantly, Venkatraman measures are based on more quantitative measures, as opposed as to the more qualitative measures proposed by Van de Ven and Drazin, and as such, suit the quantitative methodology approach taken by this research. Thus under the Venkatraman measures, for each perspective, there is a mathematical formulation that links questionnaire responses to measures of fit that subsequently allow for the statistical testing of the theory,. This was the fundamental issue in selecting the definition of fit needed for this study.

Venkatraman's fit perspectives thus lead to more useful and powerful operationalisation, analysis and interpretation. The six different specifications of fit within the single study are able to uncover insightful nuances of the structural contingency theory that otherwise may have been missed using the broader measures.

3.2.3 Contingency Theory of Fit Studies in Literature

Numerous studies in the production operations management field have been carried out using this contingency approach, which look at relationships between AMT implementation and organisational elements such as firm size, human resource management and practice (Lai and Guynes, 1997; Germain, 1996; Thong and Yap, 1995; Schroder and Sohal, 1999); ownerships (Sohal et. al., 1991; Sohal, 1994; Schroder and Sohal, 1999) or planning and infrastructure (Schroder and Sohal, 1997) and their relationships to performance.

However, the literature shows that relatively little attention has been given to the conceptualisation of fit. The lack of attempts to conceptualise the fit has led to inconsistent results and this could eventually alter the very meaning of a theory (Venkatraman, 1989; Van de Ven and Drazin, 1985; Selto et. al., 1995). For example, Selto et. al. (1995) condemn the mixed results of studies on the correlation between measure of fit and performance which are caused by the ad hoc operationalisation of fit itself. Furthermore, explaining the performance of organisational units requires a more sophisticated approach. Drazin and Van de Ven (1985) reveal that both congruent and contingency forms of fit are operating in organisations, thus the comparative evaluation of several forms of fit should be designed for any contingency studies.

Instead, the majority of the studies in the production operations management area, are assuming the moderating effect of other variables on the relationship between adoption of AMT and overall performance (Ramamurthy, 1995; Boyer et. al., 1997; Small and Yasin, 1997; Schroder and Sohal, 1997; Schroder and Sohal, 1999). For instance, Schroder and Sohal (1997) reveal that the planning and infrastructure variables, moderate the relationship between adoption of AMT and overall operations and business performance. Kotha and Swamidass (2000) use the contingency of fit to explain the failure of AMT-adopting companies in materialising its full benefits by using the interaction perspective that defines fit as a moderator.

It is in contrast to the approaches adopted by current scholars in the strategic management domain, where the comprehensive examination of fit has been used widely (Selto et al., 1995; Van de Ven and Ferry, 1980). For example, Selto et. al. use multiple perspectives, i.e. selection, interaction and system approach to define fit. It is in fact pointed out by Knoll and Jarvenpaa (1994) that strategic management and organisation science domains 'have sought to better define fit'.

Bergeron et. al. (2001) carried out a comparative analysis study to look at the role of fit between an organisation's management of information technology, its environment, strategy, structure, and its performance, using the six perspectives of fit proposed by Venkatraman (1989). The findings suggest that the system approach, i.e. the profile deviation and covariation perspectives of fit appear to be better suited to theory testing while the gestalts perspective would be more appropriate to theory building. This finding somehow disagrees with the earlier findings that the moderation model is best used to explain the performance impacts of aligning the information system function with organisational strategy (Bergeron and Raymond, 1995).

3.2.4 Conclusions

Based on the presentation of the contingency theory from both the strategic management and production operations management area, the researcher has adopted the proposition from the strategic management expert, Venkatraman (1989), to study the fit between the two variables from multiple perspectives, due to their comprehensiveness, and quantitative nature.

The literature review in the area also suggests that there is an apparent gap in the study of AMT implementation that adopts the comprehensive perspectives of fit to examine the impact of AMT on performance. The inconsistent findings, mixed views on the operationalisation of fit, the different focus of each aspect of fit and the fact that it is still unclear which is the most appropriate definition and measure of fit, have also called for the use of a more comprehensive definition of fit. This is imperatively an imminent gap in the literature.

3.3 Alignment Between AMT and Manufacturing Strategy

The decision to invest in AMT is strategically directed (Cook and Cook, 1994; Tidd, 1994; Das and Narasimhan, 2001). In other words, choosing a manufacturing technology is a strategic decision in operations management, with attendant implications for performance. According to Cook and Cook (1994), installing AMT, in itself, is not enough to create a world class manufacturing system, as the technology is neutral. In order to achieve a unique and sustainable source of competitive advantage, organisations must correctly select and properly manage AMT projects that enhance an organisation's core competences. Thus, manufacturing strategy and AMT should be consistent (Tidd, 1994).

The rationale of aligning manufacturing technology to manufacturing strategy can be drawn from the view of the broader perspective of strategy, where the corporate strategy is the umbrella for all other levels, that influences and moulds lower levels of strategy. Each distinct business unit within the corporation would then craft its own business strategy. And in turn, this business strategy should be supported by functional level strategies, such as marketing, manufacturing, and finance strategies. Thus, lower levels of strategy are consistent with higher levels of strategy so as to foster their successful implementation (Porth et. al., 1998). In other words, these strategies should be a complement and support (i.e. fit) between each other. For example, Grant et al., (1991) posit that 'optimal' technology for a business is contingent upon the firm's strategic goals, its available resources, and the nature of its product-market environment.

However, the alignment between manufacturing technology and strategy is complex as operations not only support the current, but also the future needs of the business. Manufacturing technology is associated with a high level of investment and it is fixed in nature. Besides to have a clear link to the needs of a company's markets, companies need to parallel it with appropriate development in manufacturing, as the market continues to be increasingly dynamic. The fixed nature of the manufacturing technology made the alignment between manufacturing technology and strategy seem difficult. This often leads to manufacturing operations being rigid and not able to support current and future needs of the business (Hill, 1994):

> *"...the inherently fixed nature of manufacturing infrastructure is often coupled with an inertia for change...lead to situations where those responsible for the realignment of the essential components of manufacturing infrastructure are unaware of, or unable to respond to, the growing need to make the necessary and appropriate changes".* (Hill, 1994, p213)

Studies on the link between AMT and strategy emerged with contending perspectives. The overwhelming majority of existing research studies the link between manufacturing technology and strategy, suggesting that there is a link between these two variables. According to Kathuria et. al. (1999), the choice and use of the right type of IT application may offer the user company the competitive edge it seeks. Thus, firms pursue competitive goals by adopting what they deem to be appropriate technology initiatives.

The other extreme view of this alignment is that the type of AMT implemented does not necessarily have to be aligned with their manufacturing strategies. McDermott et al. (1997) find that there is essentially no difference in the rate and scope of adoption of AMT and practice across different operational environments.

Given that different manufacturing strategies have different manufacturing goals, it is reasonable to argue that some differences can be expected in the way that different manufacturing strategies would configure their technology-based initiatives. Furthermore, each technology offers its own basket of differentiated operational, strategic and marketing capabilities (Primrose, 1991; Small and Chen, 1995; Demmel and Askin, 1996; Lefley, 1996; Small, 1999).

For example, CIM may be more compatible with a low volume, differentiation strategy orientation, than a cost leadership company. In contrast, robotics are more likely to be found in assembly line systems (Das and Narasimhan, 2001), which produce mass quantities for economies of scale.

The lack of empirical studies in UK manufacturing and the inconsistency of findings of the link between the manufacturing strategy and AMT have triggered the researcher to undertake this study. Given the contribution of UK manufacturing in the economy, and the fact that AMT is fixed and on the other hand, the manufacturing strategy is dynamic in nature, thus, it is of imperative importance to find out the state of AMT diffusion in the UK, whether the AMT invested in are associated with the manufacturing strategy and that they are capable to support the company to achieve its competitive advantage.

The following section will look specifically at the type of AMT to support each type of manufacturing strategy mentioned earlier. Discussion will be gathered around the characteristics of companies pursuing each strategy, and the types of AMT that are best suited to support each strategy.

3.3.1 Cost Leadership Strategy and AMT

Firms pursuing a pure cost leadership strategy aim to gain a competitive advantage by becoming the lowest-cost producers in an industry (Porter, 1980). They seek stable and predictable markets to minimise product adaptation costs and to achieve economies in manufacturing (Miller, 1987). They emphasise on efficiency (Clark, 1996; Kotha and Swamidass, 2000) and cost reduction initiatives from all possible sources (Kotha and Swamidass, 2000). As such, these companies compete on cost (Jaikumar, 1986; Lei and Goldhar, 1990; Parthasarthy and Sethi, 1992) and scale (Miller, 1988).

The logic of maximising throughput efficiency dictates that firms place a greater reliance on standardisation and simplification through low product variety and high-volume production (Porter, 1985; Clark, 1996). This emphasis, i.e. low product variety and high volume, has enabled the full exploitation of mass production techniques (Hayes and Wheelwright, 1979). An assembly line, which has a capability for extended production runs, and usually entails relatively high set-up costs best fits this environment (Das and Narasimhan, 2001).

However, the type of AMT to be used in companies employing a cost leadership strategy is confusing. Kotha and Swamidass (2000) who classified AMTs according to the information processing capability, find rather contradicting results that high-volume automation technologies such as computer-aided quality control performed on final products, computer-aided inspection performed on incoming or in process material and robotics, are not related to a cost leadership strategy. Instead, they reveal that process technology such as CAM, CNC machines and programmable controllers, which focus on manufacturing processes, be used in such companies. According to the authors, this is perhaps due to the fact that quality is not the major concern of these companies.

Nevertheless, there are studies in this area that found there is no connection between AMT and a cost leadership strategy. For example, Robb and Xie (2003) posit that AMTs are deployed to improve flexibility, quality and delivery, rather than cost. There is no specific type of AMT for companies employing a cost leadership strategy. Research finds that cost leadership companies tend to be indifferent to AMT use (Kotha and Swamidass, 2000). This is probably due to the fact that AMT's flexibility capabilities are not likely to be used to their full potential when they are utilised as part of a cost leadership strategy (Parthasarthy and Sethi, 1992). Another reason perhaps is due to AMT which is revenue-producing (Kotha and Swamidass, 2000), and not benefiting companies which are concerned with cost-cutting (Lei and Goldhar, 1990).

The level of integration that is appropriate for cost leadership companies, is expected to be that of a limited integration. There is relatively more information processing on the manufacturing process side, as compared to the product side (Kotha and Swamidass, 2000). If there is any inter-department integration, it is normally less complex and for more routine inter-departmental interaction and information processing (Miller, 1988). Additionally, in the monolithic and ritualised orientations that prevail in this environment, they are relatively less complex but have more routine inter-departmental interaction and information processing (Miller, 1988). In short, relative to a differentiation strategy, the overall needs for information processing requirements are likely to be less complex, but more routine in a cost leadership strategy.

Based on the above discussion, it is concluded that AMT investments for companies employing a cost leadership strategy are minimal, have little investment in AMTs, with no or limited integration, or more stand alone pieces of technology. There will be mild or no association between the AMT investigated and cost leadership. These cost leadership companies would probably use mechanical or conventional technologies (Hayes and Wheelwright, 1979, 1984) which do not require integration between those machineries.

3.3.2 Differentiation Strategy and AMT

Porter (1980) defines a firm pursuing a differentiation strategy as aiming to gain a competitive advantage by offering a unique product or service. Such a firm selects one or more attributes that consumers perceive as important and positions itself uniquely to meet those needs, and seeks reward for its uniqueness by charging a premium price (Porter, 1985). Companies pursuing this strategy can emphasise on product innovation, dynamic product mix, new product development, delivery and speed to market, or quality or any other non-price factor (Hambrick, 1983; Porter, 1985; Kotha and Swamidass, 2000).

Companies with a differentiation strategy tend to maintain a lower volume of production, combined with an emphasis on flexibility and adaptiveness toward the marketplace, such as wide product range, new product development, or quality (Kotha and Orne, 1989). This suggests more flexible forms of automation, and small-batch production (Porter, 1980), high set-up frequencies, with relatively low set-up costs (Das and Narasimhan, 2001). A job shop seems capable to address these needs (Das and Narasimhan, 2001).

It is inevitable that companies with a differentiation strategy use several dimensions of AMTs. This is supported by Kotha and Swamidass (2000) who lament that firms pursuing a differentiation strategy tend to employ more AMTs. Thus the AMT usage is higher for firms pursuing a pure differentiation strategy than a cost leadership approach. The authors even coined the term 'technology hog' for companies employing a differentiation strategy. According to them, 'these companies are more AMT dependent compared to others'. Results also show that the use of a few AMTs is insufficient for success, but the use of the all AMT is proven to be more effective. This may be the heart of AMT effectiveness as argued in the extant literature (Meredith, 1987; Dean and Snell, 1996), which denotes that the use of all AMT factors increases the potential for integration.

Goldhar (1990) reveals that firms adopt AMTs that emphasise flexibility are able to compete on the basis of time-to-market and product variety. Robb and Xie (2003) reveal that AMTs are more closely associated with flexibility and innovation, rather than on value (quality) and speed. In this study, they refer to AMT as CAD, CAM, robotics and FMS. The flexibility nature of AMTs has increased the performance of firms employing them to achieve the quality leadership strategy (Parthasarthy and Sethi, 1993).

Small and Chen (1997) in their study, confirm strongly that integrated technologies such as FMC/FMS, CIM assist companies to achieve higher levels of time-based flexibility (time between conceptualisation and manufacture of a new product, time needed for a major design change in an existing product, production changeover times, delivery lead times and setup times). It is because these technologies, when properly implemented, are closely linked to the firm's business and marketing systems (the company's main links with their customers). Therefore, firms that have installed them are able to recognise and respond more quickly to changing customer needs.

Das and Narasimhan (2001) propose that CNC and CAM are capable of decreasing set-up frequencies, improving set-up times, more accurate scheduling and increasing productivity. The authors also found that CAE and CAD are related positively to customisation performance, which is referred to as flexibility in this study. Safizadeh et. al. (1996) reveal that FMS can be used in line flow industries to achieve customisation.

As companies tend to have more complex product lines and several discontinuities in the process side to facilitate greater product variety, the information needs of a differentiation strategy are varied and diverse (Kotha and Orne, 1989). This is due to an increase in both market diversity (i.e. environment complexity) and manufacturing and technological complexity (Egelhoff, 1982). In turn, requirements for information exchange and processing between interdependent subunits increase (Galbraith, 1977). Thus, the need for information exchange and processing technologies increases for firms pursuing a differentiation strategy.

According to Kotha and Swamidass (2000), these companies rely on technologies that assist in storage, retrieval and manipulation of large quantities of process-related information, usually on a real-time basis. Additionally, along with the increased need for information exchange, there is also an increased need for tactical and strategic information processing related to product matters (Egelhoff, 1982). Hence, the technologies essential for a differentiation strategy are those that assist in the storage, retrieval and manipulation of product-related information, so that these firms can manage the associated uncertainty and complexity.

The above discussion concludes that AMTs are important to assist companies to achieve a differentiation strategy. In general, companies pursuing a differentiation strategy would invest rather heavily on the extensive list of AMTs, in order to achieve its fullest potential benefit, with full integration within company or extended integration that extended along its supply chain.

3.3.3 Conclusions

From literature, it is possible to infer that for companies employing a cost leadership strategy, the AMT investment is minimal, with no or limited integration, or more stand alone pieces of technology, and there will be mild or no association between the AMT investigated and the cost leadership, whilst for companies pursuing a differentiation strategy, they would invest rather heavily on the extensive list of AMTs, with full integration within company or extended integration that extended along its supply chain. However, as there is mixed and inconsistency in findings in AMT implementation studies, the researcher would like to find an answer to the first main research question: How does the manufacturing strategy affect the levels of integration and investment of AMT in manufacturing companies?

Thus, the hypotheses developed from these propositions are as follows:-

Hypothesis 1: Differentiation Strategy is positively associated with multiple AMTs.

Hypothesis 2: Cost Leadership Strategy is not associated with multiple AMTs.

3.4 AMT and Manufacturing Strategy Fit and Its Implications on Manufacturing Performance

A trawl of the AMT literature reveals that AMT may not always achieve its benefits. Despite enormous investments in resources and time, there has generally been ineffective usage and poor exploitation of these technologies (Hayes and Wheelright, 1984; Jaikumar, 1986), hence not reaping its full potential (Davis, 1986; Voss, 1988; Cooley, 1984; Bessant, 1990). There are studies that support the view that AMTs have little impact on performance

(Beaumont and Schroder, 1997; Demeter, 2003), and found no direct link between AMT and performance (Boyer et. al., 1996; Dean and Snell, 1996).

The extensiveness of AMT does not guarantee the achievement of higher levels of manufacturing performance (Small, 1999; Das and Narasimhan, 2001). According to Cook and Cook (1994), the failure is due to the misalignment of the AMT to support its manufacturing strategy. The authors deem manufacturing strategy is imperative for achieving competitive advantages of AMT. Investment in technology by itself does little to improve competitiveness and profitability (Voss, 1988). Day (1984) postulates that, 'business strategy should be integrated with functional strategies to achieve a sustained competitive advantage'. Therefore AMT creates synergy if it is synchronised with the manufacturing strategy.

There is a growing awareness in the industry that the key to competitive manufacturing lies in the fit between the AMT and its manufacturing strategy in order to achieve its intended objectives. For example, Schlie and Goldhar (1995) call for US companies to take advantage of AMT and formulate and implement competitive strategies that are based on or feature advanced manufacturing attributes. In other words, 'a linkage must be developed between production operations, technology and the competitive strategy of the firm or business unit' to ensure business success.

The match of manufacturing strategy and its technology is fundamentally important. Dean and Snell (1996) reckon that organisations can become too enamoured of particular tools that they lose sight of their overall strategic missions. Others may use a tool in the context of a strategy to which it is ill suited and they are unlikely to reap the competitive rewards the tool offers. Hayes and Wheelwright (1984) also agree that a fit between a firm's strategies at the business and functional levels is expected to have a positive impact on performance. The provision of a 'strategic link' between business objectives and technology in the context of manufacturing is important as this will ensure strategic consideration of technology in the context of market characteristics, competitive response, economic trends and other environmental variables.

Given the growing consensus on the strategic importance of manufacturing, and the increasing availability of various AMTs, it is reasonable to expect that the utilisation of AMTs in manufacturing firms will be related to performance (Parthasarthy and Sethi, 1992; Dean and Snell, 1996). Yet, evidence directly supporting AMT-strategy-performance relationships is relatively rare (Boyer, 1997). For instance, Adam and Swamidass (1989) in their article, comment that the 'greatest weakness' is the insufficient research that studies relationships among variables, and particularly, the effects of such relationships have on performance. According to the authors, 'what is glaringly absent is a body of studies that would investigate the interrelationship among variables or the effect of a subset of variables on performance'. Clearly, there is a pressing need for research in this area.

Furthermore, existing studies that look at these linkages produce inconsistent findings. Some researchers have found no relationship between strategy-AMT-performance (Boyer et. al., 1996; Dean and Snell, 1996), but Kotha and Swamidass (2000) found many significant relationships. Adoption of AMT needs to be discriminated, i.e. carefully matching the strategy and AMT in seeking growth or profitability. Thus, the fit between these two variables resulted in superior performance. As different AMTs emphasise different goals, the following section will discuss the link of AMT with different types of strategy and its implications on performance.

Kotha and Swamidass (2000) confirm that the judicious matching of AMT and strategy leads to superior performance. However, there is the exceptional case where AMT is used to support a cost leadership strategy. This means profitable firms emphasising a cost leadership approach are indifferent to AMT use. This result is consistent with findings provided by Dean and Snell (1996) that no relationship exists between a cost leadership strategy and AMT.

These findings strongly echo the observations that scale and cost competition may be inconsistent with AMT use (Jaikumar, 1986; Lei and Goldhar, 1990; Parthasarthy and Sethi, 1992). This is probably due to the fact that AMT's flexibility capabilities are not likely to be used to its full potential when it is utilised as part of a cost leadership strategy (Parthasarthy and Sethi, 1992). AMTs may indeed be important for gaining a competitive advantage but they are by no means the only approach to competition (Garvin, 1993).

In terms of the effect of fit between AMT and a differentiation strategy, Kotha and Swamidass (2000) suggest that firms are achieving high growth when pursuing a wider range of AMTs. Thus, differentiators invest relatively higher in AMT in order to achieve its stipulated benefits. As the study does not include the combined strategy, there are no empirical findings of whether the fit between AMT and a combined strategy affect performance.

The lack of empirical studies in this linkage and inconsistency of the findings suggest that this is one of the imminent gaps that need to be addressed. Thus, this derives the second main research question which is about 'what is the implication of fit between the AMT and the manufacturing strategy on the manufacturing performance'. In order to answer this question, the researcher uses the multiple perspectives of fit definition to investigate the 'fit' between the manufacturing strategy and AMT.

3.5 Conclusions

This study is to investigate the fit between AMT-strategy and its implication on manufacturing performance. The research proposition is that manufacturing strategy will regulate or configure resource investments in these technology dimensions in different patterns in order to maximise manufacturing performance. Alignment or lack thereof, between manufacturing strategy and technology investment is hypothesised to be a determinant of manufacturing performance.

Thus, this study raises the issue of what is the role of AMT - manufacturing strategy fit in a contingency theory framework. This study uses contingency theory of fit in studying the interrelationships between AMT, manufacturing strategy and its performance. This is based on the argument that there is no other theory except the contingency theory which directly concerns fit.

As relatively little attention is given to conceptualisation of fit in AMT literature, the lack of specific definition or variations in defining fit in the operations management field, it is suggested that this study adopts a rather holistic approach in defining fit, i.e. using the six perspectives pioneered by strategic management expert, Venkatraman. It is hoped that the study will provide contributions to literature and manufacturing companies in determining the type of AMT to be invested in and integrated to support their manufacturing strategy in order to achieve the desired manufacturing performance.

The next chapter will look at the research methodology which defines the research design to undertake the study. It will discuss issues related to research instruments, sampling methods, data analysis and measurement.

CHAPTER 4

METHODOLOGY

4.1 Introduction

This study attempts to examine the link between AMT and manufacturing strategy, and the role of fit between AMT and manufacturing strategy and its effect on manufacturing performance. This study provides a conceptual and methodological approach in applying contingency theory in examining such relationships. By nature, it is a quantitative research.

Having developed the rationale for undertaking this study and its research framework in the last chapters, this chapter discusses the approach taken to answer the research questions. The methodology issues applied in conducting this study, such as research design, research instruments, sampling methods, data analysis and measurement are discussed under each different heading.

4.2 Research Design

This section proposes a research design for the study. A research design is the 'blueprint for fulfilling objectives and answering questions' (Cooper and Schindler, 2001). This research followed a systematic research process that consists of the following stages: theoretical foundation, research method, data collection, actual research work, data analysis and finally reporting the findings (Flynn et al, 1990).

A number of research design approaches exist, the most common classifications of research design are exploratory, descriptive and causal (Churchill and Iacobucci, 2002). Exploratory study tends toward loose structures with the objective of discovering future research tasks. The immediate purpose of exploration is usually to develop hypotheses or questions for further research (Furlong et al, 2000; Dillman, 2000; Cooper and Schindler, 2001). Both qualitative and qualitative techniques are applicable, although exploration relies more heavily on qualitative techniques. The techniques associated with exploratory research are secondary data analysis, experience surveys, focus groups and two—stage designs (Cooper and Schindler, 2001).

Descriptive study seeks to identify the frequency of a particular occurrence, or the relationship between two variables (Churchill and Iacobucci, 2002). Descriptive research assumes a degree of knowledge about the phenomenon under investigation, possibly derived from exploratory research. It has a very clear specification and well-defined boundaries.

In a causal study, it is concerned with learning why – that is, how one variable produces changes in another (Fowler, 1988; Cooper and Schindler, 2001). Thus, the experimental approach is most appropriate where the researcher requires to control and manipulate the variables in the study, to measure whether certain variables produce effects in other variables (Cooper and Schindler, 2001; Churchill and Iacobucci, 2002).

As the study is aimed to examine the relationship between two variables and its effects on manufacturing performance, thus by nature, it is a causal study (Ziesel, (1984) that examines the impact of fit between the two variables, i.e. manufacturing strategy and AMT on performance outcomes.

Data can be collected from a sample of a population, either adopting a longitudinal or a cross-sectional approach. Cross-sectional studies are carried out once and represent a snapshot of one point in time, while longitudinal studies are repeated over an extended period (Cooper and Schindler, 2001). The study is a cross-sectional study as questionnaire was sent out in a period of time to examine the practice of manufacturing companies in regards to their AMT diffusion, strategy orientation and their perceived performance during a particular of time.

4.3 Research Method

A methodology defines how one will go about studying any phenomenon. Any approach to solving a research problem should stem from the problem and the goals of the researcher (Selltiz et al., 1964; Benbasat, 1984; Arbnor and Bjerke, 1997). Other determinants of the appropriate research method, among others are: the research question of interest (Yin, 1994), the current state of knowledge regarding a particular phenomenon and the feasibility of using a given method to perform the study (Birnberg et. al., 1990).

Research methodology is about specific research techniques (Silverman, 2000), such as survey, observation, interview, focus groups etc. These research techniques can be grouped into qualitative or quantitative approaches. The nature of the problem is an important factor in determining whether a qualitative or quantitative approach is suitable. Different types of research method draw different types of conclusion for the studies (Furlong et al., 2000). There is no true or false in each technique, rather more or less useful, depending on their fit with the theories and methodologies being used and the hypotheses being tested, and/or the research topic that is selected (Silverman, 2000).

Generally, a quantitative approach is used to answer questions about the relationship among measured variables with the purpose of explaining, predicting and controlling phenomena (Leedy and Ormrod, 2001). Quantitative research usually starts with a specific hypothesis to be tested, and uses a standardized procedure to collect some form of numerical data, and then use statistical procedures to analyse and draw conclusions from the data. It usually ends with confirmation or disconfirmation of the hypotheses that were tested. Quantification reduces issues to the simplest measurable elements, thereby permitting generalisation provided samples are large.

According to Chia (2001), a quantitative approach is not suitable for an area that has lack of 'explicitly stated theories'. Studies under such an approach normally evolve from a substantial body of literature that needs to be tested and verified (Silverman, 2000). The underlying theory of the study, contingency theory of fit, has been established over the years in management studies. These explicitly stated theories related to the research question in this research indicate that the quantitative approach is appropriate (Chia, 2001).

The central role of this study is to empirically test the nature of the relationship and linkage between the manufacturing strategy and AMT, and its implication on performance. Qualitative techniques are not appropriate because firstly the study is not in the exploratory stage of research (Silverman, 2000), rather it is finding the causal effect of variables on the outcomes; secondly there are specific hypotheses (Leedy and Ormrod, 2001), thirdly, the variables are known, with constructs (Creswell, 1994), and finally, the outcomes of the study is whether to confirm or disconfirm the hypotheses (Silverman. 2000).

Another term referring to the quantitative approach is positivism. Trawling literature in AMT implementation found that most of the studies are dealing with establishing relationships, which is the main aim of positivism (Johnson and Duberly, 2000).

> *"...to generate laws which govern the ways in which organisations operate. The generation of these causal relationships or laws will enable management to become more scientific and managers to become better able to predict and control their environments. The focus in on the observable and the approach to the analysis of organisations assumes that their reality is objectively given, functionally necessary and politically neutral...*" (Johnson and Duberly, 2000, p.40)

This is indeed in line with the key idea of positivism, that the social world exists externally, and that its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection or intuition (Easterby-Smith et al, 1991).

The study, which is descriptive in nature, needs an objective and quantitative method to answer the research question. A number of primary data collection methods are available in the research methodology literature, such as face to face, computer administered, telephone, self-administered and postal survey (Ziesel, 1984). The postal survey method was chosen due to its strength over other techniques, which is discussed below.

In order to find the role of fit between AMT and manufacturing strategy, its effect on manufacturing performance, and compare the findings with previous research in the field, the application of a questionnaire survey is perceived as a good methodological choice (Fowler, 1988; Robson, 1993). Executed in a cross-sectional design, massive information can be gathered within a short period of time in an economical manner. Due to the survey being done at a single juncture in time, the study is interested in variation across the sample. Thus, a careful random selection of a relatively large sample size is needed.

It is also to help to reach conclusions to be generalised to wider populations with a high degree of confidence (Robson, 1993; Gill and Johnson, 1997). The results could highlight broader and more general patterns and relationships. This would provide the researcher a basis for the formulation of explanations and theories. With its economical administrative nature and its efficient way of sampling a large number of respondents, it is an extremely useful tool for collecting data for this work. Hakim (1987) comments that the main attraction of the survey method is its transparency or accountability, which refers to the fact that the survey process can be shown and is accessible to other parties for assessment.

The quantitative approach is deemed the most appropriate method based on the argument that it aims to achieve neutrality through quantification, replicability and generalisation. Quantitative data are normally required to explain causal relationships, with a structured methodology to facilitate replication (Saunders et al, 1997). As the sample size ought to be large enough in order to reduce issues to the simplest measurable elements, thereby permitting generalisation, mail survey which can access dispersed populations (Flynn et al., 1990; Chia, 2001) is most appropriate. Besides, this technique involved less cost and time (Dillman, 2000). While the issue of cost is secondary to most theoretical concerns, endorsement is found in Jobber (1989) who states that, 'no other survey method can compete in terms of cost for reaching widely dispersed populations'.

Other advantages of the postal questionnaire cited are based around three main areas: 1) the anonymity afforded to the respondent in terms of feedback on potentially sensitive internal issues, 2) the respondent is allowed to work at their own pace, 3) the elimination of interviewer bias (Churchill, 1979). These issues are particularly relevant as 1) it is likely to contain potentially sensitive material, 2) the senior managers targeted, are unlikely view a research questionnaire as their main priority, and hence brevity and being easy for completion could be key factors, 3) personal bias could be a problem within an interview situation.

However, there are limitations associated with the postal survey, such as low response rate and non response bias (Diamantopoulos and Schlegelmilch, 1996; Churchill and Iacobucci, 2002). To overcome this problem, techniques such as reply paid envelopes, postcard follow up, personalisation of the covering letter and a promise of anonymity to the respondent were used in order to increase the response rate. Based on the above discussion, it is certain that a postal survey was identified as being the most effective and appropriate method.

Improper questioning techniques could impede proper communication of the research questions (Bradburn, 1983). Insufficient knowledge in implementing survey design would result in an ambiguous response which affects the internal validity. In addition, if the researcher incorrectly selects the sampling frame or wrongly executes the sampling techniques, a sampling error would occur. In this event, the research fails its external validity issue. Thus, the findings cannot be generalized. Meanwhile, it is normal that a poor response rate is expected if the survey is conducted through mail. Excessively long questionnaires can also lead to 'respondent fatigue', which in turn may lead to lower response rates (Bryman, 2001). Thus, this non-response error could distort the research findings.

In addition, due to the 'socially acceptable impression factor', respondents have the tendency to exaggerate or understate their responses by giving favourable responses (Robson, 1993). The bias responses could deliberately be from the possible influence of the perceived purpose of the survey and/or the researchers' personal characteristics. Thus, if this occurs, it would affect the research accuracy and precision.

4.4 Sampling Design

Sample design is an integral part of the total research design (Neuman, 1991). The basic idea of sampling is that by selecting some of the elements in a population, we may draw conclusions about the entire population (Fowler, 1988; Dillman, 2000; Cooper and Schindler, 2001). There are several compelling reasons for sampling, including: 1) lower cost, 2) greater accuracy of results, and 3) greater speed of data collection (Cooper and Schindler, 2001).

4.4.1 Population Definition

A population is the total collection of elements about which we wish to make some inference (Cooper and Schindler, 2001). In this case, as the focus is on the manufacturing technologies employed in organisations, manufacturing companies will be the most appropriate organisations. The manufacturing sector continues to be the major player in the UK economy, as indicated by its average contribution of 50 percent of the share of exports for the past three years (BERR, 2008). Additionally, as noted in the literature review chapters, only a few of the studies examining the relationship between AMT and performance were from organisations outside the US, (like Australia, Germany, UK), hence, this was seen to be important to the context of this study.

The surveyed population consisted of manufacturing firms whose major products were classified in several subgroups of UK Standard Industrial Classification (UKSIC2003) major groups 27-35 (the discrete parts, durable goods manufacturing classifications). These categories include firms involved in making fabricated metal products, industrial machinery and equipment, transportation equipment, instruments and related products, electronic and electrical products.

Given the need for a large sample size, and the need to keep the industries relatively homogeneous (from a manufacturing/ production perspective), this group of six industries is a reasonable compromise that accomplishes both goals. More importantly, the study focuses on these segments because of their acknowledged adoption of AMTs (Dean and Snell, 1991; Ward et al, 1994; Small and Chen, 1997; Kotha and Swamidass, 2000).

These are the industries that have been acknowledged to employ AMTs extensively. Moreover, industries that belong broadly to these SIC codes employ similar discrete manufacturing processes to manufacture products. Perhaps, this latter reason is the cause for several investigations of this industry specific grouping in the literature (Swamidass, 1996). The US Department of Commerce 1988 Survey of Manufacturing Technology, which investigated the usage of AMT in the US, revealed substantial AMT usage among firms in these SIC groups. Small and Chen (1997) also confirm that firms in these SIC classifications continued to be major adopters of AMT.

4.4.2 Sampling Procedure

Sampling procedure is used to maximise the chances that the sample is representative, i.e., similar to the population so that the conclusions drawn from the sample can be generalised to the population as a whole (Furlong et al., 2000). A variety of sampling techniques is available. The selection of a particular technique depends on the requirements of the project, its objectives, and the funds available (Creswell, 199).

Generally, the member of the sample can be selected either on a probability or non-probability basis. Probability sampling is a sampling procedure that allows every member of the population to have an equal chance of being selected for the sample (Babbie, 1990), whereas with non-probability sampling, each member does not have a known nonzero chance of being selected (Fowler, 1988; Cooper and Schindler, 2001). As the selection of members in non-sampling is arbitrary and subjective, thus, probability sampling was the preferred method.

The most common type of probability sampling is the simple random sample. One of the leading database companies, Dun and Bradstreet Inc (UK) was approached to provide a list of 2000 manufacturing companies. The samples were drawn from the population of companies classified under SIC 27-35 that produce discrete products, stratified by the type of industry using a simple random sampling. Under this technique, the population is segregated into several mutually exclusive subpopulations, i.e. the type of industry and members are then taken randomly from the given sub-grouping (Churchill, 1979).

4.4.3 Unit of Analysis

The rationale of just choosing one area of application – manufacturing related technology is based on the advice that one should take on a more homogeneous set of applications and consider them against a relatively well-mapped-out territory, where this brings enquiry down to more manageable proportions (Wall and Kemp, 1987). The study focused on the application of AMT in the manufacturing industry, particularly the computer-based technology used directly in the manufacturing process, and its implications at the operational level, i.e. the manufacturing performance.

Most of the unit of analysis of studies on AMT adoption and implementation are on plant/ firm level (Young and Selto, 1993; Kotha and Swamidass, 2000; Small and Chen, 1997; Schroder and Sohal, 1999). According to Young and Selto, (1993), a single organisation unit study minimizes confounding effects common in across-firm, cross-sectional studies, and the design of the study controls the many external confounding effects. A single organisation unit study is appropriate when the focus of the study is to assess the performance of each individual AMT. As the objective of this study is to assess each individual AMT implementations in different organisations to explain similarities and differences in the implementation approach, and the benefits achieved, the single organisational unit is deemed appropriate.

Rather than attempting to address how an overall technology strategy affects an entire organisation, we examine how the choice of each individual technology impacts a clearly defined part of the manufacturing organisation. This approach limits the number of exogenous variables that could confound the results and should enable stronger inferences about the relationship between AMT and manufacturing strategy and subsequently on the manufacturing performance.

4.5 Operationalisation of Constructs

The following section examines the constructs to be measured, incorporating criticism of previously utilized measures, and details the development of measures for the factors identified in the proposed model in order to allow testing of the associated propositions.

4.5.1 Manufacturing Strategy

The questionnaire solicited information on the type of manufacturing strategy being implemented. Manufacturing strategy was measured by adapting the empirically tested and validated measures as used by Robb and Xie (2003). Respondents were asked to indicate the importance of the thirteen manufacturing priorities in order to compete effectively with their competitors. These items were used to operationalise four competitive priorities, namely cost leadership, quality, flexibility, and delivery. In this context we explore the four core strategic manufacturing orientations, namely; cost leadership strategy, quality strategy, flexibility strategy and delivery strategy.

4.5.1.1 Cost Leadership Strategy

Under the dimension of cost leadership strategy, companies compete directly on price, thus cost will be their major operations objective. The lower the cost of producing their goods and services, the lower can be the price to their customers.

Thus, this strategy can be measured using two items, i.e. companies to offer prices as low as or lower than their competitors, and continuously looking for cost reductions. Besides marketing their products at the possible lowest prices than their competitors, companies that compete based on the cost leadership strategy would also strive for finding all sources possible to reduce cost, thus, a cost reduction initiative is closely link to this strategy.

For the purpose of making comparison among the strategies examined, there is a need to generate indexes to represent each type of the strategy by calculating the mean score of each of it. This can be achieved by summing up all the constructs of each strategy and divided by the number of constructs of that strategy. For example, as the cost leadership strategy comprises of two constructs: i.e. companies that adopt a cost leadership strategy will strive to offer prices as low or lower than their competitors, and continuously looking for cost reductions, thus the mean score of the cost leadership strategy can be derived as follow:

$$\text{Cost Leadership Strategy Score} = \text{CSS} = \frac{\text{Q4B1} + \text{Q5B1}}{2}$$

Where: QiB1 = score on question i from questionnaire section B1

4.5.1.2 Quality Strategy

Quality means 'doing thing right' (Slack et al, 1995) and it varies for different types of operations/ business. The quality strategy would lead to customer satisfaction and internal aspect to it leads to a stable and efficient organisation.

Under the quality dimension of manufacturing strategy, companies were measured on their emphasis on three measures, i.e. providing reliable products, high performance products and products with zero defect error.

Once again, the mean score of the quality strategy can be derived by summing up all the relevant constructs and divided by the number of constructs. The formula is shown as follow:

$$\text{Quality Strategy Score} = \text{QSS} = \frac{\text{Q1B1} + \text{Q2B1} + \text{Q3B1}}{3}$$

Where: QiB1 = score on question i from questionnaire section B1

4.5.1.3 Flexibility Strategy

Companies pursuing a flexibility strategy offer a wide range of products, excellent after-sales service, customised products, new models introduced to their existing products, new product lines, and also produce according to the quantity required.

The mean score of the flexibility strategy can be achieved by summing up the six constructs that are used to measure the strategy, i.e. wide range of products, excellent after-sale service, customised products, new models introductions to their existing products, new product lines, and also to produce according to the quantity required. The flexibility strategy score is as follow:-

$$\text{Flexibility Strategy Score} = \text{FSS} = \frac{\text{Q6B1}+\text{Q7B1}+\text{Q8B1}+\text{Q9B1}+\text{Q10B1}+\text{Q11B1}}{6}$$

Where: QiB1 = score on question i from questionnaire section B1

4.5.1.4 Delivery Strategy

Delivery is regarding how long customers have to wait to receive their products for services. Companies competing on delivery strategy can compete on dependability, i.e. on time delivery and or quickest to reach their customers, i.e. speed of delivery.

Thus, the delivery strategy score can be calculated as follow:-

$$\text{Delivery Strategy Score} = \text{DSS} = \frac{\text{Q12B1}+\text{Q13B1}}{2}$$

Where: QiB1 = score on question i from questionnaire section B1

4.5.2 Advanced Manufacturing Technologies (AMTs)

The list of AMT was adopted from Small and Chen (1997), omits the management/information technologies: just-in-time with the reason that it is not a technology per se. The study investigates 14 types of advanced manufacturing technologies (AMTs) which are commonly used by manufacturing companies. These technologies can be grouped, based on their functionalities, into 5 subgroups:

1. Product design and engineering technologies (PDETs)
2. Production planning technologies (PPTs)
3. Material handling technologies (MHTs)
4. Assembly and machinery technologies (AsMTs)
5. Integrated manufacturing technologies (IMTs)

Companies were asked to indicate the amount of investment the company has in the individual technology, on a Likert scale of 1-5, where 1 indicates little investment, 3 as moderate investment and 5 to show heavy investment. Firms were determined to be either users or non-users of each technology sub-group. For example, an adopter of the design and engineering technology sub-group would be using a combination of either CAD, CAE, GT, CAM or all the above.

The respondents were also asked to indicate the level of integration of each AMT invested in the company, i.e. i.e. whether the piece of technology is connected to another appliance or system within the department, company or the enterprise, or just a piece of stand alone technology. Four levels of integration have been identified from the literature, i.e.:

1. No integration
2. Limited integration
3. Full integration
4. Extended integration

Analyses of the AMTs adoption of the companies surveyed is based on the level of investment in the technology, and its level of integration, This presents a major departure from other studies where respondents were only asked to indicate the level of investment of the AMT.

4.5.2.1 Product Design and Engineering Technologies (PDETs)

Manufacturing companies invested in various product design and engineering technologies (PDETs), such as computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), and group technology (GT) to assist them in designing and testing a product, from a structural or engineering point, controlling of manufacturing machinery, and also for part classifications and coding systems.

4.5.2.2 Production Planning Technologies (PPTs)

Manufacturing companies invested in various production planning technologies (PPTs), such as material requirement planning (MRP), manufacturing resources planning (MRP II), or enterprise resources planning (ERP) to assist them in planning, scheduling and controlling of material and resources requirements for the production of manufacturing companies. ERP covers a wider scope by integrating the operations throughout the companies and also facilitates global integration.

4.5.2.3 Material Handling Technologies (MHTs)

Material handling technologies (MHTs) are AMTs used by manufacturing companies to facilitate the handling of material in manufacturing operations. Automated storage and or retrieval systems (ASRS) use computers to direct automatic loaders to pick and place items for production processes or storage by automatic high-lift trucks. Companies employ transport automation by using automated guided vehicles (AGVs) to move materials to and from value-adding operations.

4.5.2.4 Assembly and Machinery Technologies (AsMTs)

The study examines the level of investment and integration of 3 types of assembly and machining technologies (AsMTs): computer-aided quality control system (CAQCS), robotics and numerical control machines (NC/CNC/DNC). These AsMTs are used to perform repetitive functions and work without permanent alteration of the equipments. CAQCS is used to perform quality inspection on incoming or final materials, robotics to carry out various operations like handling, process or assembly tasks, whilst numerical control machines exist for almost all types of machining, like turning machines, boring and milling machine, horizontal boring machines and machining centres.

4.5.2.5 Integrated Manufacturing Technologies (IMTs)

As the name of the technology group suggests, technologies within this integrated manufacturing technologies (IMTs) group are already integrated in some forms, for example, flexible manufacturing cells (FMC) or systems (FMS) consist of two or more NC/CNC machines which are interconnected by handling devices and a transport system. The difference between FMS and FMC is that FMC is capable of single path acceptance of raw materials and single path delivery of a finished product, whilst FMS is capable of multiple paths, and may also be comprised of two or more FMCs linked in series or parallel.

Another technology within this subgroup is called computer-integrated manufacturing (CIM), which incorporates all elements in the manufacturing process from product design to distribution. It links beyond company departments by integrating computer systems, thus islands of computer application in the firms are integrated.

4.5.2.6 Generation of AMTs Scores and Gross Comparisons

For the purpose of a summary and analysis, the aggregate of investment and integration of each individual group of AMT of surveyed companies can be calculated by summing up the score of each type of AMT in the particular group and divided by the number of AMT in that category.

There are four AMT that can be grouped under the product design and engineering technology category, such as CAD, CAE, GT and CAM. Thus, the average score of product design and engineering technology investment (PDETinv) and integration (PDETint) are as follow:

$$PDET_{inv} = \frac{CAD_{inv} + CAE_{inv} + GT_{inv} + CAM_{inv}}{4}$$

$$PDET_{\text{int}} = \frac{CAD_{\text{int}} + CAE_{\text{int}} + GT_{\text{int}} + CAM_{\text{int}}}{4}$$

Where, CAD_{inv} = score of investment in CAD

CAE_{inv} = score of investment in CAE

GT_{inv} = score of investment in GT

CAM_{inv} = score of investment in CAM

CAD_{int} = score of integration in CAD

CAE_{int} = score of integration in CAE

GT_{int} = score of integration in GT

CAM_{int} = score of integration in CAM

Likewise, as MRP, MRPII and ERP, are the AMTs used to assist in production planning activities, the score of these AMTs will be included in calculating the mean score of production planning technology investment (PPTinv) and integration (PPTint) as follow:-

$$PPT_{inv} = \frac{MRP_{inv} + MRPII_{inv} + ERP_{inv}}{3}$$

$$PPT_{int} = \frac{MRP_{int} + MRPII_{int} + ERP_{int}}{3}$$

Where, MRP_{inv} = score of investment in MRP

$MRPII_{inv}$ = score of investment in MRPII

ERP_{inv} = score of investment in ERP

MRP_{int} = score of integration in MRP

$MRPII_{int}$ = score of integration in MRPII

ERP_{int} = score of integration in ERP

Both ASRS and AGVs are normally used to perform the handling of material on production floor, thus, they are classified as material handling technology (MHT). The average score of material handling technology investment (MHTinv) and integration (MHTint) can be calculated as follow

$$MHT_{inv} = \frac{ASRS_{inv} + AGV_{inv}}{2}$$

$$MHT_{int} = \frac{ASRS_{int} + AGV_{int}}{2}$$

Where, $ASRS_{inv}$ = score of investment in ASRS

AGV_{inv} = score of investment in AGV

$ASRS_{\text{int}}$ = score of integration in ASRS

AGV_{int} = score of integration in AGV

As for assembly and machinery technology, there are CAQC, CN/CNC/DNC and robotics. So, in order to calculate the average score of AsMT investment (AsMTinv) and integration (AsMTint), formula as follow can be used:-

$$AsMT_{inv} = \frac{CAQC_{inv} + CNC_{inv} + ROBOTIC_{inv}}{3}$$

$$AsMT_{\text{int}} = \frac{CAQC_{\text{int}} + CNC_{\text{int}} + ROBOTIC_{\text{int}}}{3}$$

Where, $CAQC_{inv}$ = score of investment in CAQC

CNC_{inv} = score of investment in NC/CNC/DNC

$ROBOTIC_{inv}$ = score of investment in ROBOTIC

$CAQC_{\text{int}}$ = score of integration in CAQC

CNC_{int} = score of integration in NC/CNC/DNC

$ROBOTIC_{\text{int}}$ = score of integration in ROBOTIC

Last but not least, there are 2 AMTs under the group of integrated manufacturing technology (IMT): FMC/FMS and CIM. Hence, the average score of IMT investment (IMTinv) and integration (IMTint) can be derived from formulae as follow:-

$$IMT_{inv} = \frac{FMS_{inv} + CIM_{inv}}{2}$$

$$IMT_{\text{int}} = \frac{FMS_{\text{int}} + CIM_{\text{int}}}{2}$$

Where, FMS_{inv} = score of investment in FMC/FMS

CIM_{inv} = score of investment in CIM

FMS_{int} = score of integration in FMC/FMS

CIM_{int} = score of integration in CIM

4.5.3 Manufacturing Performance

The questionnaire section on performance measurement contained 12 items which can be categorised into 4 main competitive priorities: quality, cost, flexibility and delivery. The measures were adapted from Robb and Xie (2003), which were the same as the manufacturing strategy. Respondents were asked to rate the organisational performance in comparison with the industry average in the manufacturing criteria which reflect the 4 main competitive priorities. For each variable, firms were asked to choose a response on a 5 Likert-point scale, where 1 is 'well below par', 3 is 'average', and 5 is 'well above par'.

4.5.3.1 Cost Leadership Performance

Cost leadership performances are reflected in two variables, performance on low price and performance on cost reduction. It claimed that companies that are adopting cost leadership strategy are strive to achieve the cost-based performance, i.e. to be able to competitive or lowest prices through efficiency from all possible sources and be able to offer competitive or lowest prices through cost reduction from all possible sources.

Once again, for the purpose of making comparison among the performance examined, an index to represent each type of the performance can be derived by summing up all the constructs of the performance and divided by the number of constructs of that performance. For example, as the cost leadership performance measurement comprises of two constructs: i.e. to be able to competitive or lowest prices through efficiency from all possible sources and be able to offer competitive or lowest prices through cost reduction from all possible sources, thus the mean score of the cost leadership performance can be derived as follow:

$$\text{Cost Leadership Performance Score} = \text{CPS} = \frac{\text{Q4D1} + \text{Q5D1}}{2}$$

Where: QiD1 = score on question i from questionnaire section D1

4.5.3.2 Quality Performance

For a company that compete in the market based on the quality strategy, the performance that it is concerned would be the ability to offer products that are reliable, ability to offer high performance products to its customers and the ability to deliver zero defect error products. Thus the mean score of quality performance is calculated as follow:-

$$\text{Quality Performance Score} = \text{QPS} = \frac{\text{Q1D1} + \text{Q2D1} + \text{Q3D1}}{3}$$

Where: QiD1 = score on question i from questionnaire section D1

4.5.3.3 Flexibility Performance

Companies that pursuing a flexibility strategy aim to be able to offer a wide range of product options to their customers, able to provide excellent after-sale service, able to customise products according to customers' specifications and requirements, able to offer new models into their existing products, and able to launch new product line to new customers, and finally able to change the output volume quickly according to their customers requirements.

The mean score of the flexibility performance can be achieved by summing up the six constructs that are used to measure the performance and divided by the number of constructs. The flexibility performance score is as follow:-

$$\text{Flexibility Performance Score} = \text{FPS} = \frac{Q6D1 + Q7D1 + Q8D1 + Q9D1 + Q10D1 + Q11D1}{6}$$

Where: QiD1 = score on question i from questionnaire section D1

4.5.3.4 Delivery Performance

Delivery performance measure the perceived performance by surveyed companies in regards to delivery on time and speed of delivery, i.e. the ability to reach their customers quickly. Thus, the delivery performance score can be calculated as follow:-

$$\text{Delivery Performance Score} = \text{DPS} = \frac{Q12D1 + Q13D1}{2}$$

Where: QiD1 = score on question i from questionnaire section D1

4.6 Questionnaire Design

A cross-sectional survey approach was conducted where information was collected at one point in time. In this survey approach, a questionnaire is an instrument used to measure reality 'objectively' (Leedy and Ormrod, 2001; Creswell, 1994).

The questionnaire used in this study incorporated inputs from various sources: most of the questions were adopted from previous published work (Small and Chen, 1997), and then the preliminary drafts of the questionnaire were discussed with academic scholars and practitioners and subsequently tested in one of the automobile part manufacturing companies in West Midlands, to assess the content validity. The feedback from the above parties was then used to improve the clarity, comprehensiveness and relevance of the research instrument. The final survey instrument incorporates some minor changes that were picked up during this preliminary test.

The questionnaire solicited information on the three elements of the study: manufacturing strategy, AMT and manufacturing performance.

In order to measure the type of manufacturing strategies that were adopted by companies, the list of items used in the study of Kotha and Swamidass (2001) were used based on Porter's model of manufacturing strategy. Respondents were asked to indicate the importance of the thirteen manufacturing priorities in order to compete effectively with their competitors. These items were used to operationalise four competitive priorities, namely cost leadership, quality, flexibility, and delivery.

The list of AMT was adopted from Small and Chen (1997), omits the management/information technologies: just-in-time with the reason that it is not a technology per se. The study investigates 14 types of advanced manufacturing technologies (AMTs) which are commonly used by manufacturing companies. These technologies can be grouped, based on their functionalities, into 5 subgroups:

1. Product design and engineering technologies (PDETs)
2. Production planning technologies (PPTs)
3. Material handling technologies (MHTs)
4. Assembly and machinery technologies (AsMTs)
5. Integrated manufacturing technologies (IMTs)

The measures of AMT are based on the amount of investment the company has in the individual technology, on a Likert scale of 1-5, where 1 indicates little investment, 3 as moderate investment and 5 to show heavy investment; and the level of integration of each AMT invested in the company, i.e. i.e. whether the piece of technology is connected to another appliance or system within the department, company or the enterprise, or just a piece of stand alone technology. Four levels of integration have been identified from the literature, i.e.:

1. No integration
2. Limited integration
3. Full integration
4. Extended integration

In order to measure the manufacturing performance of the companies, respondents were asked to rate the company's performance in comparison with the industry average in the manufacturing criteria which reflect the 4 main competitive priorities. The measurements contained 12 items under the 4 main competitive priorities: quality, cost, flexibility and delivery, which are the same as the manufacturing strategy.

4.7 Main Data Collection

The main survey was administered by post to the sample described above. A self-addressed, stamped return envelope and follow-up letters were used in order to minimise further limitations of the mail questionnaire (Sekaran, 2000).

During the first quarter of 2005, 2000 questionnaires were mailed to the managing directors or chairmen of manufacturing companies. 62 questionnaires were returned as undeliverable. A total of 276 responses were obtained from this survey, however, 14 of these responses were unusable. Thus, a survey response rate of 14 percent was achieved. This response rate is comparable to those reported in recent studies on similar topics (Kotha and Swamidass (2000) -18%; Dean and Snell (1996)-18%, Das and Narasimhan (2001)-19%).

4.8 Overall Research Design and Methodology

This section summarise the overall methodology undertaken to answer the research questions developed in the previous chapters. The research started with an understanding of the fundamental theories in the areas relevant to the topic such as AMT diffusion, contingency theory, fit, manufacturing strategy and manufacturing performance.

Because of the nature of the research questions proposed, a quantitative approach was preferred, and due to the lack of existing secondary data on AMT and manufacturing strategy, primary data collection was undertaken via a questionnaire.

The questionnaire used in the survey incorporated inputs from various sources: the majority of the questions were adopted from previous works of Small and

Chen (1997), and Robb and Xie (2002) and was tested before being distributed to the full sample.

The questionnaires were administered by post together with a covering letter and business reply envelope, to a total of 2000 companies, whose details had been supplied by Dun and Bradstreet Ltd - randomly selected from its manufacturing companies listed under SIC codes 27-35 which produce discrete and durable parts. The letter was addressed to the managing directors or chairmen of the companies.

A follow-up letter together with the questionnaire and a business reply envelope were sent to non-responding companies – identified through the individual series number on the each questionnaire. In total, 276 responses were obtained from this survey, however, there are 14 responses unusable, thus giving an overall useable response rate of 14 percent.

4.9 Statistical Analyses

This section looks at the statistical techniques used to analyse data collected from the questionnaire. The first part of the section explains the technique used to perform the hypotheses testing, and the last part of the section looks at the analyses techniques used to measure fit.

4.9.1 Hypotheses Testing

There were two hypotheses derived from literature:

Hypothesis 1: Differentiation Strategy is positively associated with multiple AMTs.

Hypothesis 2: Cost Leadership Strategy is not associated with multiple AMTs.

The information for the statistical analyses was collected via a questionnaire completed by the informant in the surveyed company, mainly from the top management team. The information consists of the type of manufacturing strategy orientation, type of AMT and their perceived performance in regards to their manufacturing capabilities.

The aim of the hypotheses testing of the study is to test the level of agreement between the type of manufacturing strategy and the diffusion of AMTs to facilitate the manufacturing processes in order to achieve the intended manufacturing performance.

A correlation, or bivariate correlation, measures the relationship between two variables. The correlation measures the strength of the relationship, which ranges from -1 to +1: the closer the correlation is to 1 or -1, indicates a strong relationship, whilst the closer the correlation is to 0, the weaker the relationship. In order to perform bivariate correlations analyses of manufacturing strategies and AMT in order to test the hypotheses, first of all, factor analysis based on the Principal Component Analysis[1] extraction method with Varimax rotation[2] is used in order to reduce the dimensions involved in each variable.

It is then followed by further tests to examine whether the samples are normally distributed in order to make meaningful inferences. This can be

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[1] **Principal component analysis (PCA)** invented by Karl Pearson, is a statistical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. The results are usually discussed in terms of component scores and loadings.

[2] **Varimax rotation** is used to see how groupings of questions (items) measure the same concept. For each factor, high loadings (correlations) will result for a few variables; whilst the rest tend to close to zero.

achieved by conducting a normal PP plot[3]. The plots from a normal distribution data should all fall in a straight line on the PP graph. Departures from the line are clues of departures from the normal distribution. After which, the hypotheses testing can be performed by testing the level of agreement between the variables by examining bivariate correlations of manufacturing strategies and AMT.

In terms of the measurement of AMT, the score of each of the five categories is derived based on two distinctive measurements: the level of investment and the extensiveness of its integration. The mean score of each type of AMT is calculated by taking the average of its investment score and integration score. Therefore, we have five measurements of AMT, which are Product Design and Engineering Technology Score (PDE), Production Planning Technology Score (PPT), Material Handling Technology Score (MHT), Assembly and Machinery Technology Score (AsMT) and Integrated Manufacturing Technology Score (IMT).

The performance score is calculated by multiplying each of the four original performance variables (mean adjusted) by the corresponding factor component score coefficient. During the calculation, all the performance variables have already been subtracted by the average of the entire variable to avoid bias. However, the original notations are still used for simplification purpose. For instance, the new *QBP* in the following equation actually indicates *QBP-Average (QBP)*. The mathematical definition expression of the equations are given as follow:

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[3] The **normal probability plot** is a graphical technique for assessing whether or not a data set is approximately normal distributed. The data are plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line. Departures from this straight line indicate departures from normality.

$$MP = \alpha_1 QBP + \alpha_2 CBP + \alpha_3 FBP + \alpha_3 DBP$$

where:

MP = Overall manufacturing performance

QP = Quality performance

CLP = Cost Leadership performance

FP = Flexibility performance

DP = Delivery performance

The model is then applied separately for each of the two clusters of firms, i.e. overall performance is modelled for those firms focussing on a differentiation strategy (this is termed Differentiation Performance) and then to those firms that follow a cost leadership strategy (this is termed Cost Leadership Performance). In this sense, companies having a high differentiation performance should perform well from the quality, flexibility and delivery aspects; on the other hand, companies having high cost leadership performance should perform well on cost related performance.

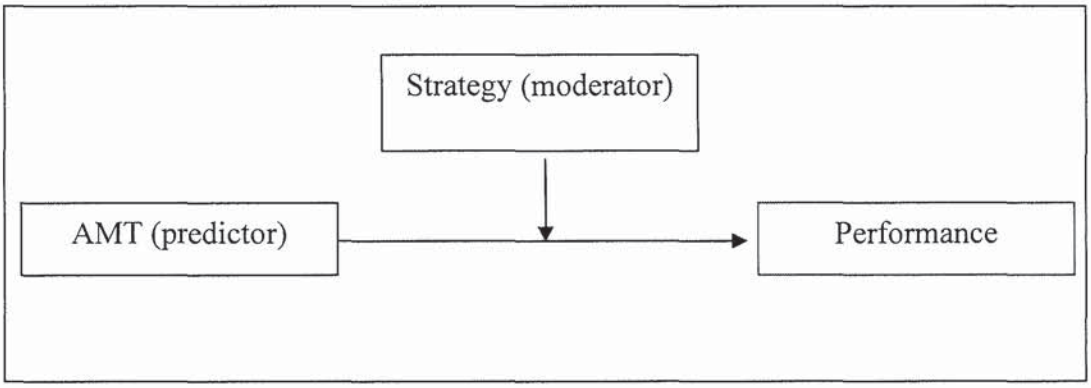
4.9.2 Measurement of Fit

The second part of the statistical analyses focuses on the contingency fit theory and the various perspective of fit as proposed by Venkatraman (1989), i.e. fit as moderation, fits mediation, fit as gestalts, fit as matching, fit as profile deviation and fit as covariation. The study examines the dataset using the multiple perspectives of fit, to discuss the impact of alignment or fit between the AMT and manufacturing strategy on the perceived manufacturing performance.

4.9.2.1 Fit as Moderation

In the moderation approach, the effect of the predictor variable, i.e. AMT on performance depends on the level of the moderator variable (i.e. strategies). The schematic representation of variables is illustrated in Figure 4.1.

Figure 4.1: A schematic representation of fit as moderation

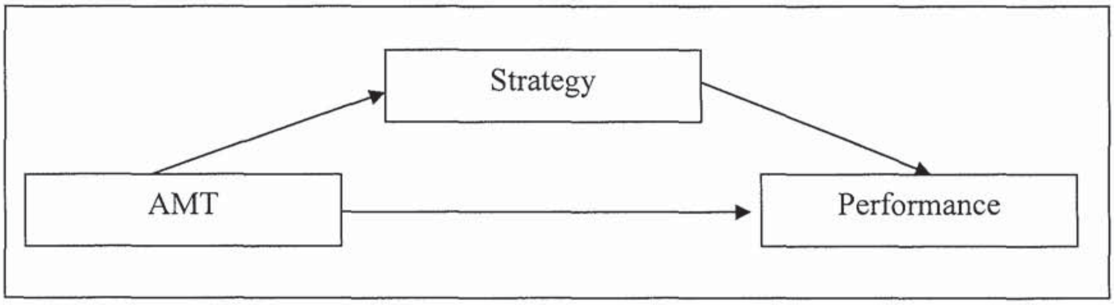


The testing for the moderation approach of fit can either be by performing a subgroup analysis on the correlation coefficients between moderators and predictors or by examining the significance of interaction terms in regression of performance against strategies and AMT.

4.9.2.2 Fit as Mediation

In the fit as mediation approach, strategies (differentiation strategy and cost leadership strategy) are considered as an intervening mechanism between antecedent variables (AMT) and the consequent variables (differentiation performance and cost leadership performance). If the effect of antecedent variables (AMT) on consequent variables (performances) is said to be direct, the intervening mechanism (strategies) could be considered as an indirect influence power in the relationship, which is demonstrated in Figure 4.2.

Figure 4.2: A schematic representation of fit as mediation



The mediation approach of fit is mainly tested by examining several equations in this report (constant term omitted):

$$Performance = \alpha_1 PDET + \alpha_2 PPT + \alpha_3 MHT + \alpha_4 AsMT + \alpha_5 IMT + \alpha_6 Strategy + \varepsilon$$

$$Strategy = \beta_1 PDET + \beta_2 PPT + \beta_3 MHT + \beta_4 AsMT + \beta_5 IMT + \varepsilon$$

Where terms α_i and β_i are the regression coefficients and ε is the term of random effect. As before the models are applied to separately to the two groups of firms, i.e. Performance refers to differentiation performance and cost leadership performance, and Strategy is the scores of differentiation strategy and cost leadership strategy. PDET, PPT, MHT, AsMT and IMT, refer to the mean score of investment and integration for each type of AMT as described in Section 4.5.2.6.

4.9.2.3 Fit as Matching

Test of fit as matching in this study mainly adopts a residual analysis approach. As Dewar and Werbel's (1979) proposed, if fit exists between two variables X and Z, the residuals of regression on X (Strategy) by Z (AMT) would have significant influence on criterion variable Y (Performance).

Based on regressions on performances by the residuals generated previously, two residual variables can be developed in order to conduct two linear regressions:

1. Residuals of regression on Differentiation strategy by AMT
2. Residuals of regression on Cost leadership strategy by AMT

Based on the two types of performance derived from the data, linear regression can be performed on the two models as below:

Model 1: Differentiation performance ~

Residuals (Differentiation Strategy ~AMT) + Residuals(Cost leadership strategy ~AMT)

Model 2: Efficiency performance ~

Residuals (Differentiation Strategy ~AMT) + Residuals(Cost leadership strategy ~AMT)

If any of the residuals are significant in the regression, we consider a fit effect exists on the performance. For instance, if residuals of regression on differentiation strategy by AMT were significant in Model 1, we consider a fit between differentiation strategy and AMT exists and such a fit has important impact on the differentiation performance of the surveyed companies.

4.9.2.4 Fit as Profile Deviation

The test of fit as profile deviation approach considers performance is negatively related to the deviation of a company to an ideal profile. Such an ideal profile should be built by the top 10% performers of the sample. Deviations are measured as the Euclidean distance between two companies on dimensions of strategy and AMT investment and integration. The more a company deviates from the ideal profile, the worse it performs on several or all dimensions.

To process the data, we first sort all companies (N=262) by their differentiation performance score, remove the lowest 10% samples (N=26) and extract top 10% performers as calibration sample (N=26). We then compute the mean score on each dimension and consider them as the ideal profile. Then we calculate the Euclidean distances of the remaining sample to the ideal profile.

4.9.2.5 Fit as Gestalts

Most other approaches test fit from variable perspectives by dimension reduction or regressions. In contrast, fit as gestalts aims to group samples into clusters—"gestalts" using Euclidean distance. Following this approach, all samples are clustered into three gestalts out of the consideration of cluster effect and convenience of explanation by PDET, PPT, MHT, AsMT, IMT, differentiation strategy and cost leadership strategy attributes. Then, using the test of fit via gestalts perspective, the attribute of each gestalt in terms of its performance, the type of manufacturing strategy, and the level of AMT investment and integration, can be revealed.

4.10 Conclusions

This chapter provided details of the methodology applied to the research problem. A measuring instrument, in the form of self-report questionnaire, was designed and administered to a sample of senior managers in UK manufacturing companies. The instrument design was based on established research practices, and through pre-testing. The mail survey was sent to 2000 senior managers and generated a usable response rate of 14 percent that represented an absolute figure of 262.

This study attempted to provide answers to the research questions by examining technology initiatives in a broad context - employing a holistic configuration approach to identify patterns of technology investments and integration related to performance. The study focuses on generic manufacturing strategies, i.e. cost leadership strategy and differentiation strategy, to explore the use of AMTs across different manufacturing strategies. Finally, the study examines the alignment between manufacturing strategy and technology investments and integrations, and its implication of manufacturing performance.

CHAPTER 5

DESCRIPTIVE ANALYSIS

5.1 Introduction

The previous chapter described the methodology employed in gathering data to address the questions raised in Chapter Three. This chapter provides the descriptive statistics of the companies who participated in this study and of their responses given on the questionnaire, before the hypotheses developed in the Chapter Three are tested in Chapter Six.

This chapter is important for a number of reasons, firstly it provides background information of the companies and managers surveyed, such as their demographic characteristics, extent of AMT adoption, their manufacturing strategy and the manufacturing performance. This information is essential in order to establish to which companies the results that are presented in the subsequent chapters can be applied to. For example, the descriptive statistics show the sample companies are predominately small to medium size mature firms, and as such care should be taken when trying to extrapolate the results beyond this form of company.

The chapter also provides a snapshot of part of the current UK manufacturing sector, and as such can be used as a benchmark which future research can use to judge whether how this part of the manufacturing sector is evolving.

Finally, a thorough review of the descriptive statistics of the sample and questionnaire answers provides a means of testing the robustness of the data and also provides the reader with a much greater understanding of exactly what type of companies have been surveyed and what answers have been given.

The remainder of this chapter is organised into four sections: the first section is centred on the respondents profile and their demographical characteristics; the second section outlines the manufacturing strategy adopted by companies surveyed; the third section describes the technology employed in their manufacturing facilities; and the final section looks at the companies' performance in regards to their manufacturing capabilities.

5.2 Respondents' Profile

Numerous elements of company profile were collected, i.e. the type of business which was based on the widely used SIC codes; the year of establishment; the formal status of the company; the principal ownership of the company; and the company size which was assessed by the number of full-time equivalent employees where one part-time equals to half a full-time employee.

A letter accompanying the questionnaire was addressed to the Chairman or Managing Director of companies. In the last part of the questionnaire, the respondents were required to fill up their job title and the duration in holding the position in the company. This information was deemed important in order to find out the credibility of the informant.

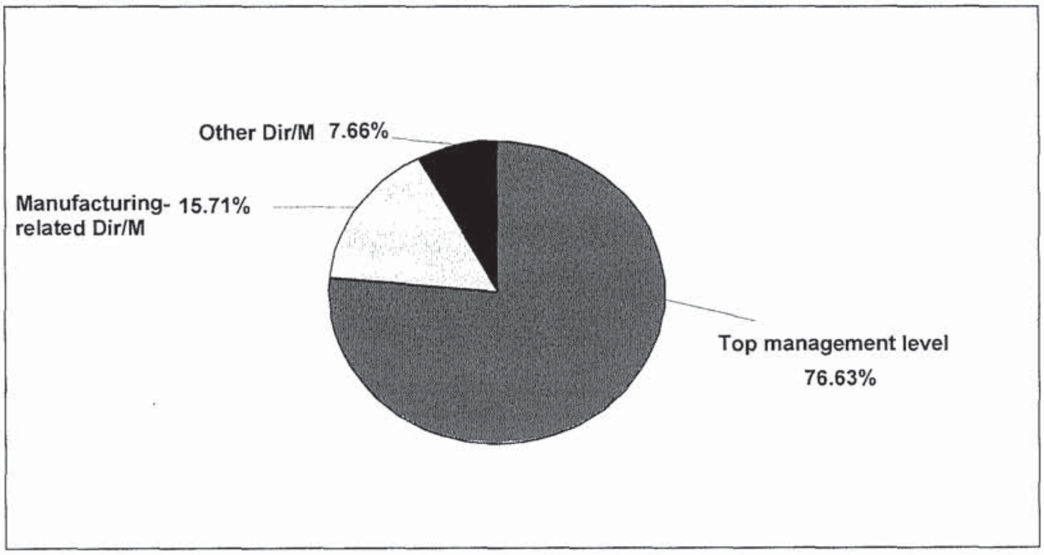
The majority of the respondents (76.6%) were from top management levels, i.e. director, managing director, chief executive officer or chairman, and approximately 15.7% of the respondents were responsible directly to manufacturing or operations or production issues of their companies. A small fraction of respondents, i.e. 7.7% were holding non-manufacturing-related positions such as administration manager (1 respondent), company secretary (1), marketing manager (1), commercial manager (1), purchasing manager (1), senior manager (1), human resource manager (2), office manager (1), sales manager or director (3) and finance director or manager (8). The presentation of these figures is as follows:

Table 5.1: Respondents Profile

Job titles	No of respondents	Percentage
Top management levels	200	76.6
Manufacturing-related directors/ managers	41	15.7
Others directors/ managers	20	7.7

As the mean firm size of companies surveyed is rather low, at around 50 employees, it is no surprise that the top management level were in-charge of their manufacturing function and involved in decision making in manufacturing issues. At a glance, we can infer that the information collected from the survey was highly credible and with good understanding of informants, with the average duration in their respective positions as 11 years. The pie chart on the next page shows the comparison of job title groups.

Figure 5.1: Comparison of Job Title Groups



5.2.1 Manufacturing Sector Distribution

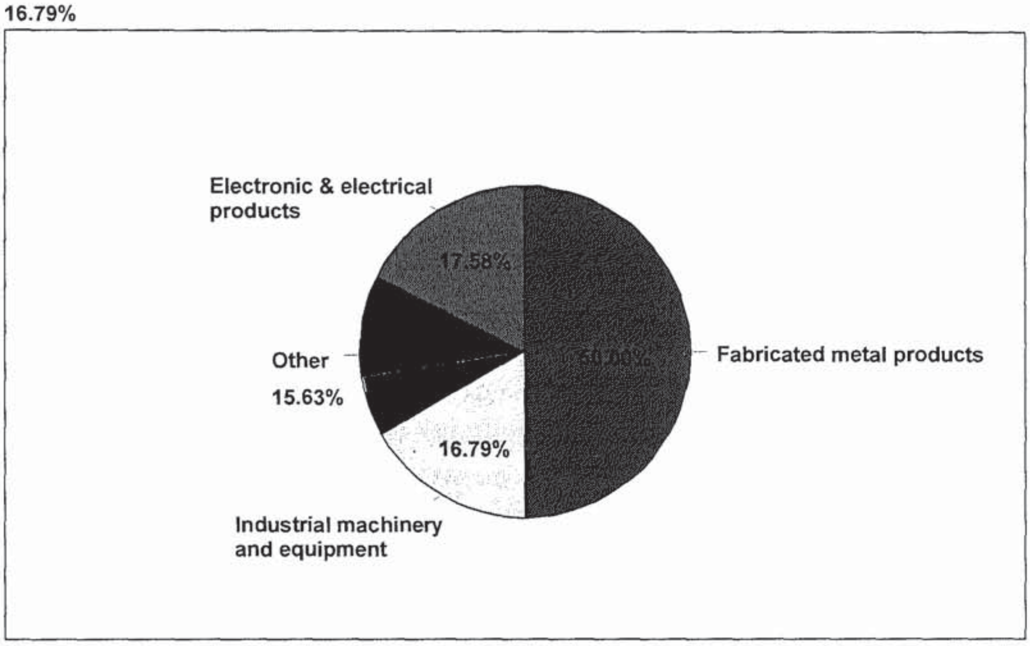
As the focal point of our study is on sectoral differences, data is presented in a disaggregated form of the manufacturing sectors. This allows better understanding about sectoral differences in terms of the structure and composition of the different sectors that constitute in aggregate the UK manufacturing sectors, and provide a basis for understanding why firms in different sectors might act differently in terms of adopting different technologies, business strategies and achieving observably different levels of performance. Table 5.2 presents the distribution of manufacturing sectors for the respondents to the survey. The manufacturing sectors were based on the SIC codes 28-36, which involved companies manufacturing discrete products. The majority of respondents, i.e. 131 of respondents, were manufacturing fabricated metal products, which counts for 50%, followed by the electronic and electrical sector at 46 (17.6%), and industrial machinery and equipment at 44 (16.8%). Other respondents represent a small fraction of sectors like transportation equipment (14 respondents), and others (15). The furniture industry represents the smallest respondent group with only 2 respondents.

Table 5.2: Manufacturing Sector Distribution

	Frequency	Percent	Cumulative Percent
Fabricated metal products	131	50.0	50.0
Industrial machinery and equipment	44	16.8	66.8
Other	41	15.6	82.4
Electronic and electrical products	46	17.6	100.0
Total	262	100.0	

Due to the relatively small number of respondents of some of the groups, i.e. 'transport equipment' sector, 'furniture' sector, and 'other' sector, these sectors were combined to form the 'Other' group. Thus, four broad sectors derived from this disaggregation, i.e. fabricated metal products, industrial machinery and equipment, electronics and electrical products, and other, as shown in the graph as follow:

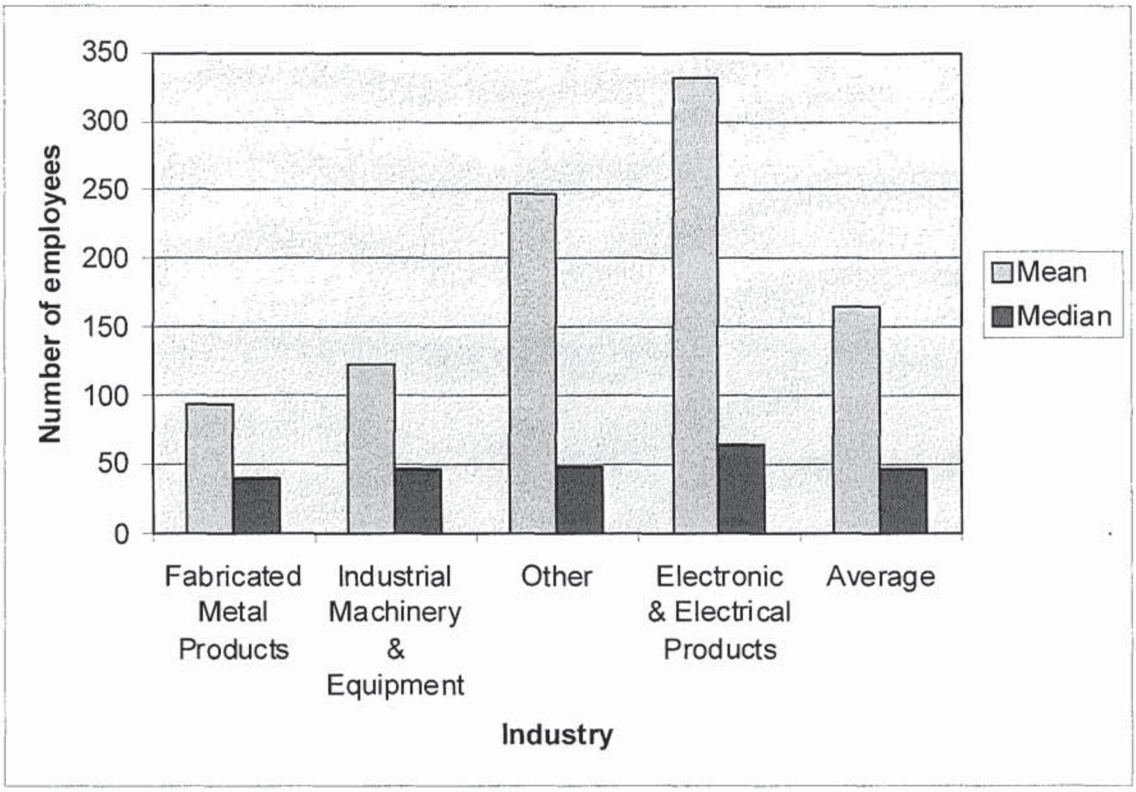
Figure 5.2: Comparison of Sector Groups



5.2.2 Employment by Industry

The study used the full-time equivalent (FTE) employees as the number of employees, where one part-time employee is equal to a half of a full-time employee. From Figure 5.3 on the next page, it is observed that, on average, firms in the electronics and electrical sector are the largest and employ more than twice the UK manufacturing average, with mean and median at 331.73 and 64.5 employees respectively. Firms in the ‘other manufacturing’ category also have high average employment. This strongly contrasts with the average employment in fabricated metal and industrial machinery where employment is around the 100 level.

Figure 5.3: Firm Size Patterns by Industry

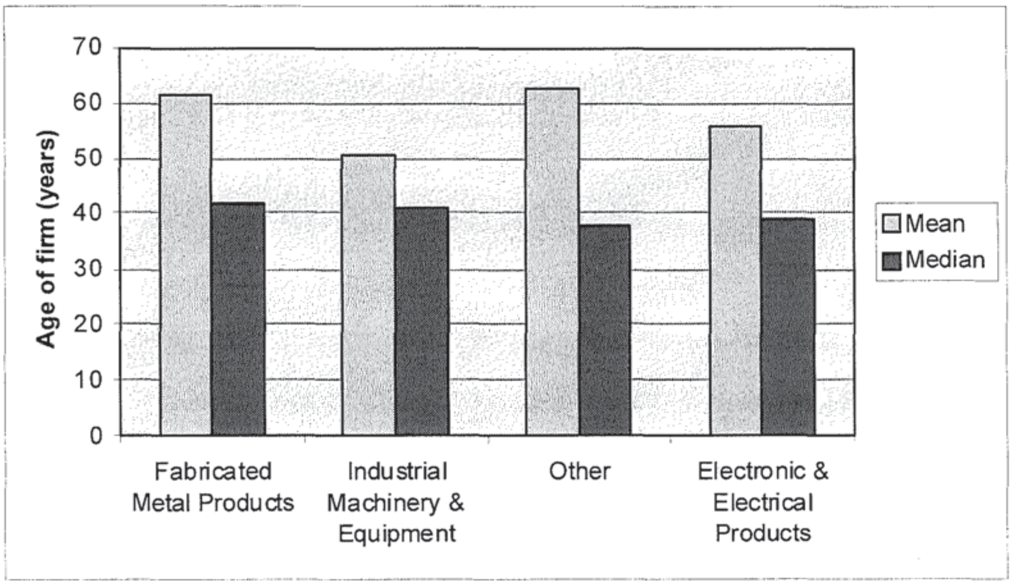


As the median firm size across all industry sectors is around the 50 employee level, it indicates the presence of some very large firms which are pulling the whole sector average up. Yet, this is most stark in electronics and other manufacturing suggesting a few giant firms are present in the industry. This suggests that these two industries may have oligopolistic tendencies, i.e. dominated by a few giant corporations.

5.2.3 Age of Industry Stock

The majority of companies surveyed were mature companies that have existed in the manufacturing scene for some time, with average firm age between 50 and 60 years old (see Figure 5.4). The fact that the median firm age is around 40 years old shows that across all of the four broad manufacturing sectors, the core stock of firms are very well established. The majority of the companies have existed in the manufacturing scene between 31 to 50 years. Once again, it is apparent that there are some very old firms that are in existence in each of the sectors as the average age is always much greater than the median. There were 14 percent of respondents (31 companies) which have been trading for more than 100 years, with almost half of them in the fabricated metal industry. There was only a fraction of young companies, 10 of them, which existed for less than 10 years. The results also show that there are some very old firms existing among the respondents, while the numbers of young companies are relatively small.

Figure 5.4: Mean and Median Age of Industry Stock

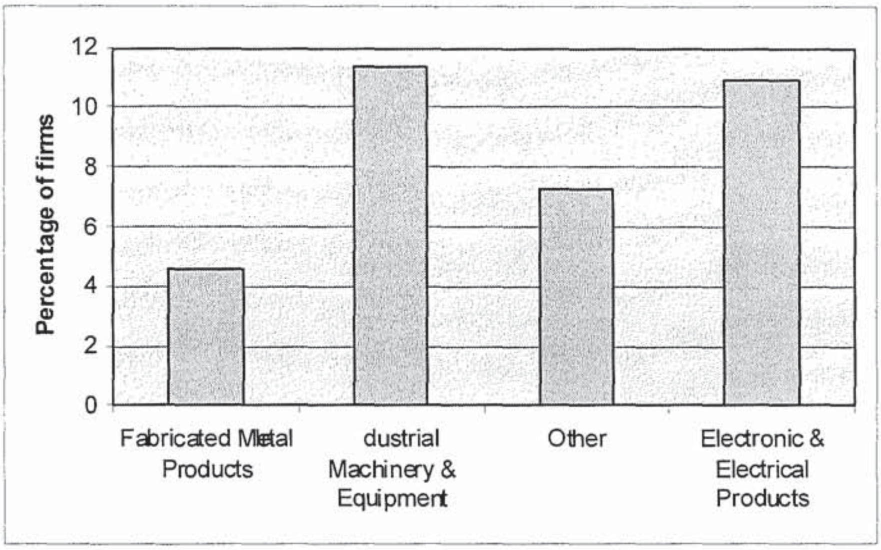


5.2.4 Legal Status of Respondents

Figure 5.5 shows the public limited company (PLC) proportion of the total stock of firms within our four broad manufacturing sectors. It is observed that the sample is overwhelmingly made up of private limited companies, as high as 89 percent of the respondents. This reflects the dominance of this form of company in the manufacturing sector in UK.

The difference between public limited and private limited companies is the accessibility of the equity market: as the shares of the public limited company are publicly traded, there is the possibility for ownership to be divorced from operational control of the firm. By contrast, privately owned businesses, whilst having limited scope for raising capital on open markets, have a direct link between ownership and control as they are typically owned and managed by an entrepreneur or a family. This has potential implications for investment capacity in new technologies and strategic orientation.

Figure 5.5: Public Limited Company Proportion of the Firm Stock



In terms of the employment size of firms of different legal status companies, it is noticed that over 50 percent of private companies are of small size; however, the majority of publicly held companies are medium sized (refer to Table 5.3).

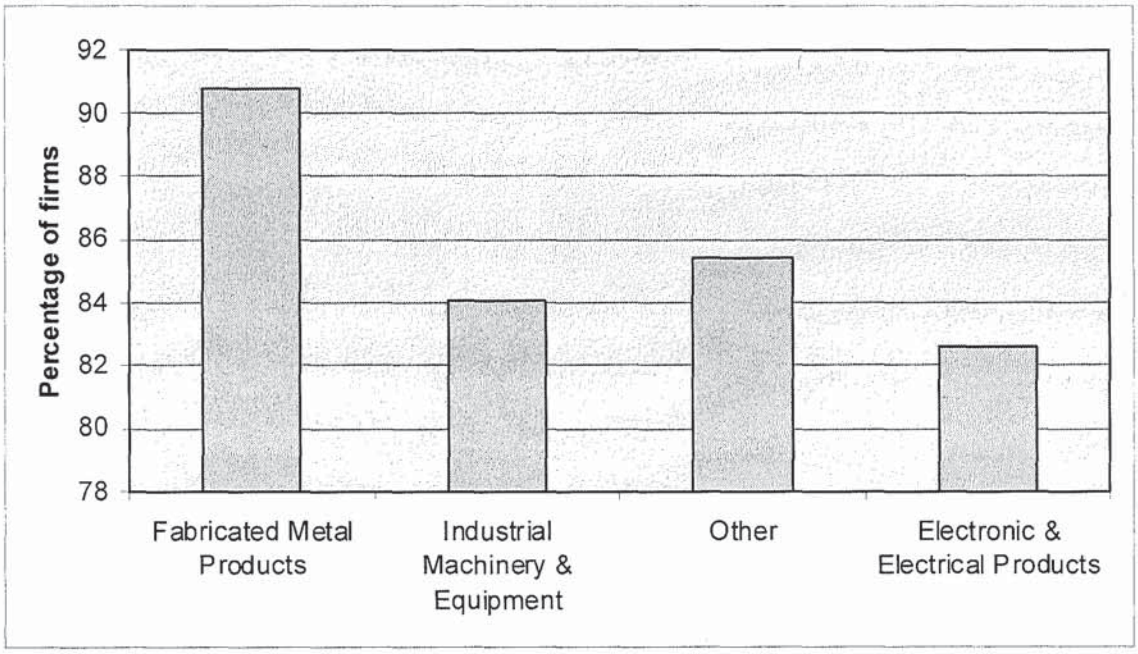
Table 5.3: Employment Size of Different Legal Status Companies

		Employment bands			Total
		Small	Medium	Large	
Private	Count	132	81	27	240
	%	55.0%	33.8%	11.3%	100.0%
Public	Count	4	11	4	19
	%	21.1%	57.9%	21.1%	100.0%
Total	Count	136	92	31	259
	%	52.5%	35.5%	12.0%	100.0%

5.2.5 Form of Principal Ownership

In terms of international presence in UK manufacturing, it is noted that there are considerable differences across the four broad sectors. In fabricated metals, for example, the sector is vastly dominated by UK owned firms, with only 9.2% of firms being foreign owned. This contrasts strongly with the electronics sector where 17.4% of the total stock of firms is foreign owned. With the presence of foreign ownership in industrial machinery, other manufacturing and electronics and electrical industries, we can speculate that competitive pressures, generated through the international presence in markets, may be higher in these industries.

Figure 5.6: UK Owned Proportion of Firm Stock



5.2.6 Summary of Respondents Profile

We have presented basic survey data for four broad manufacturing sectors on an array of firm and industry characteristics. Overall, we have identified some important differences across our four sectors which might be important in terms of understanding why firms in different sectors have different levels of AMT adoption, adopt different types of AMT, have different strategies in place to deal with AMT and have different levels of performance.

Broadly, we might classify the fabricated metals product sector as having a well established firm stock with a high domestic share of the total firm stock, which is typically held in private hands and operates at a single site. The typical firm can be classified as a small business. The industrial machinery equipment sector also has a core of relatively well-established firms, and relatively competitive. There is also a relatively high level of foreign ownership and the publicly owned share of the stock is also high. Yet most firms still operate at a single site, and can be classified as small.

Both of these sectors appear different from the other manufacturing and electronics sectors in terms of their fundamental make-up. For example, in these latter two sectors, firms are slightly younger and face less competition from new entrants. There are also relatively high levels of foreign ownership and a significant share of publicly owned firms. There is also a higher share of medium and large sized businesses and also of multi-plant operations. In addition, it is evident that medium sized companies bear a higher share in publicly owned businesses in contrast with that of private businesses, which are more of small sizes.

5.3 Manufacturing Strategy

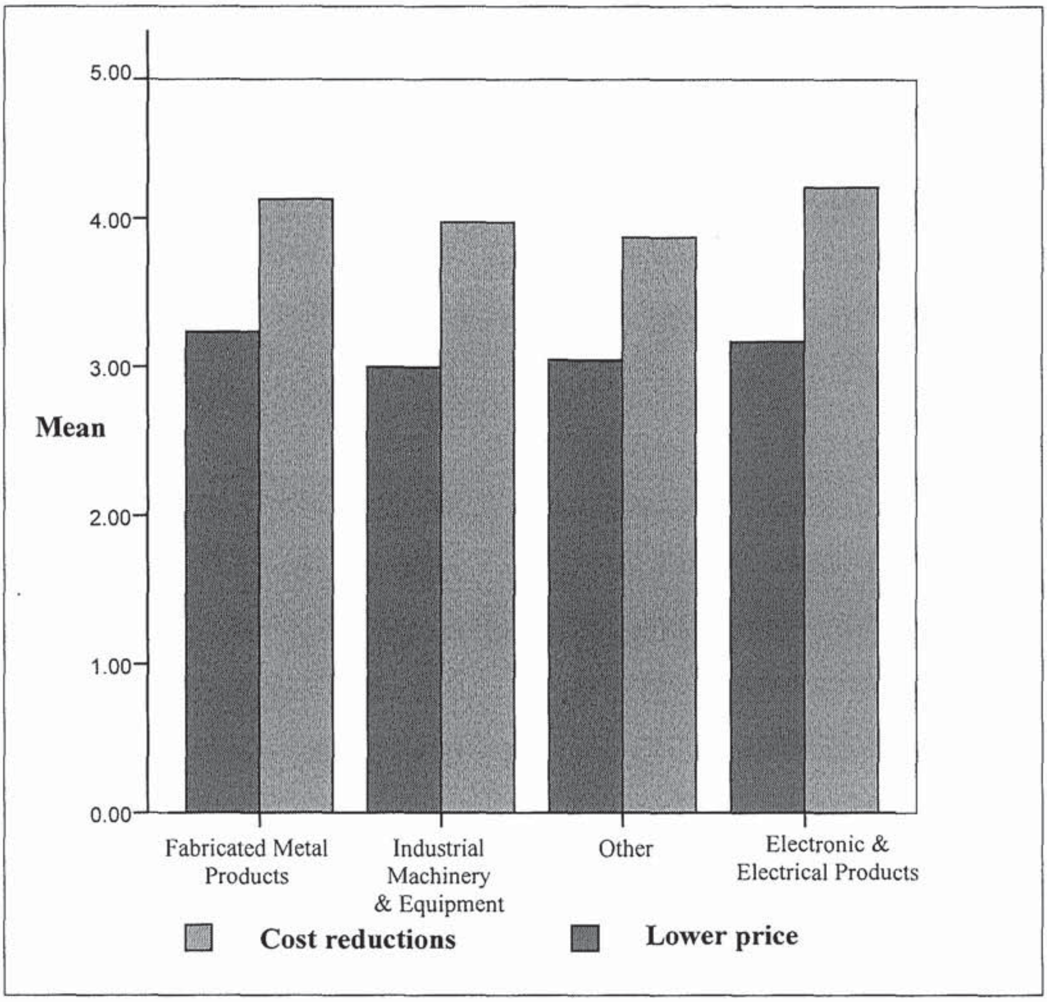
Having explored some basic differences in the nature of firms across broad manufacturing sectors, this section focuses on the manufacturing strategy of companies surveyed. In this context we explore the four core strategic manufacturing orientations, namely; quality strategy, cost leadership strategy, flexibility strategy and delivery strategy.

Firms were asked to indicate the manufacturing strategy employed. For each item, respondents were requested to choose a response on a five-point interval scale; anchored at one end with 'not important' meriting a score of 1, and the other by 'absolutely critical' meriting a score of 5.

5.3.1 Cost Leadership Strategy

Under the dimension of cost leadership strategy, which was measured using two items, i.e. companies to offer prices as low as or lower than their competitors, and continuously looking for cost reductions. Besides marketing their products at the possible lowest prices than their competitors, companies that compete based on the cost leadership strategy would also strive for finding all sources possible to reduce cost, thus, a cost reduction initiative is closely link to this strategy.

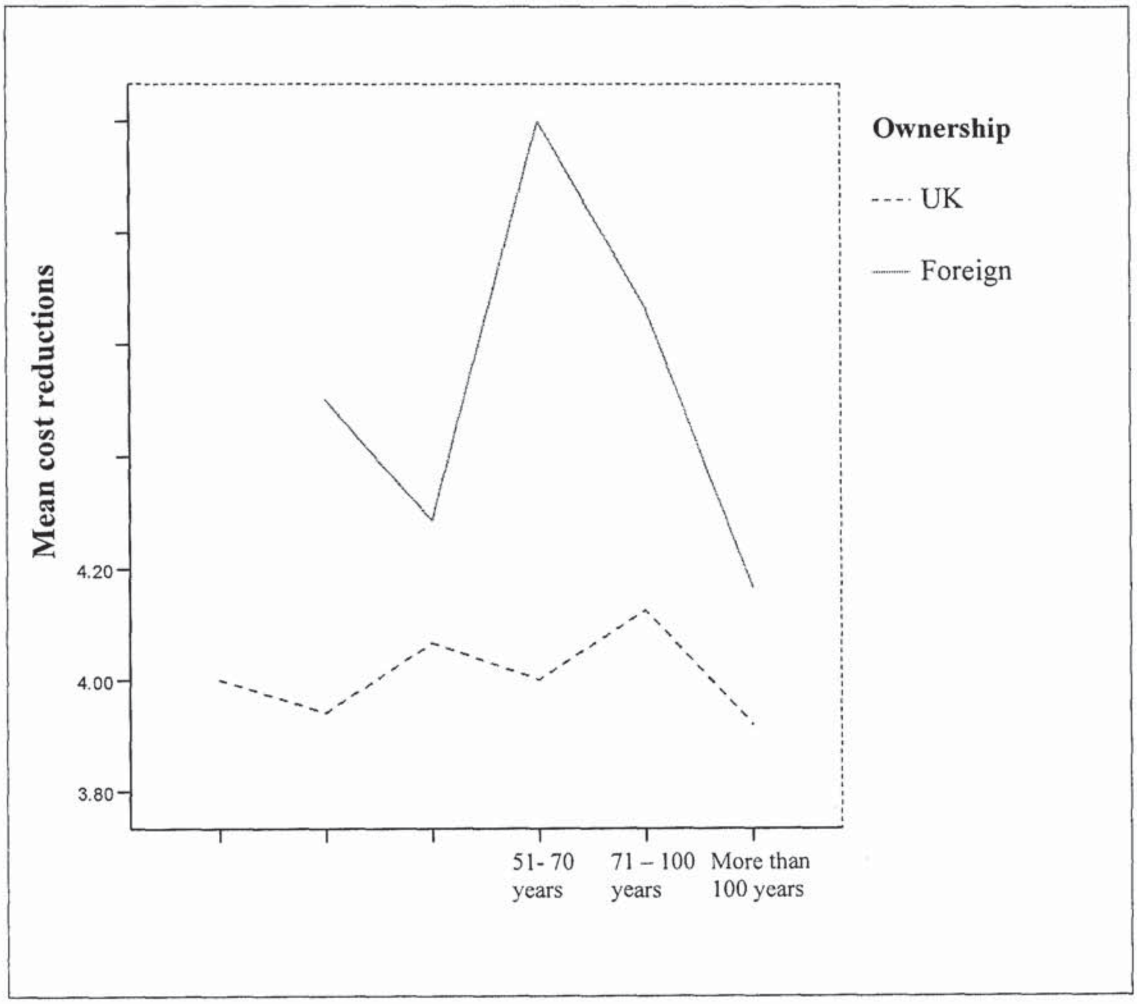
Figure 5.7: Cost Leadership Strategy



As shown in the figure 5.7 above, it is observed that companies surveyed are indifferent in their view on the cost leadership strategy, although the cost reduction initiative is relatively higher than low price strategy. From the data, it is also observed that the importance of lower price strategy is moderate for both UK and foreign companies.

However, non-native companies are slightly more keen on cost reduction initiatives. The data also suggests that the cost reduction initiatives vary depending on the age of the company. For example, the initiatives are very crucial for UK companies within the 71-100 year band, whilst Foreign companies emphasize the initiatives, in 51-70 year band (refer to figure 5.8).

Figure 5.8: Comparison of Cost Reduction Initiatives Amongst UK and Foreign Companies



5.3.2 Quality Strategy

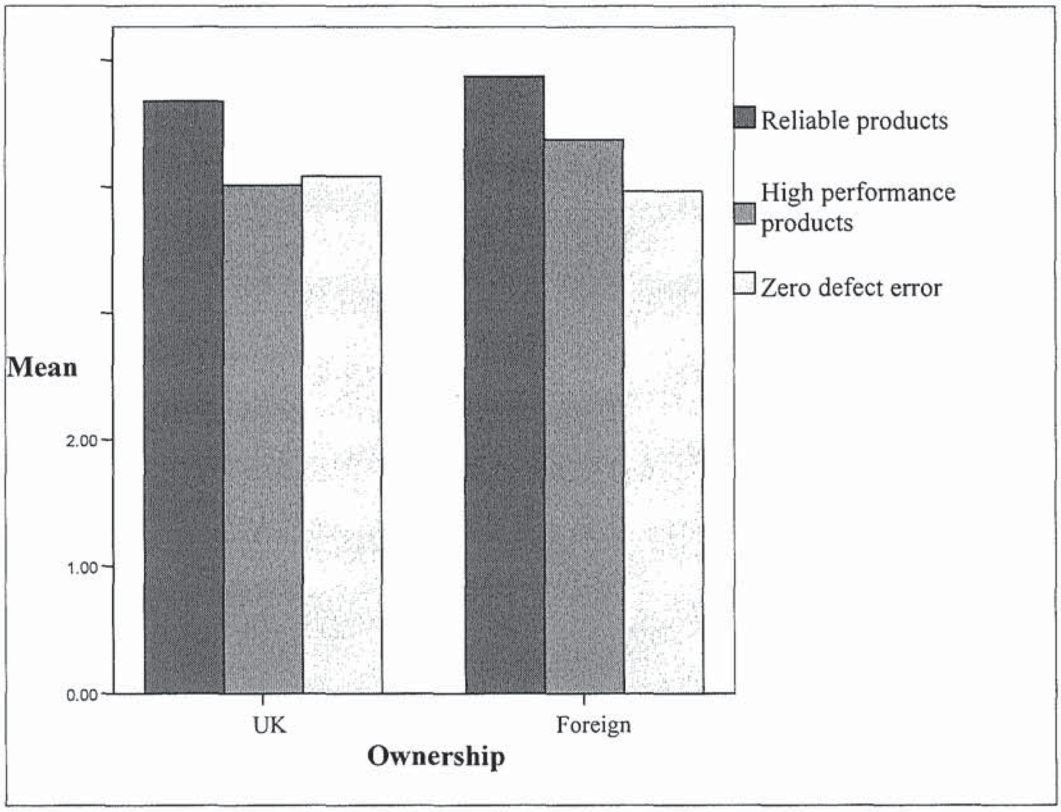
Under the quality dimension of manufacturing strategy, companies were measured on their emphasis on three measures, i.e. providing reliable products, high performance products and products with zero defect error.

Overall, across the four sectors, the mean rankings are above 3, which suggest a quality strategy is considered as important for any industry. The result shows that there is a strong agreement between the four sectors in providing quality products which are reliable, high performance and with zero defect error in order to compete effectively in the market.

In terms of the emphasis pattern on each measure among the sectors, offering high performance products is perceived to be much more important in the electronics sector and far less important in fabricated metals. By contrast, producing products with zero defect error is regarded as being far more important in fabricated metals than all other sectors. In the industrial machinery sector this is seen as of only moderate importance.

By comparing the mean scores of quality manufacturing strategy by ownership, we can observe an interesting phenomenon. The mean score of surveyed foreign owned companies are higher than that of UK owned companies in each of the three ranking scores except for that of their indifference rankings in zero defect error, which indicates non-native firms generally respect quality strategies higher than native companies. In addition, for both UK and foreign companies, providing reliable products is the most important issue. However, they have slightly different attitudes toward providing products of high performance and zero defect error. Native companies generally consider that high performance products carry more weight than those with less defect error. In contrast, foreign firms prefer offering products with advanced performances.

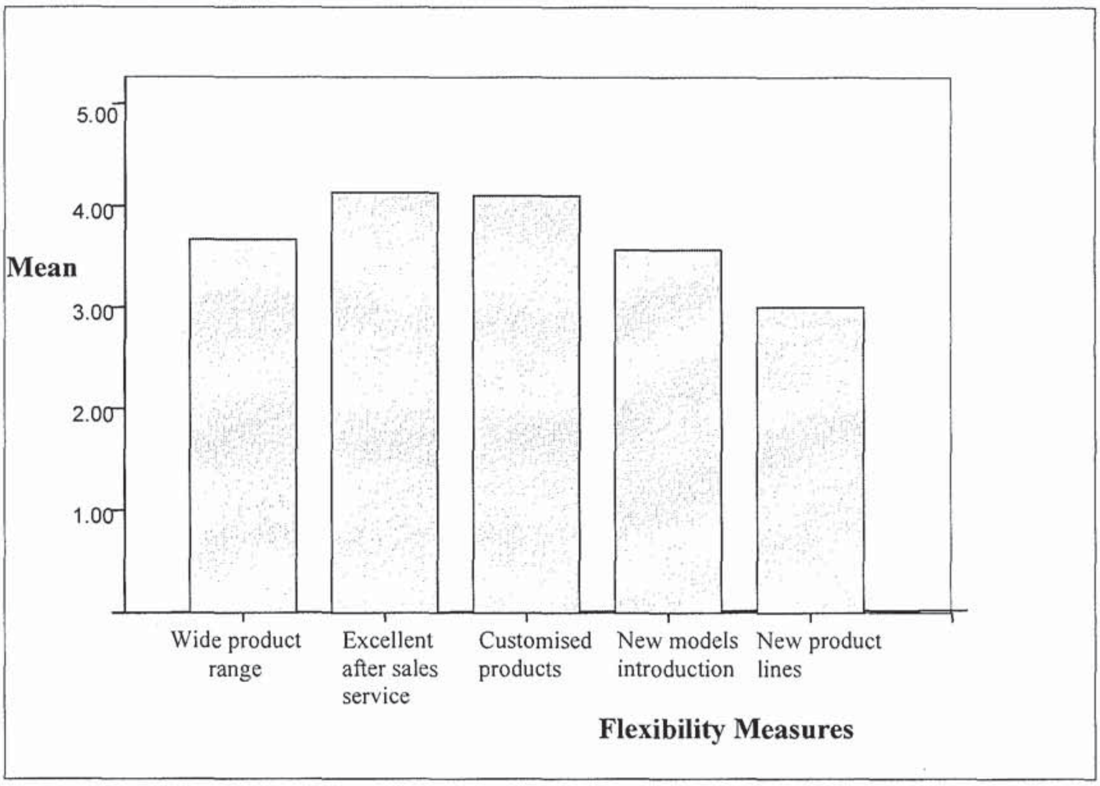
Figure 5.9: Comparison of Companies Emphasising Quality Strategy with Ownership



5.3.3 Flexibility Strategy

Companies pursuing a flexibility strategy offer a wide range of products, excellent after-sales service, customised products, new models introduced to their existing products and also introduction of new product lines. Referring to Figure 5.10, the mean scores of flexibility strategy variables, to summarise, almost of the items are considered as very important as their scores are larger than 3, except that companies perceived new product lines introduction is considered as moderately important, with a mean score slightly less than 3.

Figure 5.10: Flexibility Strategy Measures



Next, by comparing the flexibility strategy scores by ownership, we notice that attitudes toward a flexibility strategy of UK companies and non-native companies do not differ much. For both of them, the ability to provide excellent after sales service and customised products are the most important strategies. The difference lies in that, UK companies generally consider all of similar importance.

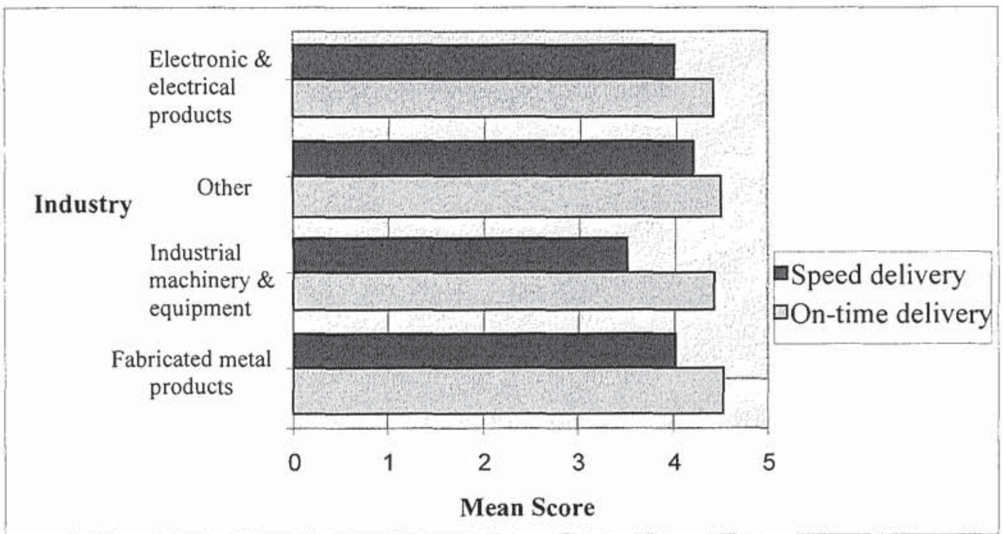
From the data, it reveals that after sales service is far more important in the electronic and electrical sector, and far less important in the fabricated metal sector. The ability to offer a wide range of product does not seem to be perceived as an important strategy in companies surveyed, especially for companies in the industrial machine sector. The remaining two variables that are not consistent with other items measured are the new models introduction (2.79) and new product lines (2.36). However, there was significant difference for these two variables among industries. The electronics industry placed most emphasis, on all the flexibility strategy measures than the other sectors. The industrial machinery companies emphasise after sales services to compete in this competitive priority, whist fabricated metal products companies considered this as moderately important.

The average scores of introducing new product lines are generally low for all sectors – which is the least important priority for surveyed companies. For example, fabricated metal producing companies have limited passion for launching new products since their ranking on this variable is lower than 3 (moderately important). In other sectors, the average score is just over 3.

5.3.4 Delivery Strategy

Companies competing on delivery strategy can compete on dependability, i.e. on time delivery and or quickest to reach their customers, i.e. speed of delivery. Figure 5.11 shows that companies surveyed place more emphasis on on-time delivery as compared to speed of delivery, however, the differences were not obvious. On time delivery scored a 4.47 mean while 3.98 for speed of delivery. There was no difference across industries surveyed.

Figure 5.11: Delivery Strategy



When comparing companies practicing the delivery dependability strategy by their ownerships, both UK and foreign owned companies placed crucial importance toward on-time delivery across industries. Scores are as high as over 4. In contrast, although the mean scores are still high for speed to customers, i.e. just around 4, but foreign owned companies have a higher priority than UK owned companies on speed of delivery.

5.3.5 Generation of Manufacturing Strategy Scores and Gross Comparisons

From the analysis above, we have descriptive knowledge of detailed manufacturing strategy variables of our surveyed companies. The four competitive dimensions derived from the manufacturing strategy literature, i.e. quality strategy, cost effectiveness strategy, flexibility strategy and delivery strategy. For the convenience of comparison among these four strategies, we generate four indexes to represent them:

(1) $$\text{Cost Strategy Score} = \text{CSS} = \frac{\text{Q4B1} + \text{Q5B1}}{2}$$

i.e. $$\text{CSS} = \frac{\text{Low price} + \text{Cost reductions}}{2}$$

(2) $$\text{Quality Strategy Score} = \text{QSS} = \frac{\text{Q1B1} + \text{Q2B1} + \text{Q3B1}}{3}$$

i.e. $$\text{QSS} = \frac{\text{Reliable products} + \text{High performance} + \text{Sero defect error}}{3}$$

$$(3)\ \text{Flexibility Strategy Score} = \text{FSS} = \frac{\text{Q6B1} + \text{Q7B1} + \text{Q8B1} + \text{Q9B1} + \text{Q10B1}}{5}$$

$$\text{i.e. FSS} = \frac{\text{Wide product range} + \text{After sale service} + \text{Customised product} + \text{New model introductions} + \text{New product lines}}{5}$$

$$(4)\ \text{Delivery Strategy Score} = \text{DSS} = \frac{\text{Q11B1} + \text{Q12B1}}{2}$$

$$\text{i.e.} \quad \text{DSS} = \frac{\text{On - time delivery} + \text{Speed delivery}}{2}$$

Where: QiB1 = score on question i from questionnaire section B1

Figure 5.12 shows the line graph of the four strategy scores compared by sectors. It is apparent that the cost leadership strategy is considered as the least important strategy by all sectors, followed by flexibility strategy, while attitudes toward quality strategy and delivery strategies vary by industry. Results show that companies producing fabricated metal products place delivery strategies at a relatively higher ranking. The results also revealed that all the other industries perceived that the quality strategy carries the most weight among all manufacturing strategies.

Figure 5.12: Manufacturing Strategy Scores By Sector

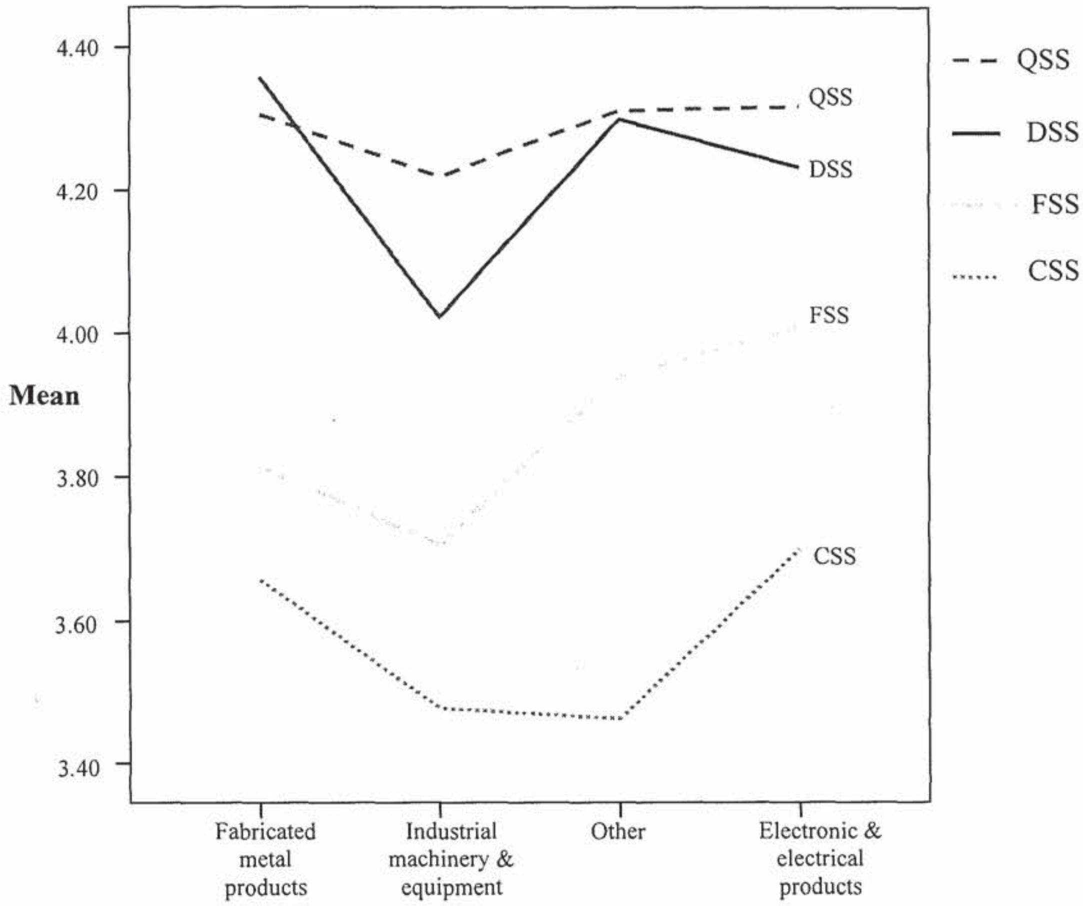
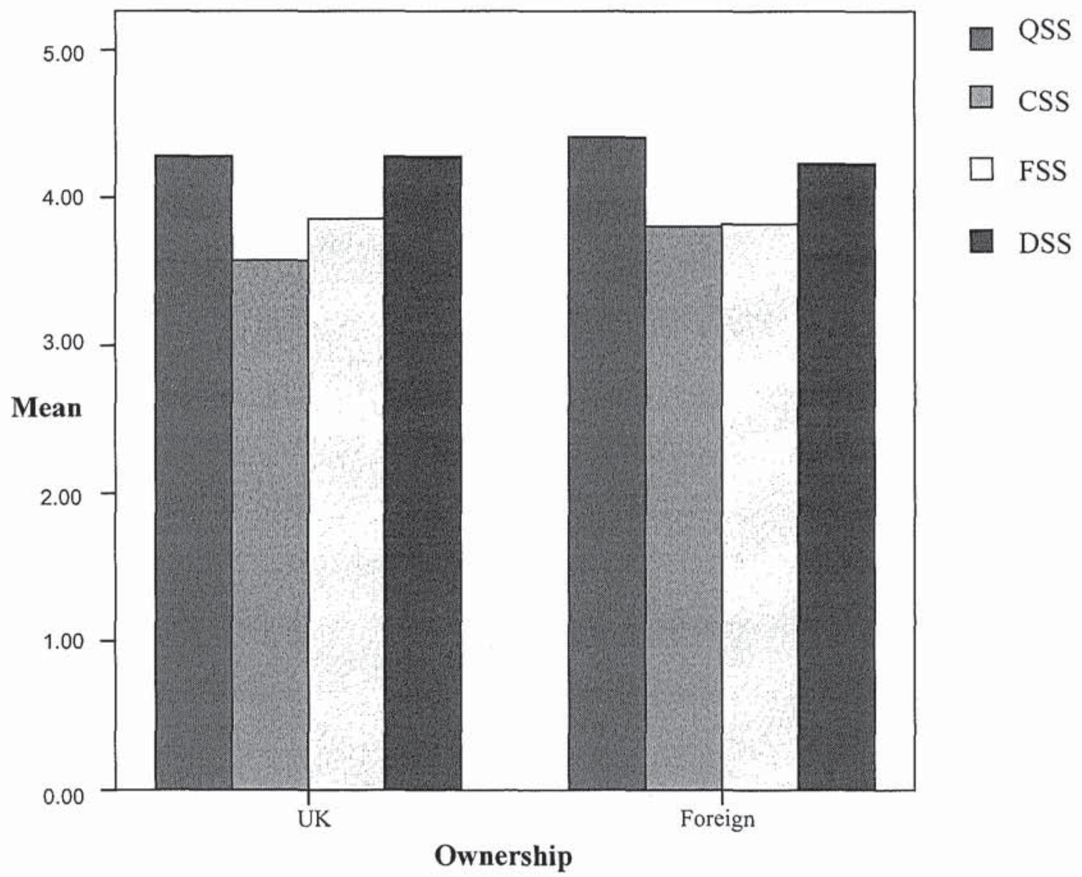


Figure 5.13: Manufacturing Strategy Scores by Ownership



The comparisons between companies of different ownerships show little contrast. UK and foreign companies generally hold similar attitudes toward the four types of manufacturing strategy. Quality strategies and delivery strategies are the most important strategies as their mean scores are over 4. The only noticeable difference lies in that UK companies perceived that flexibility strategies are relatively more important than cost issues. But foreign firms see no difference.

When comparing between UK owned and foreign owned companies, surveyed companies show no difference on quality strategy – both groups of companies regard quality issues as very crucial to the success of their business. In terms of the type of industry, non-native industrial machinery producing companies consider the cost leadership strategy as more important than native companies. Foreign companies think flexibility strategies are much more important for the electronic industry than the fabricated metal industry. However, UK companies show indifference.

5.3.6 Summary of Manufacturing Strategy

We have presented the emphasis and pattern of manufacturing strategy for four broad manufacturing sectors. Overall, we can conclude that companies surveyed do not compete on any particular strategy alone, rather a combination of different dimensions of competitive advantage, i.e. cost, flexibility, delivery, and quality. The quality strategy is by far the most important competitive strategy, followed by delivery, and flexibility. The least important of all manufacturing strategies is the cost leadership strategy. Both UK and foreign owned companies show no significant contrasts – they both hold similar attitudes toward the four types of manufacturing strategy.

5.4 Advanced Manufacturing Technologies (AMTs) Adoption

The study investigates 14 types of advanced manufacturing technologies (AMTs) which are commonly used by manufacturing companies. These technologies can be grouped, based on their functionalities, into 5 subgroups:-

1. Product design and engineering technologies (PDETs),
2. Production planning technologies (PPTs),
3. Material handling technologies (MHTs),
4. Assembly and machinery technologies (AsMTs), and
5. Integrated manufacturing technologies (IMTs).

Companies were asked to indicate the amount of investment the company has in the individual technology, on a Likert scale of 1-5, where 1 indicates little investment, 3 as moderate investment and 5 to show heavy investment. Firms were determined to be either users or non-users of each technology sub-group. For example, an adopter of the design and engineering technology sub-group would be using a combination of either CAD, CAE, GT, CAM or all the above.

Analyses of the AMTs adoption of the companies surveyed is based on the level of investment in the technology, and its level of integration, i.e. whether the piece of technology is connected to another appliance or system within the department, company or the enterprise, or just a piece of stand alone technology. Four levels of integration have been identified from the literature, i.e.

1. No integration
2. Limited integration
3. Full integration
4. Extended integration

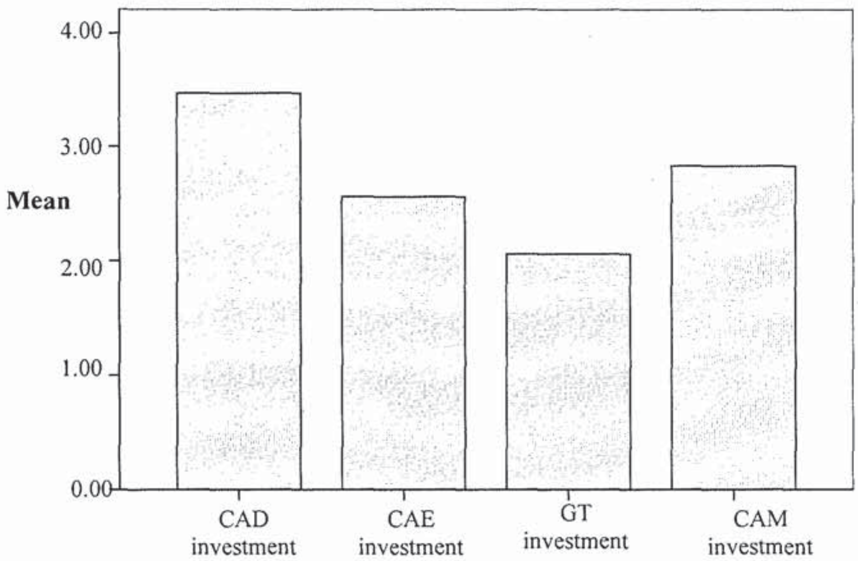
5.4.1 Product Design and Engineering Technologies (PDETs)

Manufacturing companies invested in various product design and engineering technologies (PDETs), such as computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), and group technology (GT) to assist them in designing and testing a product, from a structural or engineering point, controlling of manufacturing machinery, and also for part classifications and coding systems.

5.4.1.1 Investment in Product Design and Engineering Technologies

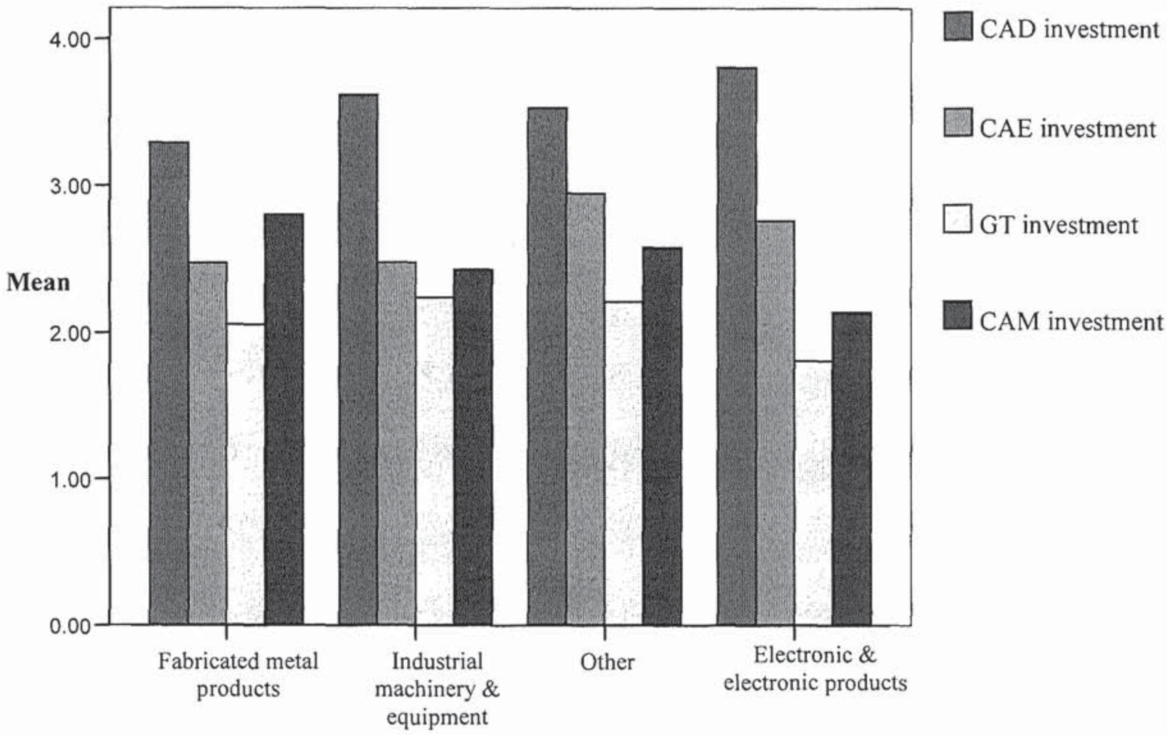
Figure 5.14 below shows the mean scores of companies which have made actual investments in each PDET. It shows that the most common PDET among the companies surveyed is CAD, which encountered above moderate investments, i.e. mean score of 3.5; followed by CAM, with mean score of 2.8. The results show that the least investment is in GT whose number only amounts to half of the total number of surveyed companies, and with mean score of less than 2.

Figure 5.14: Investments in Product Design and Engineering Technologies



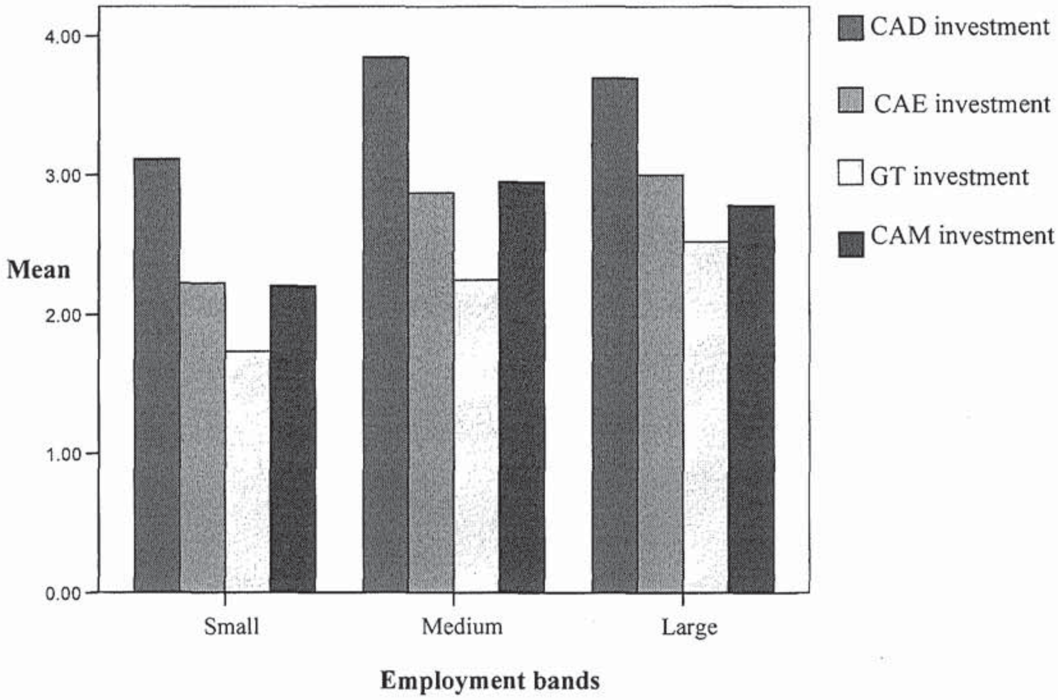
All sectors share the same point, as shown in Figure 5.15, that investment in CAD takes the most important position, with mean of 3.47, while GT is worth the least to put money in with a mean of 2.06. In detail, the electronic industry relies on CAD the most, followed by the machinery industry. Similarly, CAE is relatively more important for the electronic industry. Most sectors consider that GT is not worth much investment (ranks about 2). Besides, companies from the fabricated metal producing industry are more likely to invest in CAM.

Figure 5.15: Comparing Mean Score of Product Design and Engineering Technologies Investments with Sectors



The scale of CAD and CAM investments are not different between native and non-native companies. However, foreign firms invested more in CAE and GT than UK companies. Interestingly, for all the PDETs except GT, companies from the youngest and oldest age groups invest the least among the entire age bands.

Figure 5.16: Comparison of Mean Score of Product Design and Engineering Technologies Investments with Employment Bands



When comparing the mean score of the PDET investments with the employment band, as shown in the Figure 5.16, it reveals that surveyed medium sized companies invested the most in CAD and CAM among all sized companies. While, in contrast, large companies invested the most in CAE and GT technologies. Especially, the scale of these investments increases with size.

5.4.1.2 Integration of Product Design and Engineering Technologies

Overall, the results show that the levels of integration in PDET are limited, since none of their scores is over 2.5. When comparing the mean score of PDET integration with the companies age bands, sector, or companies ownership, they show that the levels of integration are negligible, with mean score less than 2.5. In terms of the individual PDET, almost 90 percent of the respondents invested moderately in CAD, however the majority of them have their CAD either stand alone, i.e. no integration, or only integrated within the department.

It is the same scenario for CAE. There is 66 percent of companies surveyed that have little to moderate investments in CAE, and again, the majority of those invested, i.e. 80.2 percent have it either with limited or no integration. The least companies surveyed have invested less than moderate in GT (with mean score around 2), and only 60 of them state to have them with limited or no integration.

The most integrated piece of PDETs is CAM. Of the number of companies investing in CAM, there is almost 19 percent of them (or 50 companies) who have integrated CAM within the company, and 8 companies extended CAM integration to suppliers or customers.

Table 5.4: CAM Investment and CAM Integration Crosstabulation

		CAM integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
CAM Investment	Little investment	26	11	2	0	39
	Some investment	15	12	5	1	33
	Moderate investment	7	23	14	0	44
	Substantial investment	4	17	18	1	40
	Heavy investment	3	5	11	6	25
Total		55	68	50	8	181

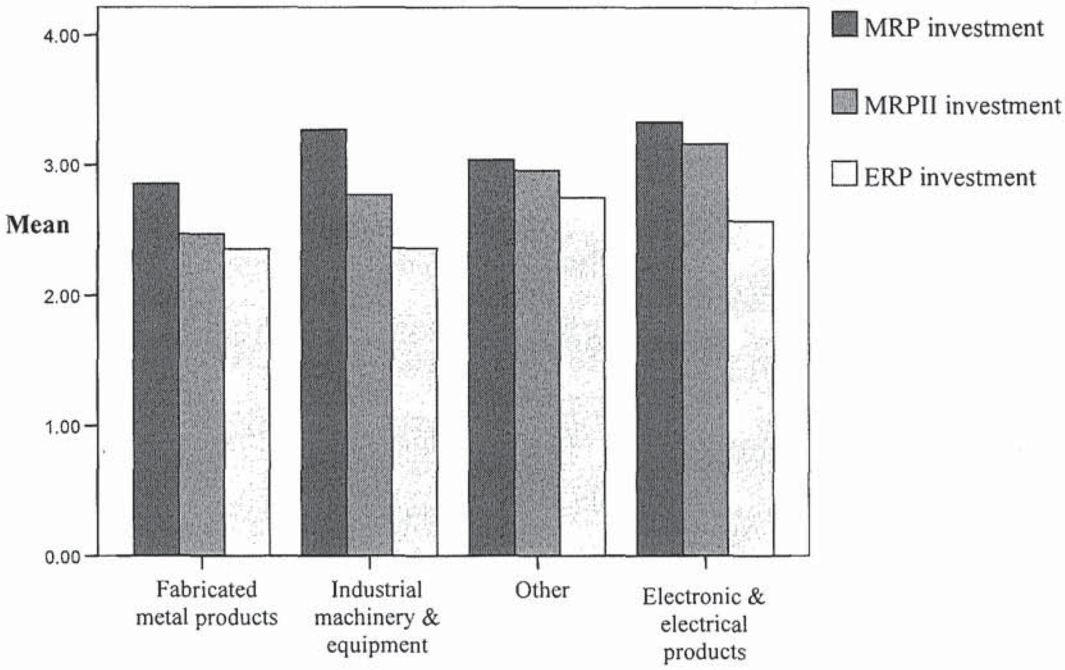
5.4.2 Production Planning Technologies (PPTs)

Manufacturing companies invested in various production planning technologies (PPTs), such as material requirement planning (MRP), manufacturing resources planning (MRP II), or enterprise resources planning (ERP) to assist them in planning, scheduling and controlling of material and resources requirements for the production of manufacturing companies. ERP covers a wider scope by integrating the operations throughout the companies and also facilitates global integration.

5.4.2.1 Investment in Production Planning Technologies

The whole manufacturing industry seems to reach an agreement on the investments in PPTs. As shown in Figure 5.17, their investments in MRP, MRPII and ERP are generally moderate. The ranking of investments in the three technologies, from highest to lowest are MRP, MRPII and ERP. It is indeed quite an interesting discovery as it shows that surveyed companies are still very much at the early version of the material requirements planning tool.

Figure 5.17: Comparing Production Planning Technologies Investment by Sectors



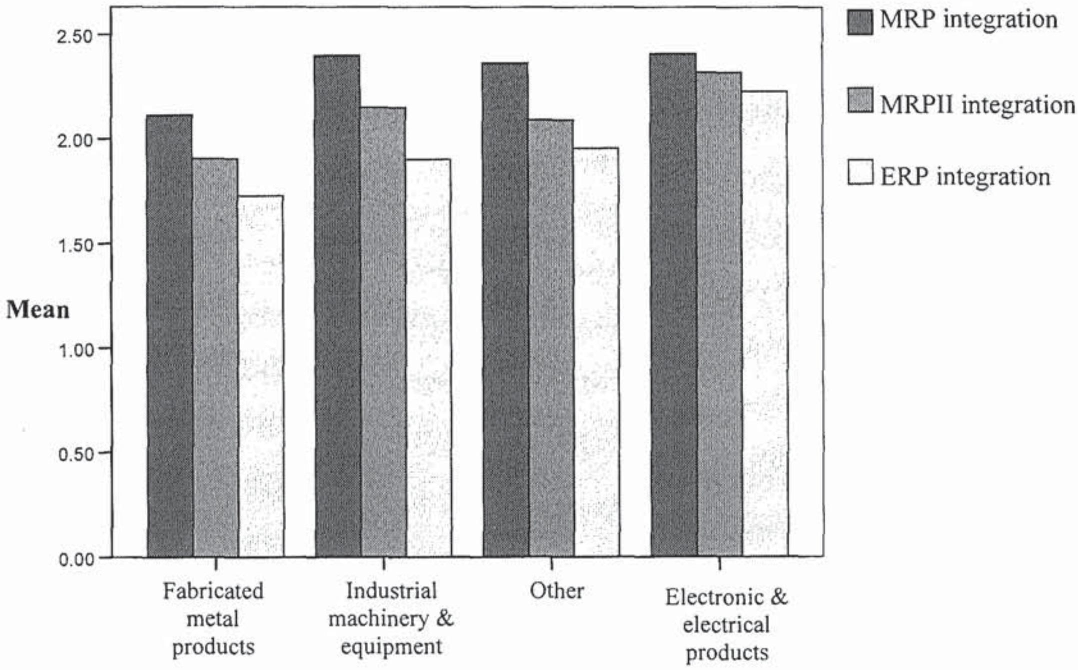
When comparing the PPTs investment among the surveyed companies based on their age band, it shows that the youngest group invest in MRP the least. The phenomenon reveals that younger companies invested in more advanced PPTs such as MRPII and ERP. The study also reveals that the larger companies are, the more they invest in PPTs, thus the scale of investment grows with size of company. Small companies have a mean score of around 2, whilst medium firms have a mean score of around 2.7, and large firms have over 3.

The scale of investment in MRP is indifferent between private and public companies (difference of 0.4). Generally, public companies invest slightly more in PPTs as compared to private companies. Besides, foreign companies invest a lot more than UK companies, where UK owned companies has a mean score less than 3, whilst foreign owned companies invested a substantial amount, i.e. at mean score of 4.1.

5.4.2.2 Integration of Production Planning Technologies

Generally, the level of integration for PPTs of companies surveyed is limited, with a mean score of 2, i.e. only within the department. As shown in Figure 5.18, the electronic and electrical industry has slightly more limited integration as compared to other manufacturing industry, with all its PPTs above 2. The fabricated metal product industry has the least limited integration, with a mean score of around 1.7.

Figure 5.18: Mean Score of Production Planning Technologies Integration by Sectors



The majority of companies who invested in PPTs have a limited to no integration with the ranking of scores of the three technologies being not very different from their investments. The results show that the degree of integration of the youngest age band, i.e. less then 10 years of existence, is significantly lower than older groups, i.e. 1, which is no integration. Again, public companies integrated all their PPTs slightly more than private companies, with an average mean score of 2.5 as compared to 2.0 for private companies.

The study also reveals that larger companies integrated their PPTs more than smaller companies. The mean scores for smaller companies are between 1.5 to 2 for all the PPTs, as compared to larger firms which have the mean scores of all PPTs between 2.5 to 2.7. Medium firms have mean scores between 2 to 2.5. Again, the level of integration is higher for foreign owned companies, with mean scores above 2.5, whilst UK owned companies have a less than 2 mean score for all the PPTs.

In terms of the individual PPT, MRP, the most invested by companies surveyed, is more often integrated fully within the company, as shown in the Table 5.5. The figures show that there is a positive relationship between the level of MRP investment and the extent of the integration, i.e. companies with little investment in MRP will limit or not integrate with other technology, while companies that have moderate and heavy investment in MRP, tend to integrate this piece of PPT within the company or extended it to suppliers and or customers.

Table 5.5: MRP Investment and MRP Integration Crosstabulation

		MRP Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
MRP Investment	Little investment	29	11	2	0	42
	Some investment	13	10	3	0	26
	Moderate investment	8	16	26	2	52
	Substantial investment	5	7	33	2	47
	Heavy investment	2	1	16	9	28
Total		57	45	80	13	195

As shown in the Table 5.6 below, of those who invested in some levels of MRP II, only 10 percent invested heavily and majority of them (94%) have either integrated it within the company of extended to external parties. In total, almost half of those invested in MRP II fully integrated it in the company or extended it within its supply chain.

Table 5.6: MRPII Investment and MRPII Integration Crosstabulation

		MRP II Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
MRP II Investment	Little investment	39	5	2	0	46
	Some investment	18	13	5	0	36
	Moderate investment	7	9	20	0	36
	Substantial investment	5	5	25	3	38
	Heavy investment	1	0	10	7	18
Total		70	32	62	10	174

The results also show that ERP is less popular among the companies surveyed. The number of companies invested in and integrating ERP is significantly lower. But companies either made little investment with no integration or heavy investment and full integration.

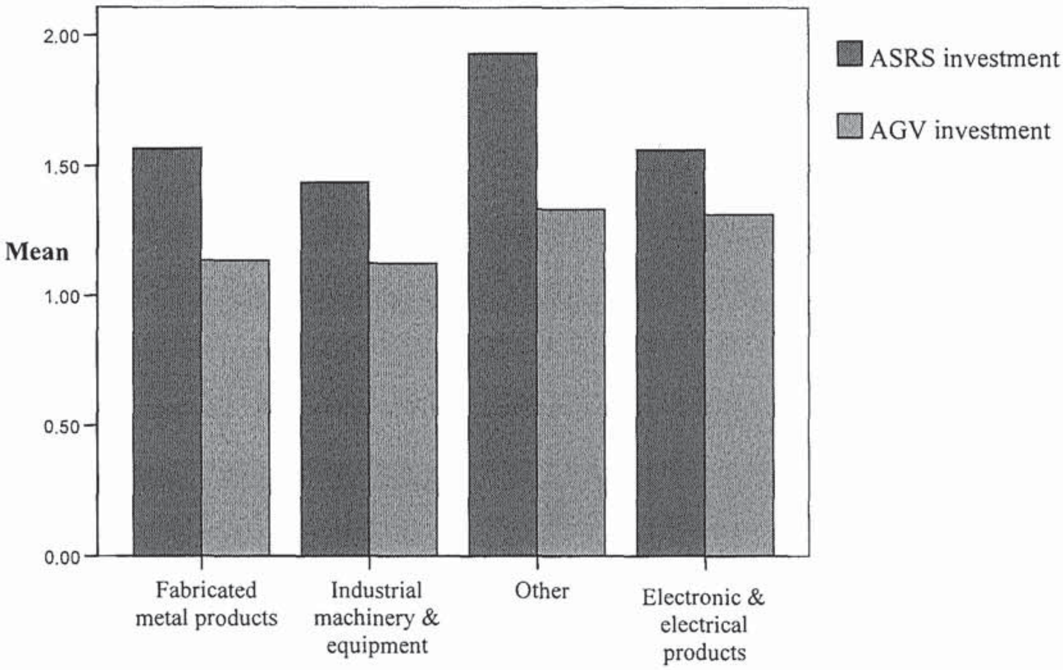
5.4.3 Material Handling Technologies (MHTs)

Material handling technologies (MHTs) are AMTs used by manufacturing companies to facilitate the handling of material in manufacturing operations. Automated storage and or retrieval systems (ASRS) use computers to direct automatic loaders to pick and place items for production processes or storage by automatic high-lift trucks. Companies employ transport automation by using automated guided vehicles (AGVs) to move materials to and from value-adding operations.

5.4.3.1 Investment in Material Handling Technologies

The study shows that companies surveyed have little investments in MHTs. Generally, companies invested more in ASRS as compared to AGV. As shown in the Figure 5.19, the electronic and electrical industry has less than moderate investment in ASRS, i.e. with a mean score of 1.5, which is the same with fabricated metal industry. Industry machinery and equipment industry has slightly lower investment, i.e. 1.4 score in ASRS investment. The other industry has almost moderate investment in ASRS. AGV investment is slightly lower than ASRS investment – where the electronic and electrical industry has lower than moderate investment, and fabricated metal and industrial machinery has almost little investment, i.e. a mean score of 1.1.

Figure 5.19: Mean Score of Material Handling Technology Investment by Sectors

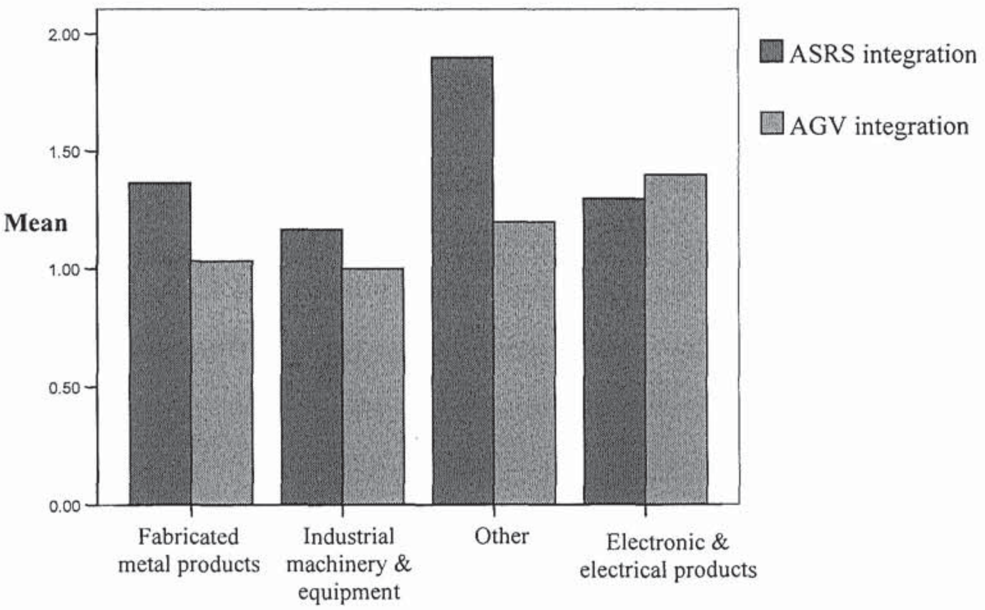


The results reveal that both private and public companies share the same view of investment in MHTs – both have little to moderate investments in MHTs. In terms of the pattern of investment by the size of the company, again, larger firms tend to invest slightly more in MHTs as compared to smaller firms. However, the mean score of investment of MHTs is between 1.7 to 2 for companies within the 31-70 age bands, as compared to younger companies with less than a 10 year existence with only little investment (i.e. mean score of 1). The graph shows a V-shape with a normal distribution pattern. Foreign owned companies appeared to have slightly higher investment in MHTs as compared to local companies, however, the difference is not likely to be significant.

5.4.3.2 Integration of Material Handling Technologies

In general, the level of integration of MHTs is virtually no integration or limited integration. As shown in the Figure 5.20, the piece of MHT is either in stand alone mode or only linked within the department. When comparing the level of integration of MHTs by type of industry, all industries have almost the same level of integration, except the other industry, which integrated its ASRS almost within the department (mean score of 1.8), however, the other industries were not integrating their MHTs.

Figure 5.20: Mean Score of Material Handling Technologies Integration by Sectors



Older companies tend to integrate their ASRSs further than younger companies, although the difference is likely to be insignificant, whilst younger and older companies acted indifferently with AGV integration – the AGV is a stand alone piece of technology in their companies. Public and foreign owned companies have higher integration level for their MHTs, and the bigger the company is, the higher the level of integration, although the level of integration for all sizes of companies is less than limited integration, i.e. the mean score is within 1 to 1.6.

The conclusion we can draw from the study is that both the level of investments and integration of MHTs in the companies surveyed are very limited.

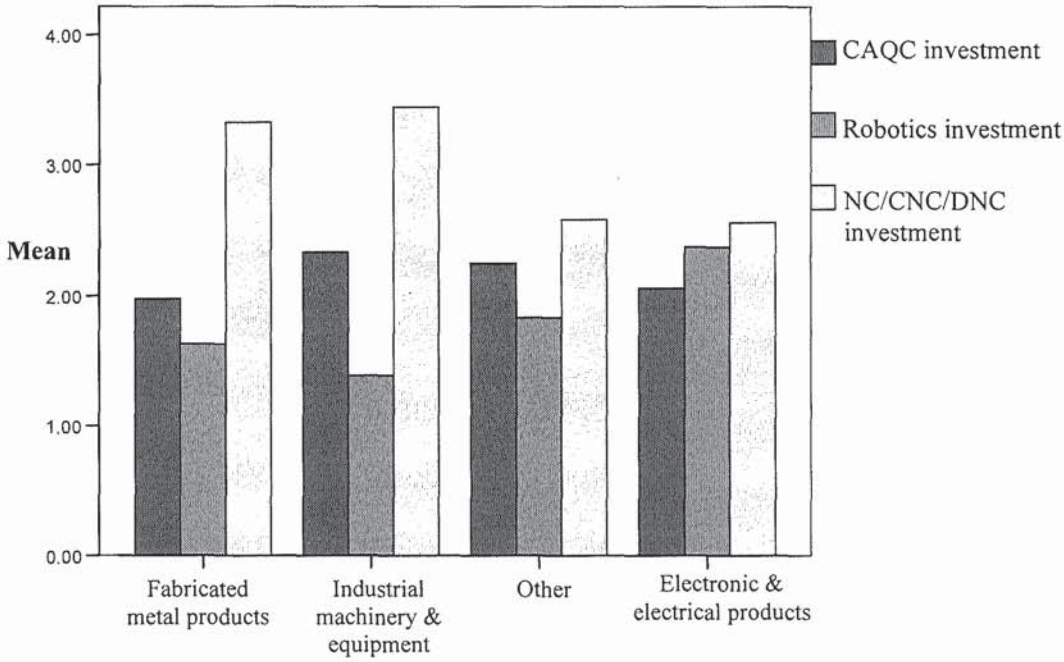
5.4.4 Assembly and Machining Technologies (AsMTs)

The study examines the level of investment and integration of 3 types of assembly and machining technologies (AsMTs): computer-aided quality control system (CAQCS), robotics and numerical control machines (NC/CNC/DNC). These AsMTs are used to perform repetitive functions and work without permanent alteration of the equipments. CAQCS is used to perform quality inspection on incoming or final materials, robotics to carry out various operations like handling, process or assembly tasks, whilst numerical control machines exist for almost all types of machining, like turning machines, boring and milling machine, horizontal boring machines and machining centres.

5.4.4.1 Investment in Assembly and Machining Technologies

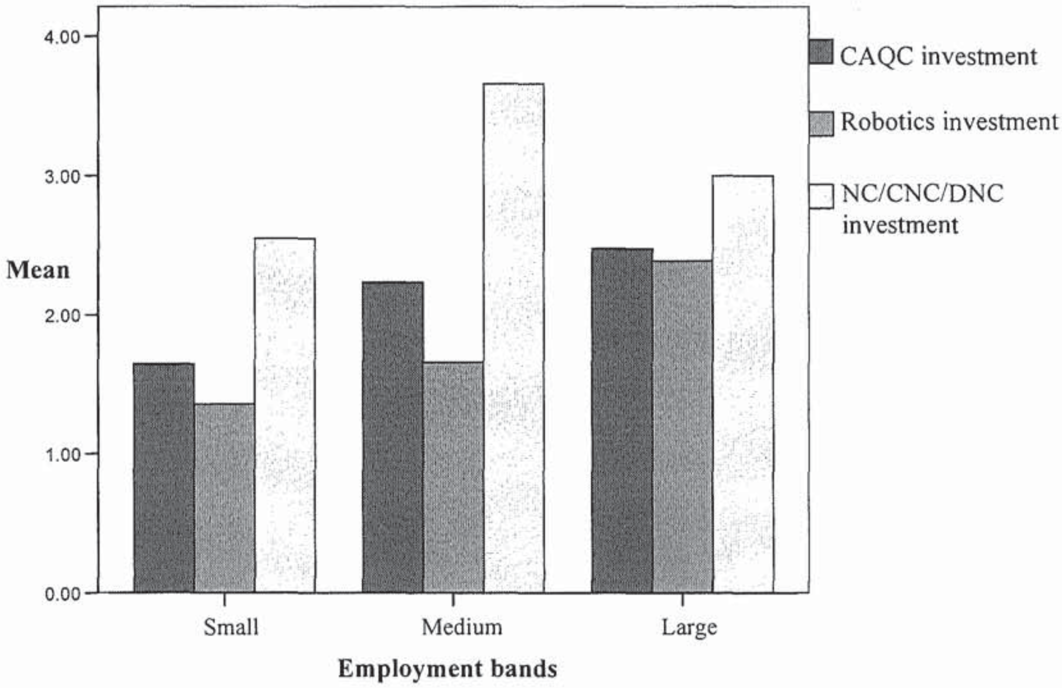
Generally, industries invested the most in NC/CNC/DNC technologies. It is obvious from the Figure 5.21, that the fabricated metal industry and the industrial machinery industry invested more moderately than the other industries, with the mean score more than 3. The investment in AsMTs for other industries is less than moderate, i.e. the mean score is around 2, i.e. investments in robotics and NC/CNC/DNC are limited. Except for the electronic industry, companies invested least in robotics technology.

Figure 5.21: Investment of Assembly and Machinery Technologies by Sector



As shown in Figure 5.22, regardless of the size of the company, the most investments are made in NC/CNC/DNC technologies, followed by CAQC technology, last comes robotics technology. Medium sized companies made substantial investments in NC/CNC/DNC technologies, significantly more than companies of the other sizes. For robotics and CAQC technologies, investment in these technologies grows with company size.

Figure 5.22: Investment of Assembly and Machinery Technologies by Employment Bands



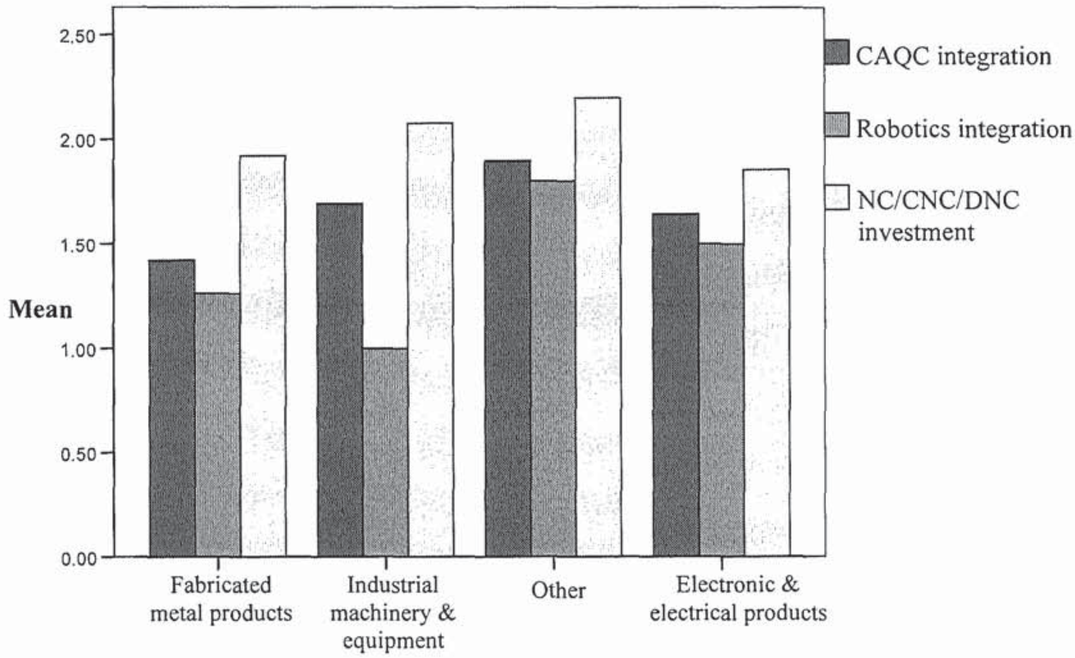
Except for NC/CNC/DNC technology, public companies invested more in assembly and machinery technologies than private companies. The investment in AsMTs is above 2 for both private and public companies. Private firms invested more than moderately in NC/CNC/DNC (mean score of 3.1) and public firms invested less than moderately (mean score of 2.8). Foreign owned companies invest more than UK companies in every assembly and machinery technology.

In general, investment in robotics and NC/CNC/DNC technologies increase with age bands. Investments from companies younger than 10 years are among the lowest level in assembly and machinery technologies.

5.4.4.2 Integration of Assembly and Machinery Technologies

Levels of integration of AsMTs are limited. As shown in the Figure 5.23 below, from the highest to the lowest, mean scores of integrations are NC/CNC/DNC, CAQC and robotics technology. There is likely to be no significant difference between industries in integration of NC/CNC/DNC technology. Integration of CAQC is on the lowest level in the fabricated metal industry. The electronic industry made the second most integration in robotics as compared to industrial machinery industry as the least.

Figure 5.23: Integration of Assembly and Machinery Technologies by Sector



Levels of integration of AsMTs increase with company size, except that medium sized companies made the most integration in NC/CNC/DNC technology. This result corresponds to the situation of investments analyzed by size.

The results also show that private companies integrated more in NC/CNC/DNC technology. Levels of integration of other assembly and machinery technologies are not very different between private and public companies. It is likely that no significant differences would be witnessed in the integration of NC/CNC/DNC technologies between UK and foreign owned companies. For CAQC and robotics technologies, surveyed companies owned by UK made slightly less integration. Even so, overall integration for either type of owned company is limited.

The study reveals that companies younger than 10 years integrated more in CAQC (mean score of 2) and NC/CNC/DNC (mean score of 3) than older companies. Except for the youngest group, integration of AsMTs increases with business years (from mean score of 1 upward to 2).

Further investigation of CAQC, as shown in the Table 5.7, reveals that most companies that invested in CAQC, i.e. 37 percent, fall into the little investment with no integration combination. The majority of surveyed companies that invested in CAQC, i.e. 60 percent, had limited investment in their CAQC, and with no or limited integration. There are still 11 companies that are substantially invested and fully integrated, despite the fact that there was only 1 company who extended CAQC integration to supplier or customers and it only made limited investment in the technology.

Table 5.7: CAQC Investment and CAQC Integration Crosstabulation

		CAQC Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
CAQC Investment	Little investment	43	5	2	0	50
	Some investment	17	13	4	1	35
	Moderate investment	8	8	4	0	20
	Substantial investment	2	6	11	0	19
	Heavy investment	2	4	4	0	10
Total		72	36	25	1	134

Table 5.8 shows the distribution of respondents in terms of the level of investment in robotics and its level of integration. It is obvious that there are a limited number of companies investing and integrating robotics technology. Among companies who provided valid answers in this section, half of them made little investment and no integration, with less than 25% of them making any integration.

Table 5.8: Robotics Investment and Robotics Integration Crosstabulation

		Robotics Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
Robotics Investment	Little investment	46	2	0	0	48
	Some investment	8	2	1	0	11
	Moderate investment	5	3	0	0	8
	Substantial investment	1	5	1	1	8
	Heavy investment	1	2	4	1	8
Total		61	14	6	2	83

The study also reveals that CNC/NC/DNC is the most invested by the respondent companies, with a total of 189 or 72 percent of respondent companies, having some level of investments. Except for companies who made no integration, the largest group appears in the combination of heavy investment and full integration, followed by substantial investment and full integration, and substantial investment and limited integration in NC/CNC/DNC technology. Worth noticing, the number of companies who made heavy investment and extended integration to suppliers or customers reaches as high as 15. Over 20 percent of companies investing in this technology have either integrated within the company or extended it to their supply chain.

Table 5.9: NC/CNC/DNC Investment and NC/CNC/DNC Integration Crosstabulation

		NC/CNC/DNC Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
NC/CNC/ DNC Investment	Little investment	25	2	1	0	28
	Some investment	11	9	0	0	20
	Moderate investment	10	14	6	1	31
	Substantial investment	8	20	22	2	52
	Heavy investment	8	9	26	15	58
Total		62	54	55	18	189

5.4.5 Integrated Manufacturing Technologies (IMTs)

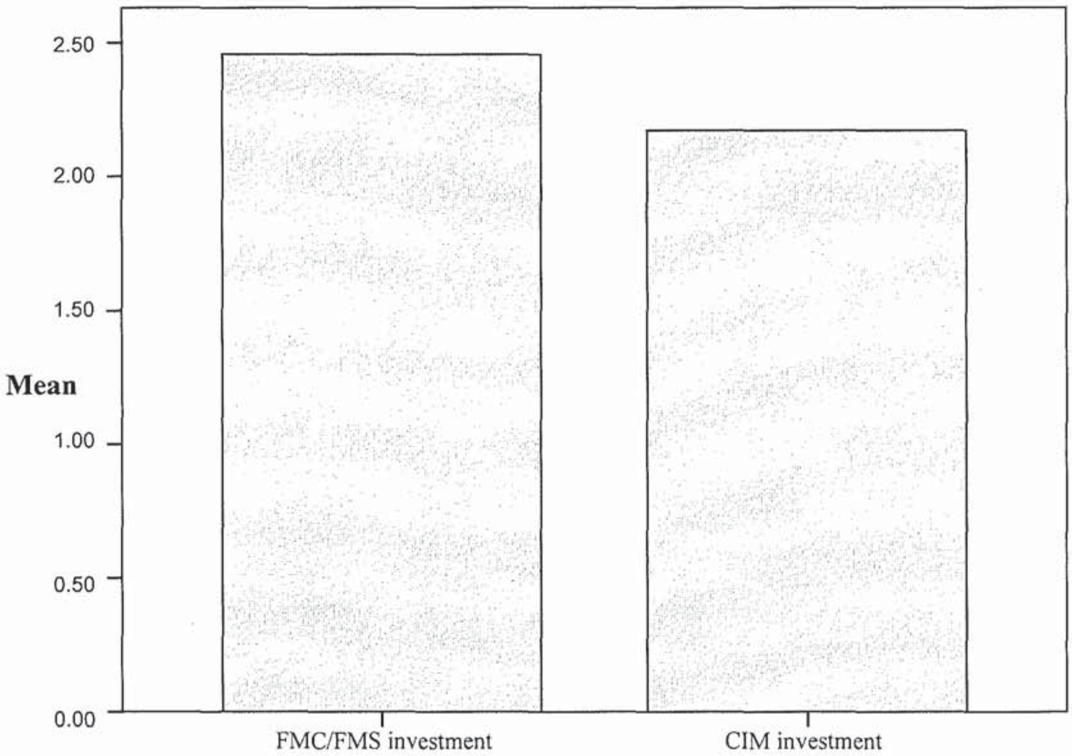
As the name of the technology group suggests, technologies within this integrated manufacturing technologies (IMTs) group are already integrated in some forms, for example, flexible manufacturing cells (FMC) or systems (FMS) consist of two or more NC/CNC machines which are interconnected by handling devices and a transport system. The difference between FMS and FMC is that FMC is capable of single path acceptance of raw materials and single path delivery of a finished product, whilst FMS is capable of multiple paths, and may also be comprised of two or more FMCs linked in series or parallel.

Another technology within this subgroup is called computer-integrated manufacturing (CIM), which incorporates all elements in the manufacturing process from product design to distribution. It links beyond company departments by integrating computer systems, thus islands of computer application in the firms are integrated.

5.4.5.1 Investment in Integrated Manufacturing Technologies

From the Figure 5.24, it shows that the mean score of investments in FMC/FMS by surveyed companies is slightly higher than CIM's, i.e. 2.45 as compared to 2.2. It is the same scenario when compared by their sectors, i.e. for most industries, investments in FMC/FMS are slightly more than in CIM. The levels of investment range between 2 (CIM's investment by the electronic and electrical sector) and 2.7 (FMC/FMS's investment by the other industry).

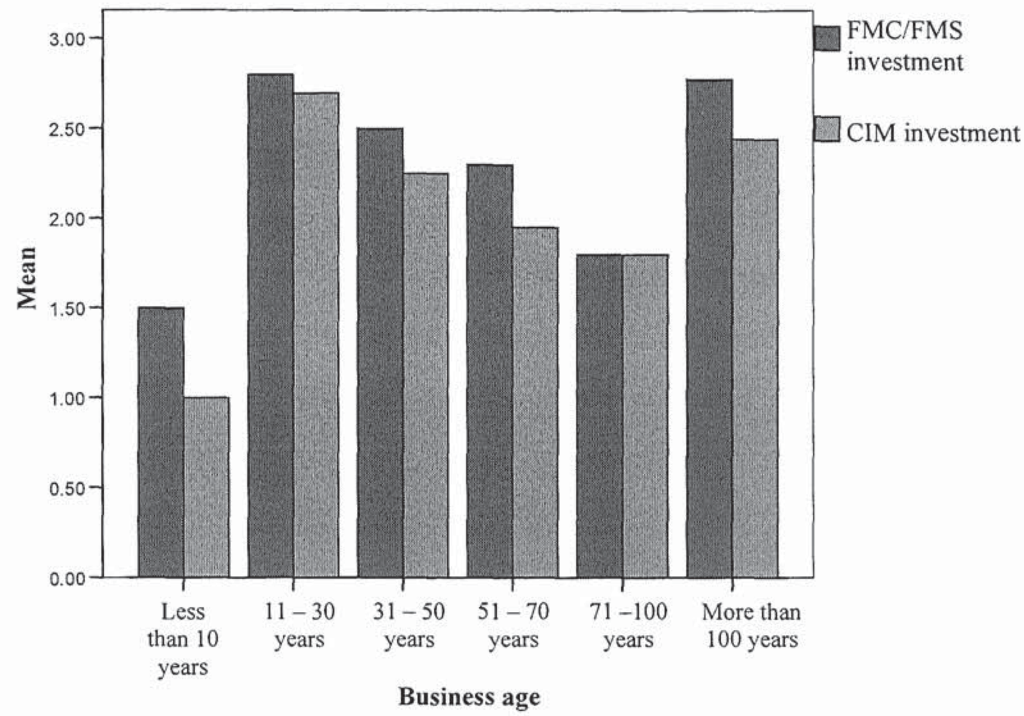
Figure 5.24: Investments in Integrated Manufacturing Technologies



When comparing the level of investment by company size, larger firms have the highest investment both in FMC/FMS and CIM. For large companies surveyed, investments in FMC/FMS are almost moderate (mean score of 2.8).

For either private owned or public owned companies, investments in FMC/FMS are more than CIM. Especially for public companies, the difference between the two integrated manufacturing technologies is rather large. On the other hand, public companies made slightly higher investments in FMC/FMS than private (mean scores of 3.00 as compared to 2.4).

Figure 5.25: Investment of Integrated Manufacturing Technologies by Age Bands



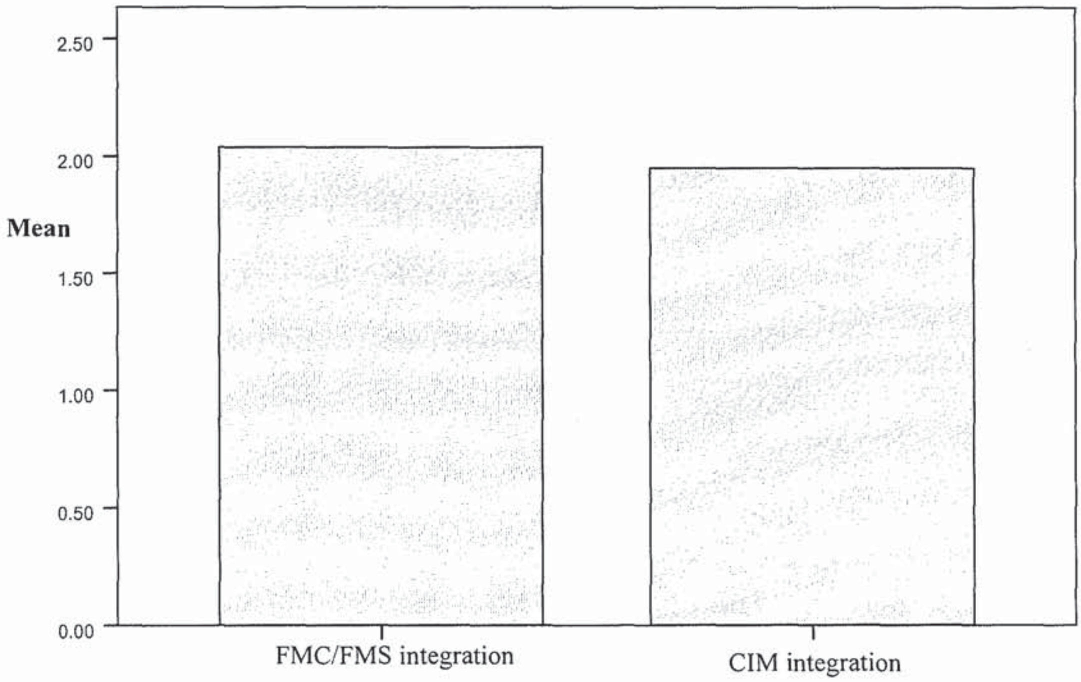
As shown in the chart above, it is witnessed that surveyed companies which are less than 10 years old invested the least in both FMC/FMS and CIM. Investments by companies in the oldest age band are among the highest level. For the other age bands, investments in IMTs decrease as history of business grow. Companies in the range of 11-30 years and more than 100 years are among those who invested almost moderately on IMTs.

Investments in FMC/FMS by foreign companies once again is higher than those by locally owned companies. Foreign owned companies invested above moderately on FMC/FMS (mean score of 3.4) whilst UK owned companies are at a mean score of around 2. The level of investment of both UK and foreign owned companies are about the same level at just above 2 in both IMTs except that foreign owned companies invested more than moderate (mean score of 3.4) in FMC/FMS.

5.4.5.2 Integration of Integrated Manufacturing Technologies

As the name suggests – one would have thought that IMTs would be fully or extensively integrated within the company or to include their supply chain. However, the level of integration, as provided by the surveyed companies, is rather low, both at mean score of 2 for FMC/FMS, and 1.8 for CIM integration., which means that both IMTs have limited integration, where only limited to the department only.

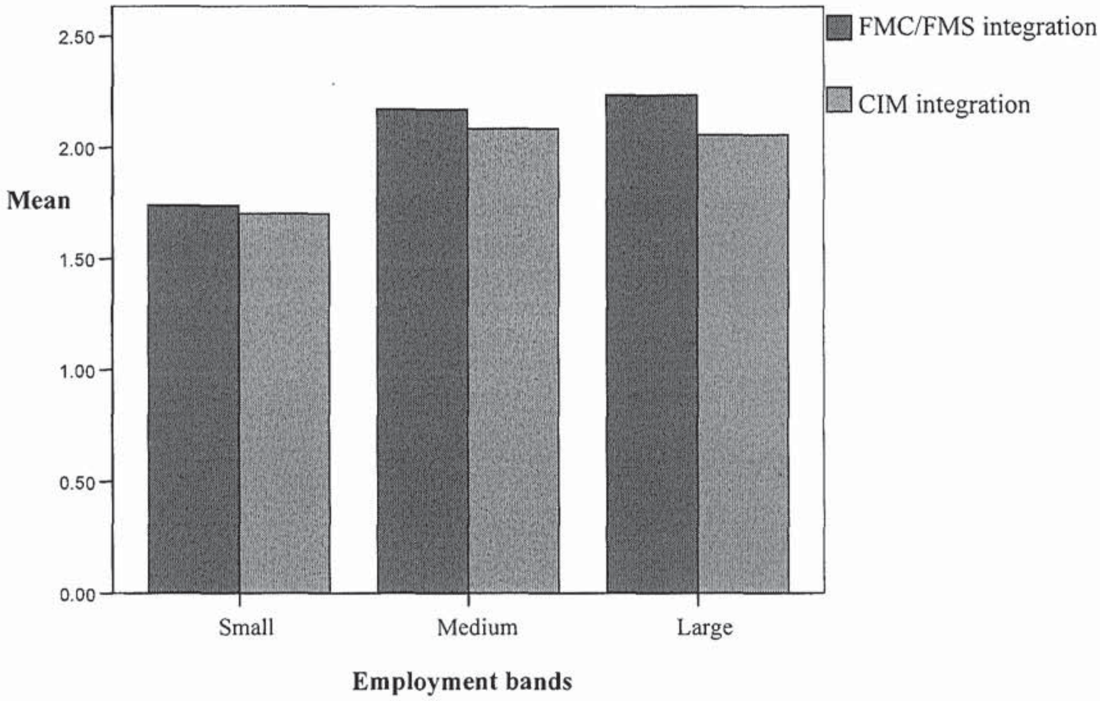
Figure 5.26: Integration of Integrated Manufacturing Technologies



The level of integration in the three main industries, fabricated metal industry (both just under 2), industrial machinery industry (FMC/FMS at 2, and CIM at 1.7) and electronic industry (just above 2), are somewhat lower than the other industry (mean score of 2.4).

Generally, the level of integration increases as size of a company grows, although the gap between companies of two adjacent sizes is rather small – refer to Figure 5.27.

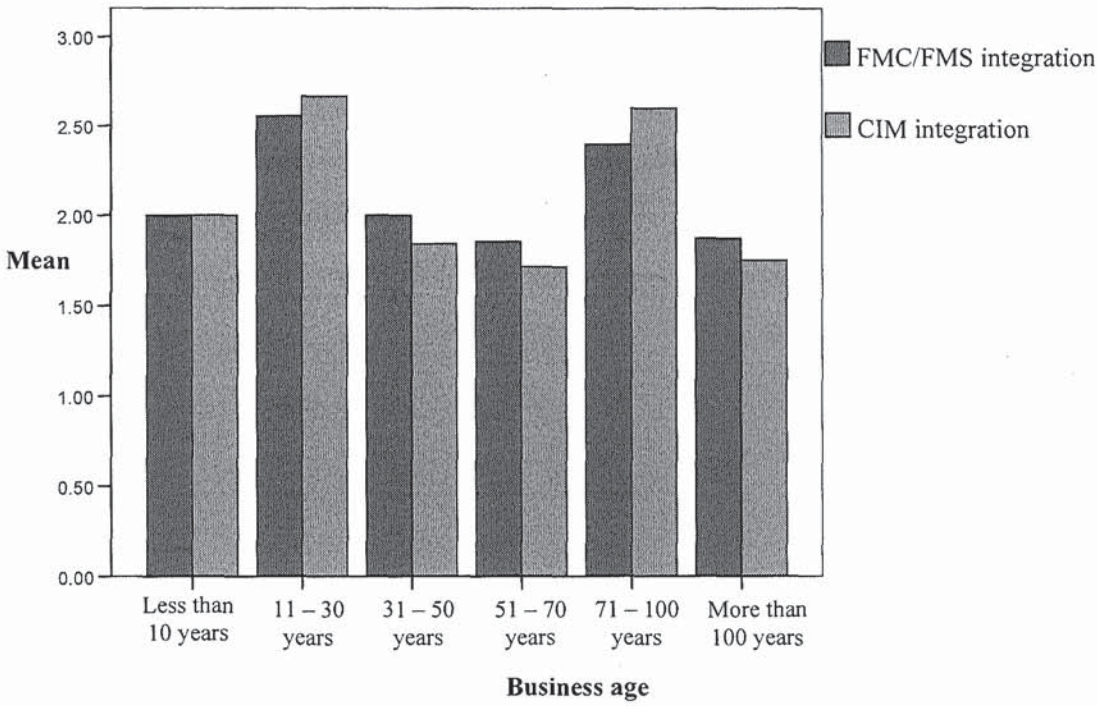
Figure 5.27: Integration of Integrated Manufacturing Technologies by Employment Bands



The levels of integration of integrated manufacturing technologies in private and public companies are almost the same, all with mean scores of around 2. From the study, it is revealed that UK companies surveyed did not distinguish the degree of integration in the two IMTs (both having a mean score of just below 2). Foreign companies made limited integration in CIM (mean score of 2), which is the same with UK owned companies, but integrated FMC/FMS slightly more than the UK owned companies, with mean score of 2.5.

From Figure 5.28 below, it shows that surveyed companies in age bands 11-30 and 71-100 years made more integration in integrated manufacturing technologies than companies in the rest of the age bands. Moreover, interestingly, companies in these two age groups made more integration in CIM than in FMC/FMS which is contrary to the others.

Figure 5.28: Integration of Integrated Manufacturing Technologies by Age Bands



The following paragraphs discuss each of the individual IMTs studied in this research. The number of companies which returned valid answers in FMC/FMS integration and investment is limited. Only 67 companies stated they made integrations, in which 30 firms made limited integration and another 32 firms fully integrated FMC/FMS in their company. Table 5.10 shows that more companies take moderate investment with limited integration and substantial investment with full integration combination.

Table 5.10: FMC/FMS Investment and FMC/FMS Integration Crosstabulation

		FMC/FMS Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
FMC/FMS Investment	Little investment	23	4	3	2	32
	Some investment	6	6	1	0	13
	Moderate investment	2	12	8	0	22
	Substantial investment	1	5	12	1	19
	Heavy investment	0	3	8	2	13
Total		32	30	32	5	99

The Table 5.11 below shows that few companies made CIM integration. 46 out of a total number of 262 companies surveyed state that they made CIM integration. It is seen that companies taking a little investment with no integration form the largest group, followed by moderate investment with limited integration. There are seven companies which either take some investment with limited integration, or moderate investment with full integration in company strategy. The number of firms that made heavy investment and extended CIM integration to suppliers or customers is as few as one.

Table 5.11: CIM Investment and CIM Integration Crosstabulation

		CIM Integration				Total
		No integration	Limited integration	Fully integration	Extended integration	
CIM Investment	Little investment	30	2	3	1	36
	Some investment	3	7	2	0	12
	Moderate investment	2	8	7	1	18
	Substantial investment	0	4	5	2	11
	Heavy investment	0	0	3	1	4
Total		35	21	20	5	81

5.4.6 Generation of AMTs Scores and Gross Comparisons

For the purpose of a summary and analysis, the aggregate AMTs investment and integration of surveyed companies generates ten AMTs investment and integration scores, which are product design and engineering technology investment score (PDETinv) and integration score (PDETint), logistics related technology investment score (PPTinv) and integration score (PPTint), material handling technology investment score (MHTinv) and integration score (MHTint), assembly and machinery technology investment score (AsMTinv) and integration score (AsMTint), and integrated manufacturing technology investment score (IMTinv) and integration score (IMTint).

Below lists the formulae of each investment and integration score:-

$$PDETinv=\tfrac{1}{4}\left(CADinv+CAEinv+GTinv+CAMinv\right)$$
$$PDETint=\tfrac{1}{4}\left(CADint+CAEint+GTint+CAMint\right)$$

$$PPTinv=\tfrac{1}{3}\left(MRPinv+MRPIIinv+ERPinv\right)$$
$$PPTint=\tfrac{1}{3}\left(MRPint+MRPIIint+ERPint\right)$$

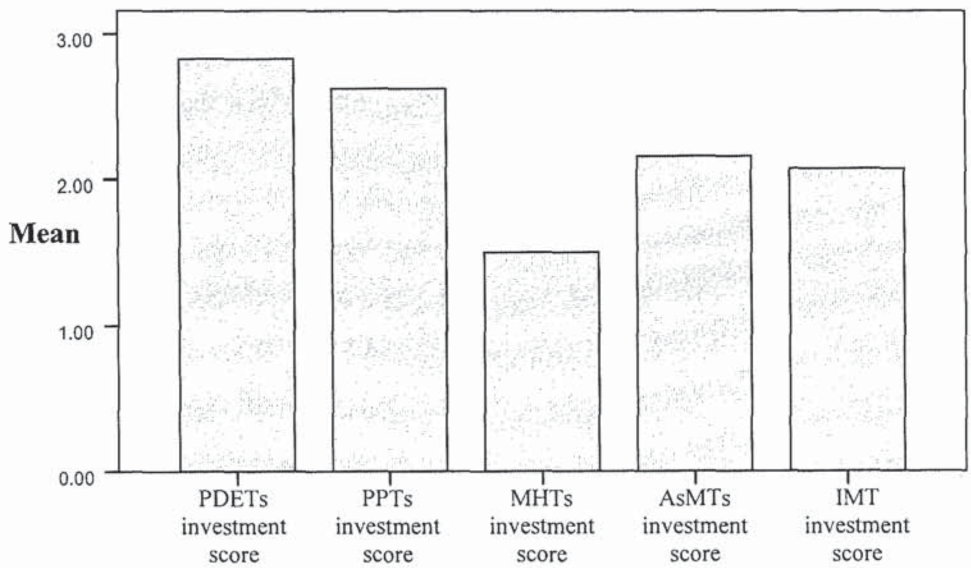
$$MHTinv=\tfrac{1}{2}\left(AMHinv+AGVinv\right)$$
$$MHTint=\tfrac{1}{2}\left(ASRSint+AGVint\right)$$

$$AsMTinv=\tfrac{1}{3}\left(CAQCinv+ROBOTICSinv+NC/CNC/DNCinv\right)$$
$$AsMTint=\tfrac{1}{3}\left(CAQCint+ROBOTICSint+NC/CNC/DNCint\right)$$

$$IMTinv=\tfrac{1}{2}\left(FMC/FMSinv+CIMinv\right)$$
$$IMTint=\tfrac{1}{2}\left(FMC/FMSint+CIMint\right)$$

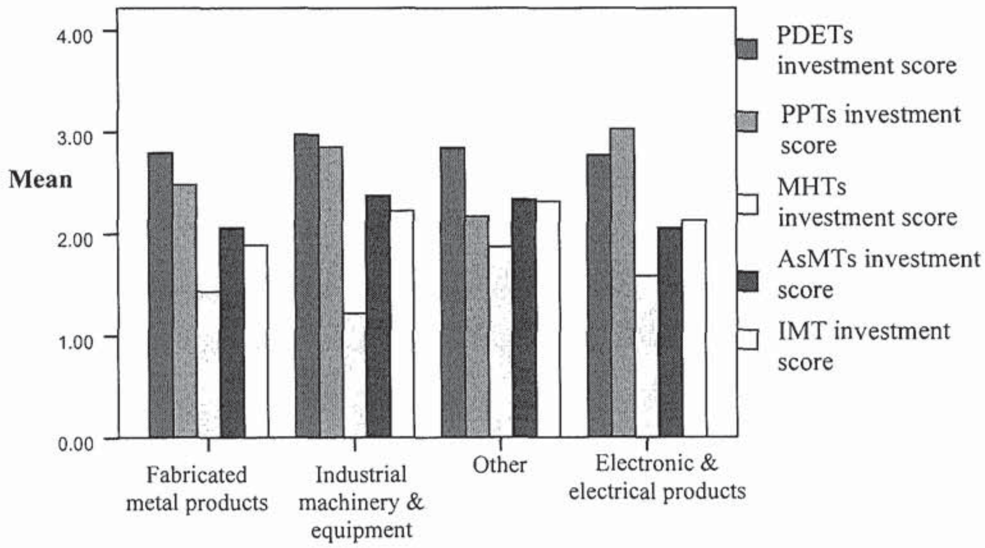
Figure 5.29 below shows the summary of AMT investments based on the five sub-groupings. Generally, surveyed companies do not invest much in AMTs, in which the investment are lower than moderate, i.e. mean score less than 3. From the chart, it shows that the most investments are made in PDETs and PPTs, which are just around the moderate level. PPTs ranked second with a mean score of 2.6, followed by AsMTS (mean score of 2.2), and IMTs (mean score of 2). Investments in MHTs hit the lowest, at the mean score of 1.5.

Figure 5.29: AMTs Investment



The results show that the investment in AMTs varies by employment sizes. In summary, the larger companies are, the more they invest in AMTs. The study also reveals that the level of investment of different sectors in AMTs varies too, for example, for most sectors, the ranking of the scale of investment in different AMTs from highest to lowest is as follows: PDETs, PPTs, AsMTs, IMTs and finally MHTs. The only exception is in electronic and electrical industry. It made the most investment in PPTs, followed by PDETs, IMTs, AsMTs and MHTs. The four main industries invest in PDETs, IMTs and AsMTs on a similar level. However, surveyed companies of the industrial machinery industry invested barely anything in MHTs— much less than the others. On the other hand, companies of the electronic and electrical industry and industrial machinery industry made moderate investment in PPTs, considerably more than the other industry.

Figure 5.30: Investment in AMTs : Comparison by Sectors



In terms of the level of integration of AMTs invested in companies, it is rather obvious that it is at a very limited level of integration. From the Figure 5.31, it is interesting to note that the ranking of mean score is very similar to the order of AMTs investments. Although integration of PDETs has the highest ranking, its mean score is as low as 2, which indicates that it is only limitedly integrated. Similarly, as MHTs were least invested by the respondents, they were integrated on the least scale, i.e. at 1.3, too.

Figure 5.31: AMTs Integrations

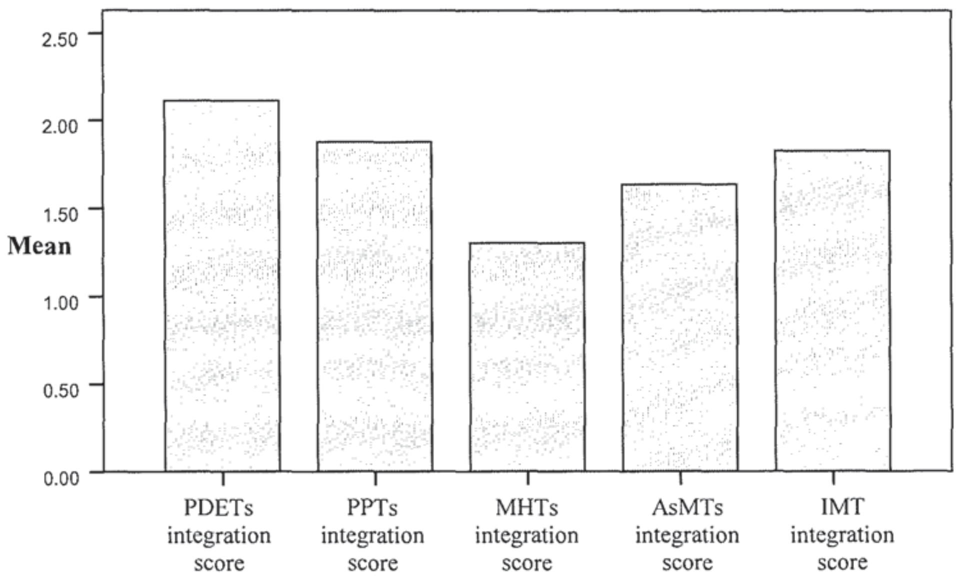
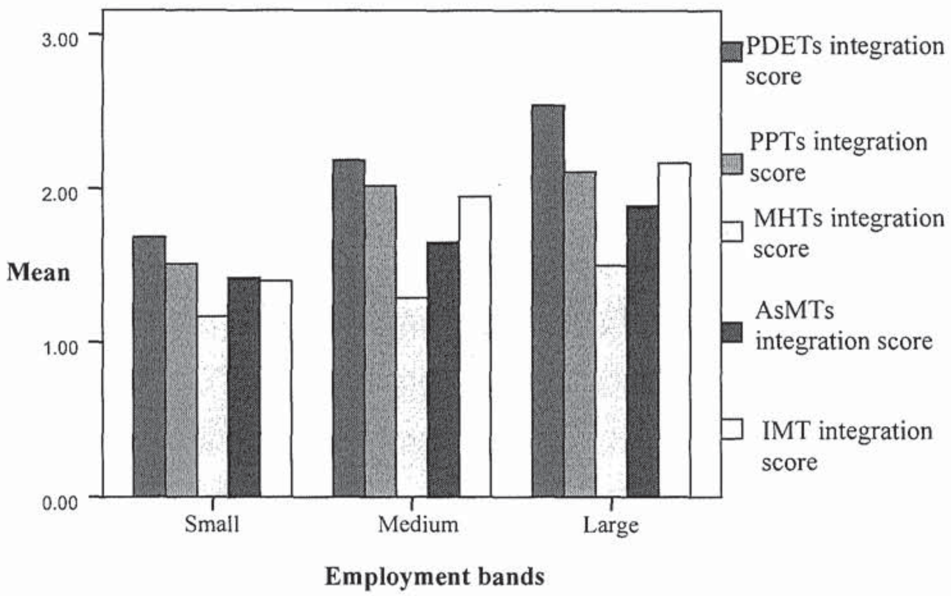


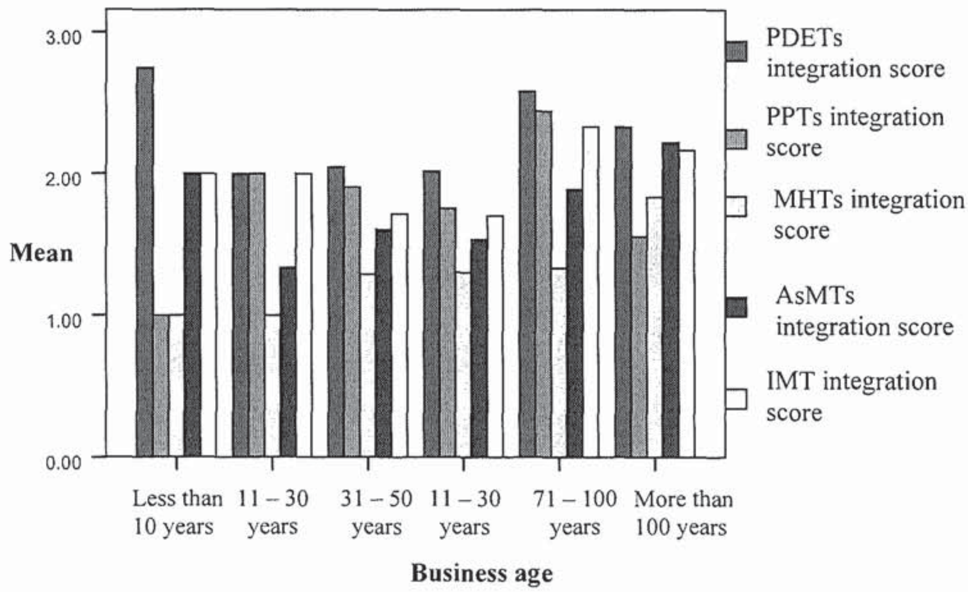
Figure 5.32 below shows the comparison of AMTs integration by employment bands. Generally, the level of integration is higher for larger companies, although PDETs for largest firms are integrated the most, but only moderately, i.e. its mean score at 2.6, and the lowest integrated technologies is MHT, which is just above 1, i.e. at no integration.

Figure 5.32: Integration of AMTs by Employment Bands



The results show that overall, foreign companies have slightly higher integration than UK owned companies, although again, the level of integration is rather low at 2.5 for PDETs, and at 1.8 for MHTs, as compared to local owned companies with 2.0 for PDETs and 1.2 for MHTs. The study also reveals that there is no specific pattern of AMTs integration when compared by the duration of existence. Companies generally integrated slightly higher when they achieved more then 71 years of existence, as shown in Figure 5.44. However, there is an exceptional case where the level of integration of PDETs of very young companies, i.e. less then 10 years has the highest level of integration at nearly a moderate level.

Figure 5.33: Integration of AMTs by Business Age



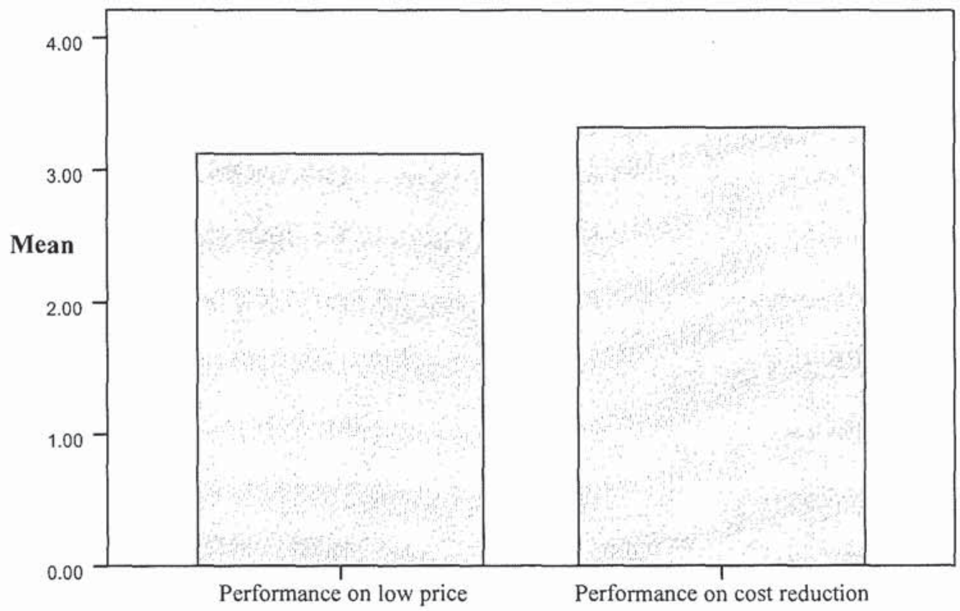
5.5 Manufacturing Performance

The questionnaire section on performance measurement contained 12 items which can be categorised into 4 main competitive priorities: quality, cost, flexibility and delivery. The measures for these priorities are the same as the manufacturing strategy. Respondents were asked to rate the organisational performance in comparison with the industry average in the manufacturing criteria which reflect the 4 main competitive priorities. For each variable, firms were asked to choose a response on a 5 Likert-point scale, where 1 is 'well below par', 3 is 'average', and 5 is 'well above par'.

5.5.1 Cost Leadership Performance

Cost leadership performances are reflected in two variables, performance on low price and performance on cost reduction. From the answers provided by the surveyed companies, they consider their performance on these aspects as on an average level in comparison with their industry average. No obvious difference in cost leadership performance is seen from comparisons between sectors. They all consider themselves on an average level on cost performance.

Figure 5.34: Cost Leadership Performance

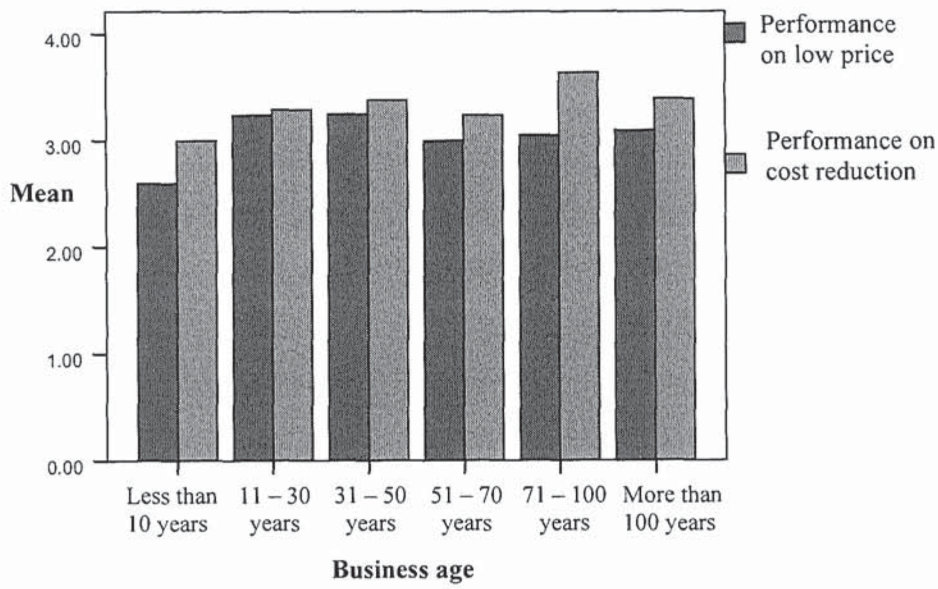


No obvious difference was witnessed from small and medium sized companies. But surveyed large companies think they perform slightly lower than average on low price and somehow above par on cost reduction.

Performances on cost reduction are indifferent between private and public companies. What is worth mentioning is that private companies think they are on an average level within their industry, but public owned firms obviously consider their performance on the same aspect is lower than par to some extent.

Except for the companies from the youngest age group, the others generally think their performance on cost related aspects are on an average level in comparison with their industry average. Surveyed companies whose business ages are less than 10 years say that their performance on low price is a little bit lower than average. On the other hand, companies aged between 71 to 100 years perform the best on cost reduction compared with companies from the other age groups.

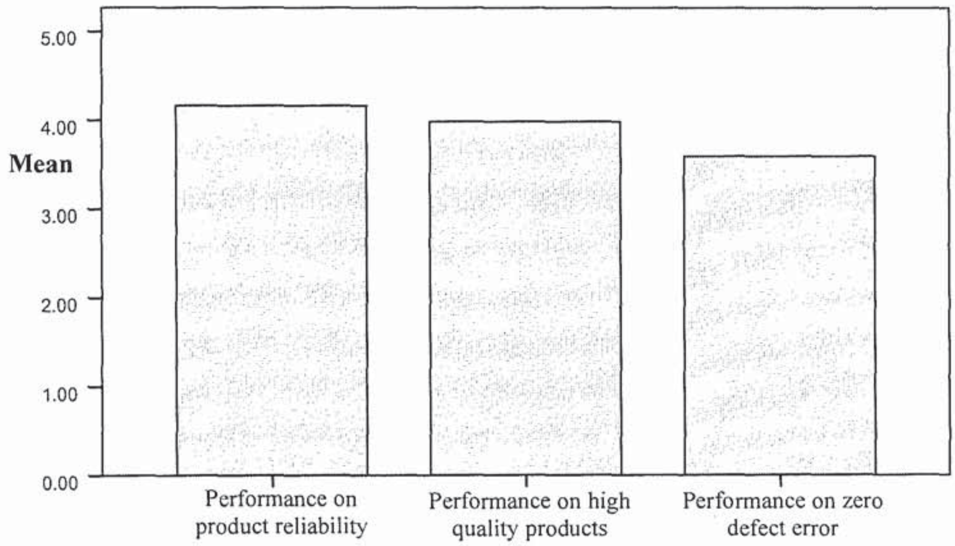
Figure 5.35: Cost Leadership Performance by Business Age Bands



5.5.2 Quality Performance

Surveyed companies generally think the quality performances are above par. Within the three rankings of quality performances, performance on product reliability is ranked the highest followed by performance on high quality products. Average score of performance on zero defects comes the last.

Figure 5.36: Quality Performance

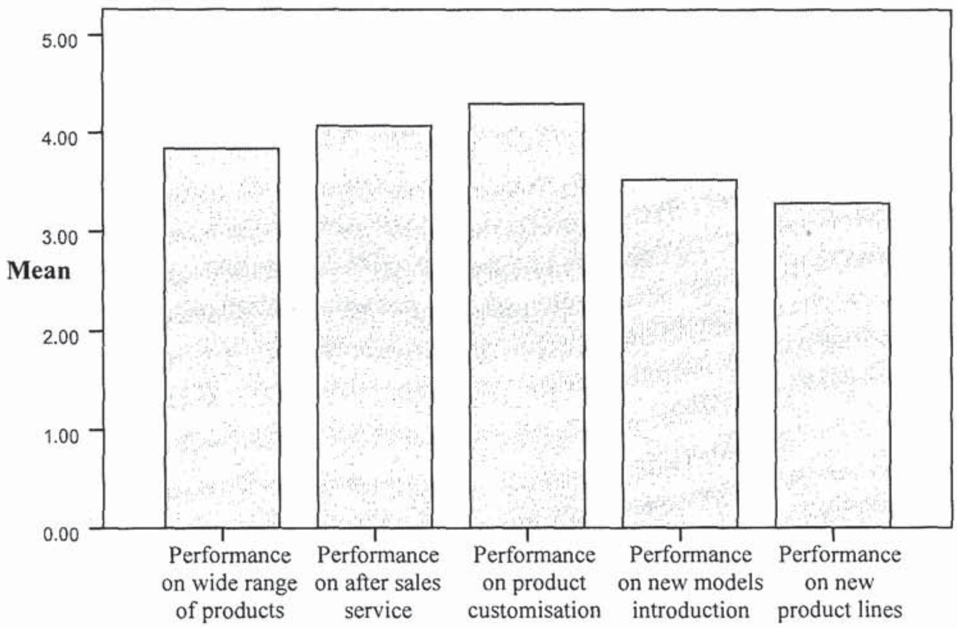


The results also reveal that companies from the fabricated metal production industry generally consider they perform better than par on each of the three quality performances. However, the other industries state their performance on product reliability and high quality products are above par, but performance on zero defects is just on an average level compared with their industry average.

5.5.3 Flexibility Performance

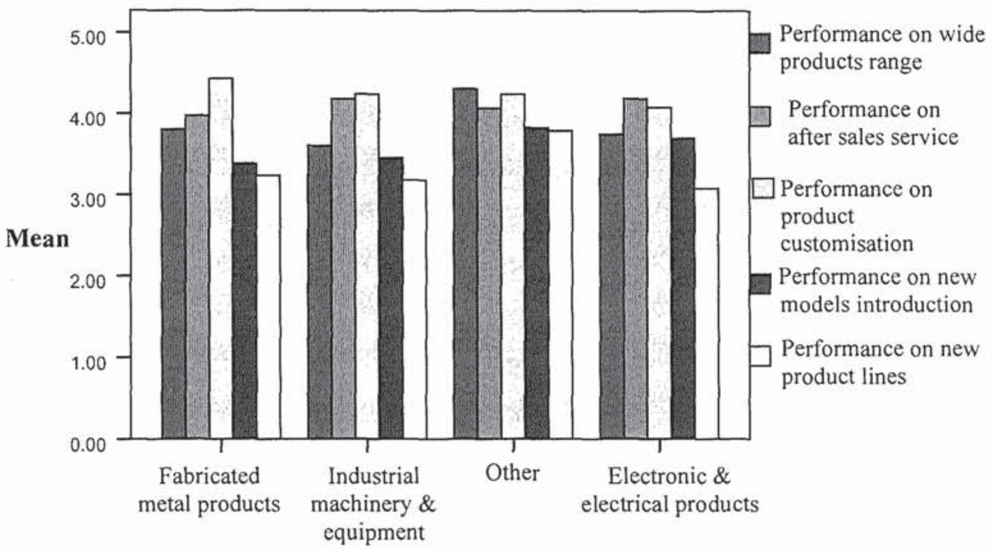
Considering flexibility performance, surveyed companies generally consider their performance are better than average. From the highest to lowest, performances on product customisation, after sales, and wide range of products are considered above par. Performances on new models and new product lines are both considered as better than industry average.

Figure 5.37: Flexibility Performance



As shown in Figure 5.38, surveyed companies from the three main sectors rank their performance on each of the five flexibility performance lower than the companies categorised in the other sector.

Figure 5.38: Flexibility Performance by Sectors

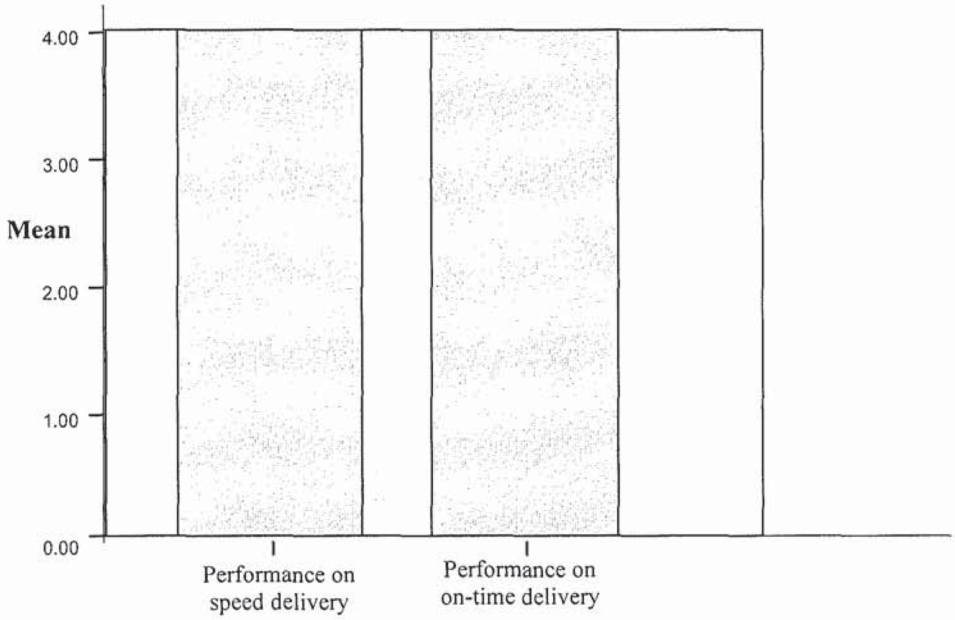


Companies younger than 10 years rank their performances on new models and new product lines highest among the entire age bands. On the other hand, senior companies aged 71 or over consider their performance on wide range of products and after sales better than their younger peers. Performance on product customisation is indifferent between any age groups.

5.5.4 Delivery Performance

As shown in the Figure 5.39, the overall ranking for delivery performance is almost 4, which means surveyed companies think their performance on delivery activities are above par. However, there is no obvious difference witnessed between sectors. All industries have no difference in ranking their delivery performance.

Figure 5.39: Delivery Performance



As for both private and public companies, performances on timely delivery are ranked the highest, and above industry average. Public owned companies surveyed ranked much lower than private ones on speed delivery. Public companies consider themselves performing on an average level on reaching their customers quickly, while private companies generally think their performances are above par.

5.6 Conclusions

This chapter provides the background information of the respondent companies, of their demographic characteristics, their competitive priorities, the level of investment of AMTs and its level of integration, and finally the perceived level of performance in regards to their manufacturing capabilities.

Broadly, the respondent companies are classified into the fabricated metals product sector, the industrial machinery equipment sector, electronics and electrical sector, the other manufacturing sector. Overall, the companies surveyed do not compete on cost leadership alone, rather a combination of different dimensions of competitive advantage, i.e. flexibility, delivery, and quality. The quality strategy is by far the most important competitive strategy, followed by delivery, and flexibility. The least important of all manufacturing strategies is the cost leadership strategy.

In terms of AMTs investment, generally, surveyed companies invested less than moderately in AMTs. The most invested technologies are in PDETs and PPTs. Companies invested least in MHTs. There is a tendency that larger companies invested more in AMTs as compared to smaller companies. There is no obvious indication as to which sector has more AMTs than the others. Electronics and electrical tends to invest most in PPTs, and the other sectors invested most in PDETs.

The surveyed companies have a very limited level of integration, with the highest integration in PDETs and lowest in MHTs. Again, larger companies have higher levels of integration than smaller companies, however, even for PDETs which are integrated the most, but the level of integration is only moderate, and the lowest of integrated technologies is MHT, which is just above 1, i.e. at no integration.

Surveyed companies generally think that both their quality and delivery performances are above par, their flexibility performance just above average, and their cost reduction performance is on the average.

CHAPTER 6

HYPOTHESES TESTING AND MEASUREMENT OF FIT

6.1 Introduction

In the last chapter, we described the characteristics of our sampled companies, and their practices in regards to their AMT deployment, their competitive priorities and their perceived manufacturing performance. In this chapter, we aim to provide answers to our two research questions set forth to undertake this study:-

1. What type of AMTs are appropriate for a particular manufacturing strategy? and
2. Does the fit between the AMT and the manufacturing strategy affect the manufacturing performance.

The first question is discussed in detail by testing two hypotheses, whilst the second question will be attempted through multiple approaches, as suggested by the strategic management expert, Venkatraman (1989), that 'the test of fit should be examined from multiple perspectives so as to evaluate the best method'. He proposes six approaches, which are fit as moderation, fit as mediation, fit as matching, fit as profile deviation, fit as gestalts and fit as covariation.

Thus, the first part of the chapter looks at the statistical procedures involved in conducting the hypotheses testing to provide the answers to the hypotheses developed from the literature; while the second part of the chapter will examine the impact of fit between the AMT and manufacturing strategies on performance through the first five perspectives. The 'fit as covariation' is omitted in this study as it failed to achieve the desirable outcomes (refer to Appendix 8: Fit as Covariation).

6.2 The Relationship Between Manufacturing Strategies and AMT

This first part of the chapter details the statistical procedures to answer the two hypotheses developed from the literature. The two hypotheses are:-

Hypothesis 1: Differentiation Strategy is positively associated with multiple AMTs.

Hypothesis 2: Cost leadership Strategy is negatively associated with multiple AMTs.

As postulated in the manufacturing strategy and operations management literature, the use of AMT is deemed to be associated with the type of manufacturing strategies. For instance, companies adopting a differentiation strategy are more likely to be using a number of AMTs; in contrast, companies that adopt a cost leadership strategy will invest far less in AMTs and its level of integration is minimal, i.e. stand alone or limited integration.

The information for the statistical analyses was collected via a questionnaire filled up by the informant in the surveyed company, mainly from the top management team. The information consists of the type of manufacturing strategy orientation, type of AMT and their perceived performance in regards to their manufacturing capabilities.

Companies were asked to indicate the importance of the various strategies in order to compete effectively with their competitors. In this regard, companies have a choice of either to compete with their competitors in terms of the quality, and/or cost, and/or flexibility and/or delivery dimensions of their products. Companies were also asked to indicate, based on a list of 14 AMTs investigated, what were the level of investment and the integration of each of the AMT in their companies. As for the performance information, it involved self-assessment where companies indicated their performance level in the manufacturing capabilities in comparison with the industry average.

For each question, numerous constructs of dimensions were asked in order to capture the information. However, it is not feasible to examine each one of them. Besides, it is very difficult when conducting regression, as too many explanatory variables would reduce the degree of freedom, which will then result in less favorable and consistent test results. Thus, first of all, it is inevitable to conduct factor analyses in order to reduce the dimensions involved in each variable. Then further tests need to be carried out on factors generated to see whether they are normally distributed in order to make meaningful inferences, which will be provided in section 6.2.1, 6.2.2 and 6.2.3. After which, the hypotheses testing can be performed by testing the level of agreement between the variables.

6.2.1 Factor Analysis on Manufacturing Strategies

The factor analysis based on the Principal Component Analysis extraction method with Varimax rotation is used to reduce the dimensions of manufacturing strategies. Loadings of the two factors extracted are shown in Table 6.1. Factor 1 has high positive loadings on Quality Strategy (QS), Flexibility Strategy (FS) and Delivery Strategy (DS), while factor 2 mostly focuses on Cost leadership strategy (CS). Therefore, factor 1 can be defined as the ***Differentiation Strategy*** and factor 2 as the ***Cost leadership Strategy***. This is confirmed with the generic strategy as proposed by Porter (1989), i.e. Differentiation and cost leadership strategy. These two factors are able to explain 63.8% of all the information (variance). Reliability of the factor analysis has been approved by Bartlett's Test of Sphericity, with a test score of 49.875 with 6 degrees of freedom and a p-value much smaller than 0.01 (Please refer to Appendix 6: Factor Analysis on manufacturing strategies for more details).

Table 6.1: Manufacturing Strategies: Factor Loadings[a]

	1 Differentiation Strategy	**2 Cost leadership Strategy**
Quality Strategy (QS)	.731	.223
Cost leadership strategy (CS)	-.103	.848
Flexibility Strategy (FS)	.824	-.066
Delivery Strategy (DS)	.681	.302

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
[a] Rotation converged in 3 iterations.

Table 6.2 below examines the basic distribution information of the strategy factor scores obtained. According to the SPSS settings and algorithm of factor analysis, all factor scores should be standardized, which means they should have zero means and unit standard deviation. Therefore, the mean values of the differentiation strategy and cost leadership strategy are both zero and their standard deviation are both 1. However, it is noticed that their skewness are below zero. Skewness measures whether the distribution of a variable is symmetric while kurtosis measures the shape of the peak compared with a standard normal distribution.

Table 6.2: Descriptive Statistics of Differentiation Strategy and Cost Leadership Strategy

	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Differentiation Strategy	-3.74	1.74	0	1	-.961	1.226
Cost leadership Strategy	-3.12	2.16	0	1	-.499	.182

Generally, a standard normal distribution is bell-shaped, with zero skewness and kurtosis (according to the algorithm adopted by SPSS). A negative skewness indicates a variable has a long tail on the left side and the majority of the distribution crowded on the right side of the graphs of their probability density functions. A positive kurtosis indicates that the distribution of a variable has a sharper peak compared with the standard normal distribution. Thus, as indicated in the Table 6.2, both differentiation strategy and cost leadership strategy are left skewed and have sharper peak than standard normal distribution.

In order to further ascertain whether a variable follows a normal distribution, a normal Probability-Probability plot (PP Plot) can be used. The plots from normal distribution data should all fall in a straight line on the PP plot. Departures from the line are clues of departures from a normal distribution.

When we draw the normal PP plots of Differentiation Strategy and Cost leadership Strategy (see Figure 6.1 and Figure 6.2 respectively), it shows that the cost leadership strategy follows a normal distribution better than the differentiation strategy. This is because its plots fit better on the line. In contrast, the differentiation strategy falls out of the line in the middle part. However, their appearances are still acceptable for regression purposes, which usually require the data follow the normal distribution.

Figure 6.1 Normal P-P Plot of Differentiation Strategy

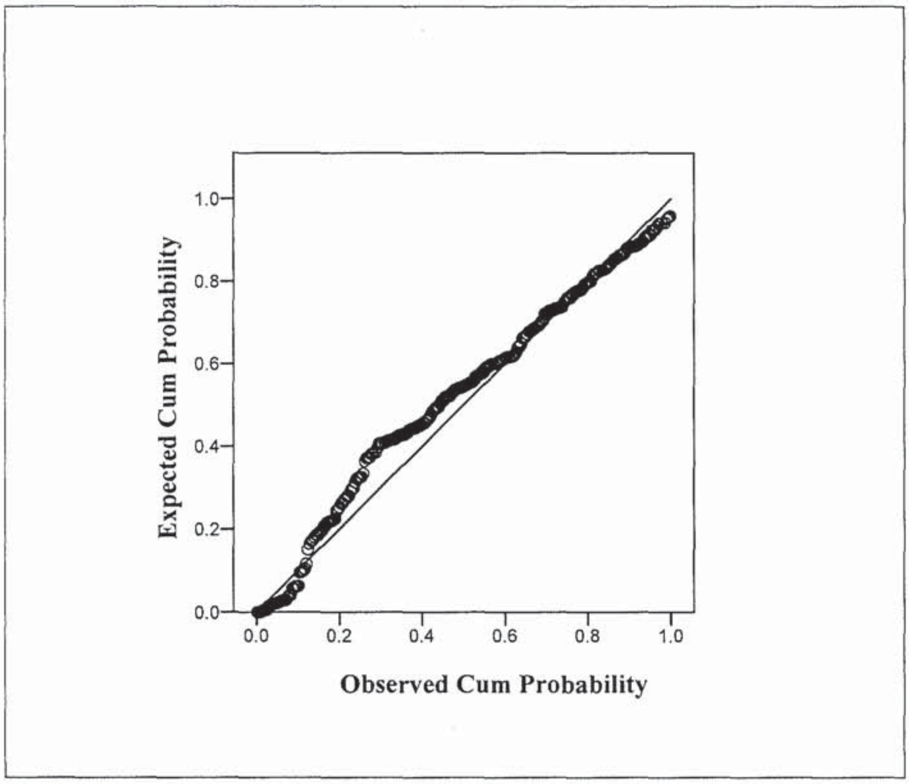
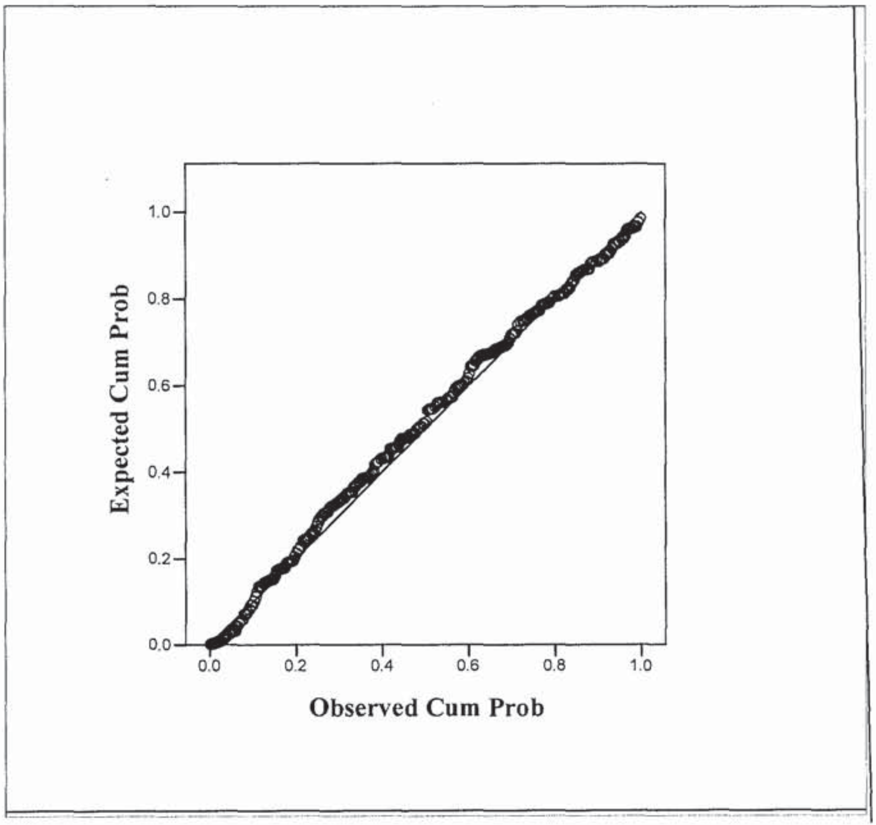


Figure 6.2 Normal PP Plot of Cost Leadership Strategy



6.2.2 Simplification of AMTs

In terms of the measurement of AMTs, the score of each of the five categories is derived based on two distinctive measurements: the level of investment and the extensiveness of its integration. The mean score of each type of AMT is calculated by taking the average of its investment score and integration score. Therefore, we have five measurements of AMTs, which are Product Design and Engineering Technology Score (PDET), Production Planning Technology Score (PPT), Material Handling Technology Score (MHT), Assembly and Machinery Technology Score (AsMT) and Integrated Manufacturing Technology Score (IMT).

Table 6.3 Descriptive Statistics of AMT

	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
PDET	.00	4.50	1.6641	.91733	.309	-.063
PPT	.00	4.50	1.6387	1.19709	.425	-.647
MHT	.00	3.25	.4685	.64935	1.567	2.454
AsMT	.00	3.67	1.2379	.92135	.340	-.644
IMT	.00	4.25	.7920	1.13236	1.286	.533

According to Table 6.3, all AMTs are positively skewed. The skewness coefficient for both the MHT and IMT are larger than 1. Moreover the kurtosis of the MHT is particularly large (2.454), which is an indication of poor normality. Since all AMTs follow normal distribution poorly, their normality test results are not provided here. Please refer to Appendix 7 for Normal PP plots of AMTs.

6.2.3 Dimension Reduction on Manufacturing Performance

According to the analysis above, companies surveyed generally adopt two different manufacturing strategies:- either a differentiation strategy or a cost leadership strategy. Naturally, it is of our interest to find out whether the adoption of a certain strategy will affect the performance of a company. For instance, will the use of a cost leadership strategy improve a company's performance in cost competence; and will a company stand out in differentiation performance by adopting a differentiation strategy. In order to make the measurement of strategy and performance more coherent, here we give two types of manufacturing performances with the component score coefficients obtained in the factor analysis on strategies. The component score coefficient matrix of strategies is provided in Table 6.4.

Table 6.4 Component Score Coefficient Matrix of the Factor Analysis on Strategies

	Component	
	1	2
Quality strategy	.542	.081
Cost leadership strategy	-.203	.723
Flexibility strategy	.656	-.174
Delivery strategy	.525	.139

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization
Component Scores.

Basically, the performance score is calculated by multiplying each of the four original performance variables (mean adjusted) by the corresponding factor component score coefficient. During the calculation, all the performance variables have already been subtracted by the average of the entire variable to avoid bias. However, please note that the original notifications are still used for simplification purposes. For instance, the new Quality Performance (*QP)* in the following equation actually indicates *mean adjusted QP*. Mathematical definitions of differentiation performance and cost leadership performance are given as below:

Differentiation Performance (DiffP)

$$=0.542*QP-0.203*CP+0.656*FP+0.525*DP$$

Cost leadership Performance (CLP)

$$=0.081*QP+0.723*CP-0.174*FP+0.139*DP$$

where:

QP=Quality Performance

CP=Cost Performance

FP=Flexibility Performance

DP=Delivery Performance

In this sense, companies having a high differentiation performance should perform well from the quality, flexibility and delivery aspects; on the other hand, companies having high cost leadership performance should perform well on cost related performance.

Table 6.5 Descriptive Statistics of Differentiation Performance and Cost Leadership Performance

	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Differentiation Performance	-1.73	1.21	.0000	.53917	-.112	.210
Cost leadership Performance	-1.84	1.87	.0000	.66967	-.045	-.320

Table 6.5 presents some of the essential distribution information of the differentiation performance and cost leadership performance. As it shows, mean values of both of them are zero. This is because we have centered them (subtracting variable means from each variables) before calculation. Their standard deviations are both smaller than 1, which indicates their distributions are slightly narrower than a standard normal distribution. Their skewness are both slightly below zero—the skewness of a standard normal distribution. Also, their kurtosis is not far from zero. All these values show that the differentiation performance and the cost leadership performance are approximately normally distributed.

When examining both performance variables on the normal PP Plot, both the differentiation performance and the cost leadership performance are normally distributed. As shown in the Figures 6.3 and 6.4, both performance variables plots rest quite well on a straight line. Although the middle part of the differentiation performance slightly departs from the straight line, it does not affect much. Generally, they could be considered as normally distributed. This is very important in the analysis later, because almost all the parametric methods require the data follow normal distribution. e.g. univariate and multivariate regressions.

Figure 6.3 Normal PP Plot of Differentiation Performance

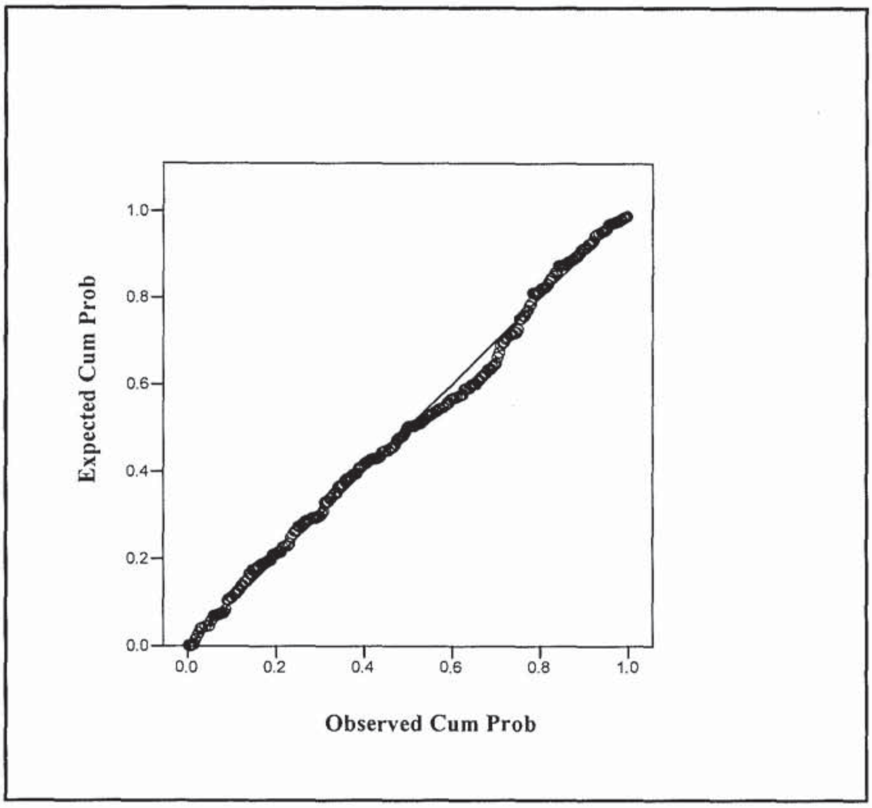
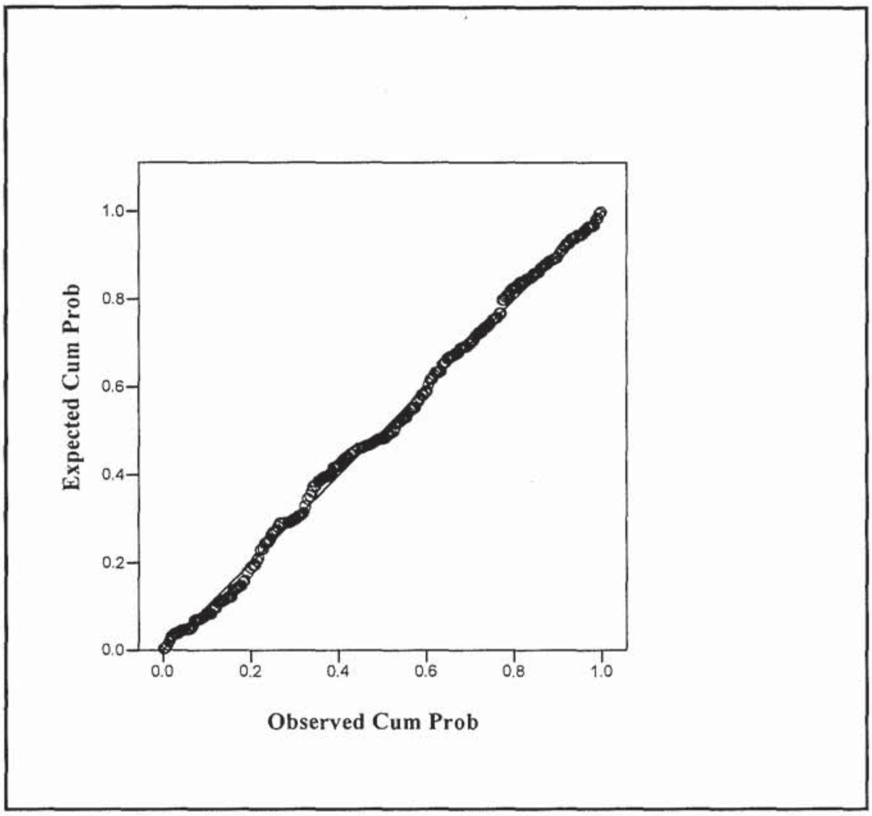


Figure 6.4 Normal PP Plot of Cost Leadership Performance



6.2.4 Hypothesis Testing: The Relationship Between Manufacturing Strategy and AMT

The aim of the hypotheses testing of the study is to test the level of agreement between the type of manufacturing strategy and the diffusion of AMTs to facilitate the manufacturing processes in order to achieve the intended manufacturing performance. It is proposed that companies who emphasise the differentiation strategy, i.e. compete with other competitors based on quality, flexibility or delivery dimensions tend to make substantial investment in AMTs and are more likely to integrate the technologies at the company level or throughout their supply chain. Thus, based on this proposition, our first hypothesis is as follows:-

Null Hypothesis 1 (H0): Differentiation Strategy is positively associated with multiple AMTs.

Alternative hypothesis 1 (HA): Differentiation Strategy is not associated with any AMT.

The testing of the hypothesis is conducted by examining bivariate correlations of manufacturing strategies and AMT. The results are shown in Table 6.6 below:-

Table 6.6: Bivariate Correlations of Differentiation Strategy and AMT

	Differentiation Strategy
PDET	.299(**)
PPT	.370(**)
MHT	.195(**)
AsMT	.121
IMT	.225(**)

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

As indicated in the Table 6.6, differentiation strategy is significantly positively related with most AMT, which strongly supports hypothesis 1. Thus, we can conclude that if a company is adopting a differentiation strategy, it is likely that there is a higher level of investment and integration in its PDET, PPT, MHT and IMT.

As for companies who are more cost conscious and thus emphasising the cost leadership strategy, i.e. compete with other competitors based on low price, are tending to limit their investment in AMTs and are more likely to use stand alone or limited integrated pieces of technologies. Therefore, our second hypothesis is as follows:-

Null Hypothesis 2 (H0): Cost leadership Strategy is positively associated with multiple AMTs.

Alternative hypothesis 2 (HA): Cost leadership Strategy is not associated with any AMT.

When Null Hypothesis 2 is rejected, we can have the evidence of low association of all AMT with cost leadership strategy. The results are shown in the Table 6.7. It seemed that although the correlations of cost leadership strategies and all AMT are over zero, only AsMT and IMT are significantly positively related with the cost leadership strategy at 0.01 level.

Table 6.7: Bivariate Correlations of Cost Leadership Strategy and AMT

	Cost Leadership Strategy
PDET	.087
PPT	.045
MHT	.071
AsMT	.156(**)
IMT	.166(**)

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

It indicates that in our study there is no significant proof of the positive relationship between a cost leadership strategy and certain AMTs such as PDET, PPT and MHT. However, the positive association between cost leadership strategy and AsMT and IMT are supported by statistical tests. Thus, companies adopting cost leadership strategy do not particularly emphasise investing in PDET, PPT and MHT to compete in the market. However, investment and integration in AsMT and IMT are to some extent positively related with a cost leadership strategy. Such a result partly supports our expectation that the Cost leadership Strategy is not strongly associated with investment and integration of AMT.

6.3 The Implication of Manufacturing Strategy-AMT Fit on Manufacturing Performance

The second part of the chapter focuses on the analyses results with respect to the contingency fit theory and the various perspectives of fit as proposed by Venkatraman (1989). It discusses the impact of alignment or fit between the AMT and manufacturing strategy on the perceived manufacturing performance.

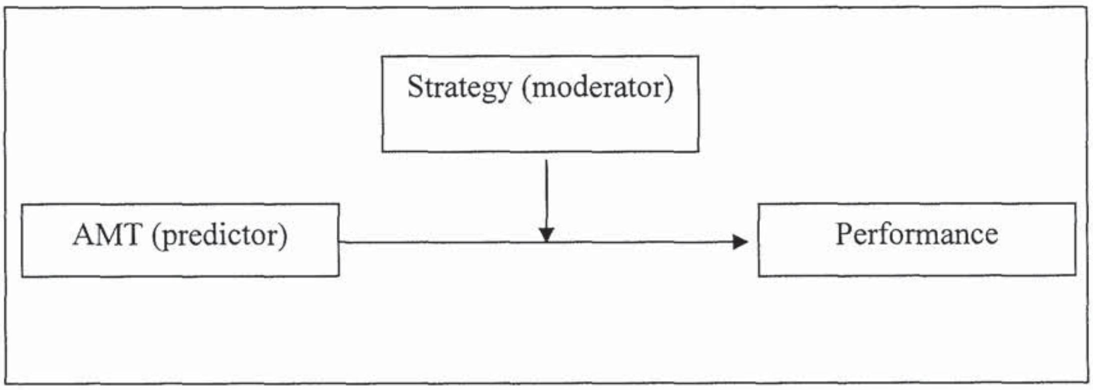
The hypothesis testing as shown in the first part of the chapter has confirmed that there are some forms of associations between a differentiation strategy and AMT, i.e. companies with a differentiation strategy invested significantly in most AMTs, PDET, PPT, MHT and IMT in particular, and with higher levels of integration; and cost leadership strategy adopters place less emphasis on AMTs . They only invested and integrated relatively more in IMT and AsMT. Previous research suggested that the fit between the manufacturing strategy and the type of AMTs, will have a positive impact on the manufacturing performance, thus, companies that have the best fit between the manufacturing strategy and AMT will reap superior performance, while mis-fit of the two variables, will result in poor performance.

Many researchers have suggested various algorithms to test the existence of fit among manufacturing strategies and technologies. Venkatraman (1989) proposes the testing of fit through multiple approaches to identify the best method, i.e. fit as moderation, fits mediation, fit as gestalts, fit as matching, fit as profile deviation and fit as covariation.

6.3.1 Fit as Moderation

In the moderation approach, the effect of the predictor variable, i.e. AMT on performance depends on the level of the moderator variable (i.e. strategies). The schematic representation of variables is illustrated in Figure 6.5.

Figure 6.5: A schematic Representation of Fit as Moderation



The testing for the moderation approach of fit can either be done by performing a subgroup analysis on the correlation coefficients between moderators and predictors or by examining the significance of interaction terms in regression of performance against strategies and AMT.

6.3.1.1 Subgroup Analysis Approach

When looking into the correlation coefficients of performances and AMT for all companies (see Table 6.8), it is noticed that differentiation performance is significantly positively associated with almost all AMT. Only MHT is irrelevant. However, cost leadership strategy is only found positively related with IMT at the 0.05 level. This is similar to our correlation analysis on strategies and AMT—differentiation strategy is positively related with the level of investment and integration of multiple AMT. However, AMT is not strongly related with the cost leadership strategy.

Table 6.8: Correlations Coefficients of Performances with AMT

	Differentiation Performance	Cost leadership Performance
PDET	.176(**)	-.007
PPT	.198(**)	-.079
MHT	-.005	.028
AsMT	.145(**)	.015
IMT	.207(**)	.139(*)

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

In order to conduct the subgroup analysis, in the first place, all the companies are sorted from high to low according to their factor analysis scores on differentiation strategy. Then they are divided evenly into three groups. The total number of surveyed companies is 262. The top 87 companies with highest scores on the differentiation strategy factor are defined as the high differentiation strategy group, and the last group (87 companies) which has the lowest scores in the differentiation strategy factor is defined as the low differentiation strategy group. The middle group (88 companies) is excluded from the subgroup analysis.

This practice is to ensure the two groups being compared have as large a difference as possible, but still contain enough entries for feasible degrees of freedom. A similar definition applies in the subgroup analysis on the cost leadership strategy, too. Then, subgroup analysis is conducted by examining the correlations of performances and AMT for the high strategy taker and low strategy taker on the two types of strategies separately. Based on the two types of strategies identified in the study, i.e. differentiation strategy and cost leadership strategy, we can further group companies who are 'High Differentiation Strategy Adopters', 'Low Differentiation Strategy Adopters', 'High Cost leadership Strategy Adopters' and 'Low Cost leadership Strategy Adopters'.

Table 6.9 shows the subgroup analysis based on the differentiation strategy. It shows that stronger positive relationships are found in Low Differentiation Strategy Adopters than High Differentiation Strategy Adopters for both differentiation performance and cost leadership performance. Also, it is noticed that coefficients of high differentiation performers are larger than lower differentiation performers on the differentiation strategy with 3 out of 5 AMT. Interestingly the opposite phenomenon is found in coefficients of cost leadership strategy against AMT.

Table 6.9: Pearson Correlations of Strategy Against AMT Grouped by Differentiation Strategy Scores

	Differentiation Performance		Cost Leadership Performance	
	High Strategy Adopter	**Low Strategy Adopter**	**High Strategy Adopter**	**Low Strategy Adopter**
PDET	.041	.103	-.012	.067
PPT	.112	.196(*)	-.110	.013
MHT	-.024	.052	.064	.042
AsMT	.064	.185(*)	-.078	.134
IMT	.125	.218(*)	.165	.205(*)

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Companies with higher differentiation strategy have weaker association between Differentiation Performance and all AMT compared with poor performers. Moreover, paired-sample t-tests show the correlation coefficients of differentiation performance and AMT are significantly different between high differentiation strategy adopters and low differentiation strategy adopters ($t=-8.838$, $p=0.001$ See Appendix 9).

On the other hand, it is found that correlation coefficients of Cost leadership performance and AMT between high and low differentiation strategy adopters are not statistically distinct ($t=-2.192$, $p=0.093$). Similar subgroup analysis is also conducted on high and low cost leadership strategy adopters (see Table 6.10). Interestingly, there are still more significant positive relationships among differentiation performance and AMT. Paired Sample t-tests show that differences in correlations are highly significant on differentiation performance against AMT ($t=3.932$, $p=0.017$). Higher Cost leadership Strategy adopters also tend to have higher correlations of cost leadership performance and AMT at the 10% level ($t=2.538$, $p=0.064$).

Table 6.10: Pearson Correlations performances against AMT of Cost leadership Strategy Adopters

	Differentiation Performance		Cost leadership Performance	
	Low Strategy Adopters	High Strategy Adopters	Low Strategy Adopters	High Strategy Adopters
PDET	.068	.333(**)	-.104	.115
PPT	.169	.250(**)	-.080	-.037
MHT	-.136	.055	-.098	.202(*)
AsMT	.111	.165	-.058	.007
IMT	.099	.340(**)	.129	.173

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Since significant differences are found in both differentiation performance and cost leadership performance, the results show that high Cost leadership strategy adopters are more likely to have tighter association between AMT and both performances. In particular, for companies adopting a high cost leadership strategy, improvements in differentiation performance and cost leadership performance are more closely related with increase in the level of AMT investment and integration.

Before regression, we have some insight into the Spearman correlation coefficients of performance scores and main effects (AMT and strategies) (see Table 6.11). It is seen that performances scores are positively related with the majority of strategies and AMT. Moreover all the significant correlations are positive. In particular, according to Table 6.11 differentiation performance is significantly positively related with the differentiation strategy ($r=0.308$, $p<0.01$), PDET ($r=0.176$, $p<0.01$), PPT ($r=0.198$, $p<0.01$), AsMT ($r=0.145$, $p<0.01$) and IMT ($r=0.207$, $p<0.01$). The correlation coefficient of Cost leadership performance and cost leadership strategy is 0.437, significant at level 0.01. Also, Cost leadership Performance is significantly related with IMT in a positive way ($r=0.139$, $p<0.05$).

Table 6.11: Spearman Correlations Coefficients of Performances and Main Effects

	Differentiation Performance	**Cost leadership Performance**
PDET	.176(**)	-.007
PPT	.198(**)	-.079
MHT	-.005	.028
AsMT	.145(**)	.015
IMT	.207(**)	.139(*)
Differentiation Strategy	.308(**)	-.029
Cost leadership Strategy	.025	.437(**)

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

When examining the correlations of interaction terms of performances, we notice that although performance scores have positive correlation coefficients with almost all AMT and strategy interaction terms, the differentiation performance is significantly associated with every single differentiation strategy and AMT combination plus a few cost leadership strategy-AMT interactions (Cost leadership Strategy*MHT and Cost leadership strategy*IMT). Whilst the Cost leadership performance is only significantly related with cost leadership strategy and AMT combinations (see Table 6.12).

Table 6.12: Correlations of performances and AMT * strategy interactions

	Differentiation Performance	Cost leadership Performance
DiffS_PDET	.295(**)	-.031
DiffS_PPT	.308(**)	-.061
DiffS_MHT	.214(**)	.017
DiffS_AsMT	.250(**)	-.055
DiffS_IMT	.208(**)	.020
CostS_PDET	.086	.413(**)
CostS_PPT	.039	.361(**)
CostS_MHT	.121(*)	.332(**)
CostS_AsMT	.035	.376(**)
CostS_IMT	.130(*)	.274(**)

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

6.3.1.2 Regression on Performance Approach

Another way of examining the fit as moderation is by examining the significance of interaction terms in regression of performance against strategies and AMT. Thus, we conduct regression on performance against 'AMT+strategy' (main effects) and 'AMT+Strategy+AMT*Strategy' (main effects and interactions) separately, then compare and discuss improvements in the regressions and finally make conclusions whether the effect of interaction terms (fit variables) exist in the regression. Venkatraman (1989) limited the moderation approach to two explanatory variables. This study has furthered this method to multiple dimensions of variables, i.e. for AMT, we included PDET, PPT, MHT, AsMT and IMT; for strategy, we included differentiation and cost leadership strategy.

6.3.1.2.1 Regression on Differentiation Performance with Main Effects Only

In the first place, we conduct linear regression on differentiation performance with AMT (MHT, PPT, AsMT, PDET and IMT) and strategies (differentiation strategy and cost leadership strategy) as explanatory variables with a backward variable selection procedure. The final model we acquired is composed of three explanatory variables—Differentiation strategy, MHT and IMT. Goodness-of-fit (Adjusted R Square) of the model is 0.137. Analysis of Variance shows that F statistic is 14.811 with $p<.01$. The results show that the regression is not very satisfying but still effective. Coefficients of the explanatory variables are shown in Table 6.13.

Table 6.13: Coefficients of Linear Regression on Differentiation Performance with AMT and Strategy Main Effects

	Unstandardised Coefficients		t	Sig.
	B	Std. Error		
MHT	-.192	.056	-3.408	.001
IMT	.126	.033	3.837	.000
Differentiation Strategy	.159	.032	5.031	.000

The regression reveals that differentiation performance is positively related with differentiation strategy and IMT, but negatively related with MHT. Thus, companies will reap higher differentiation performance if they were to adopt differentiation strategy and invest higher in IMT. However, the investment in MHT is negatively related with differentiation performance. So companies who aimed to achieve the differentiation performance should avoid investing and integrating in any MHT.

6.3.1.2.2 Regressions on Differentiation Performance with Main Effects and Interactions

With a backward model selection method, two-way interaction terms are introduced into the regression. However there is nothing changed in the composition of the regression model. As shown in the Table 6.14, the regression model remains identical to the one when only main effects are considered.

Table 6.14: Coefficients of Linear Regression on Differentiation Performance with AMT and Strategy Main Effects and Two-way Interactions

	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
MHT	-.192	.056	-3.408	.001
IMT	.126	.033	3.837	.000
Differentiation Strategy	.159	.032	5.031	.000

After seeing this result we can realize that, in Table 6.12, the reason that all interactions between differentiation strategy and AMT are significantly related with differentiation performance is and only is due to differentiation strategy. The regression on differentiation performance fails to identify any significant interaction term.

Therefore we come to the conclusion that in a moderation approach, no effect of fit between differentiation strategy and AMT exists on the differentiation performance for our surveyed companies.

6.3.1.2.3 Regression on Cost Leadership Performance with Main Effects Only

Similarly, when regressing cost leadership performance with main effects of AMT and strategies, we found out that it is positively related with Cost leadership strategies and IMT, but negatively with PPT (Table 6.15). The effect of the regression is acceptable. Adjusted R Square is 0.204 with F-statistics 0f 23.362. The significance value of the F test is far less than 0.01, which shows that the regression is effective.

Table 6.15: Coefficients of Linear Regression on Efficiency Performance with AMT and Strategy Main Effects

	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
PPT	-.065	.026	-2.517	.012
IMT	.096	.039	2.493	.013
Cost leadership Strategy	.278	.037	7.420	.000

Adopting a cost leadership strategy will help improve the companies' performance on the cost competency. In particular, 1 unit rise in cost leadership strategy is associated with 0.278 units increase in cost efficiency performance. IMT is also beneficial to serve this purpose. However, PPT should be avoided, since one unit investment and integration of PPT is associated with .065 unit loss in the cost efficiency performance.

6.3.1.2.4 Regressions on Cost Leadership Performance With Main Effects and Interactions

When two-way interaction terms are considered in the regression, the effectiveness of regression is slightly improved. Goodness-of-fit increases to 0.212 and the F-statistics rises to 18.599. On the other hand, cost leadership strategy, PPT and IMT remain highly significant (Table 6.16). Interaction between the cost leadership strategy and MHT appears significant in the new model. Coincidently Table 6.12 suggests that interaction between cost leadership and MHT is significantly related with cost leadership performance. However, it also suggests that all interactions between cost leadership strategy and AMT are significantly related with cost leadership strategy. More possibly those relations are driven by the cost leadership strategy rather than the effect of fit.

Table 6.16: Coefficients of Linear Regression on Cost Efficiency Performance with AMT and Strategy Main Effects and Interaction Terms (Fit Variables)

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
PPT	-.067	.026	-.203	-2.587	.010
IMT	.091	.038	.187	2.360	.019
Cost leadership Strategy	.232	.045	.346	5.206	.000
CostS_MHT	.116	.061	.127	1.899	.059

According to the analysis, if companies are willing to achieve higher cost leadership performance, their cost leadership strategy should be accompanied by MHT. IMT could also stand alone, but again investment and integration in PPT should be avoided.

6.3.1.3 Conclusions on Fit as Moderation

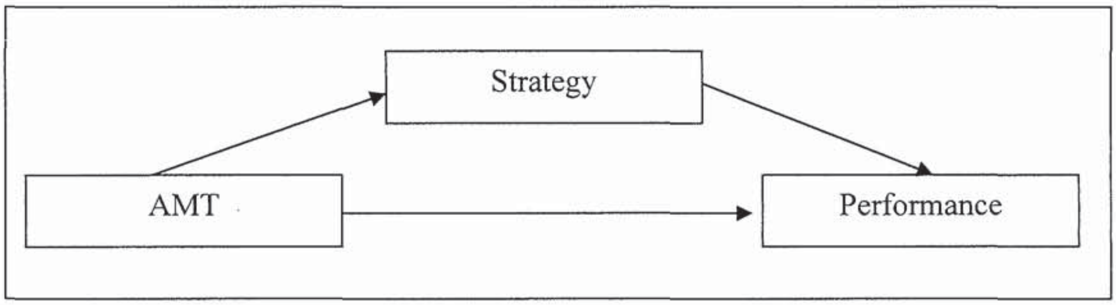
Through subgroup analysis and regression analysis approaches, the effects of strategy and AMT fit on performance have been approved. In particular, we find that differentiation performance is more closely associated with AMT for companies adopting a low differentiation strategy. In contrast, for high differentiation strategy adopters, differentiation performance does not change with level of investment and integration in AMT significantly. This result indicates that if a company is using a high differentiation strategy, it does not need to pay more for AMT, but the strategy alone is enough. No fit between differentiation strategy and AMT exists. Our findings figure out that adopting a differentiation strategy or not have no significant influence in the relationship between AMT and differentiation performance. No matter how differentiation performance changes equally rapid with changes in investment and integration of AMT.

Interestingly, high cost leadership strategy adopters are found to have slightly stronger positive associations between AMT and cost leadership strategy. It means if a company uses a cost leadership strategy, more increase in its cost leadership performance would be accompanied by a unit rise in the level of investment and integration of AMT, MHT in particular. The only exception is PPT, which is harmful for cost leadership performance. In summary, we came to the conclusions that differentiation performance is not affected by any 'fit' between differentiation strategy and AMT. Moreover, fit between a Cost leadership strategy and MHT is positively related with cost leadership performances.

6.3.2 Fit as Mediation

In the fit as mediation approach, strategies (differentiation strategy and cost leadership strategy) are considered as an intervening mechanism between antecedent variables (AMT) and the consequent variables (differentiation performance and cost efficiency performance). If the effect of antecedent variables (AMT) on consequent variables (performances) is said to be direct, the intervening mechanism (strategies) could be considered as an indirect influence power in the relationship, which is demonstrated in Figure 6.6.

Figure 6.6: A schematic representation of fit as mediation



The mediation approach of fit is mainly tested by examining several equations in this report (constant term omitted):

$$Performance = \alpha_1 PDET + \alpha_2 PPT + \alpha_3 MHT + \alpha_4 AsMT + \alpha_5 IMT + \alpha_6 Strategy + \varepsilon \qquad (1)$$

$$Strategy = \beta_1 PDET + \beta_2 PPT + \beta_3 MHT + \beta_4 AsMT + \beta_5 IMT + \varepsilon \qquad (2)$$

Where constant terms are omitted in the regression, α1, α2 and β1 are the regression coefficients and e is the term of random effect. Performance refers to the scores of differentiation performance and cost efficiency performance in the factor analysis. And Strategy is the scores of differentiation strategy and cost leadership strategy in the factor analysis. AMT refers to the mean score of investment and integration for each type of AMT (PDET, PPT, MHT, AsMT and IMT).

According to the linear regression in section 6.3.1.2: *Regression on Performance Approach*, the following relationships hold:

$$DifferentiationPerformance$$
$$= 0.159 DifferentiationStrategy - 0.192 MHT + .126 IMT \qquad (1)$$
$$CostLeadershipPerformance =$$
$$0.278 CostLeadershipStrategy - 0.065 PPT + 0.096 IMT \qquad (2)$$

Thus, we will be only examining the relationship between strategies and AMT in the following analysis. Linear regression with backward variable selection is conducted on differentiation strategy and cost leadership strategy against AMT (PDET, PPT, MHT, AsMT and IMT). The equations below exist:

$$DifferentiationStrategy = -0.254 AsMT + 0.142 IMT + 0.194 PPT \qquad (3)$$
$$CostLeadershipStrategy = 0.098 IMT \qquad (4)$$

All explanatory variables and both models are significant at 5% level. For detailed regression results please refer to Appendix 10: Fit as Mediation.

6.3.2.1 Testing Fit as Mediation on Differentiation Performance

In Equation 3, two types of AMT, i.e. MHT and IMT, and differentiation strategies, are found strongly related with differentiation performance. On the other hand, as Equation 5 and 6 shows, AsMT, IMT and PPT are significantly related with the differentiation strategy, and IMT is strongly associated with the cost leadership strategy. IMT is significant in both Equations 3, 5 and 6. It has both direct and indirect impact on differentiation performance, which means the differentiation strategy is a partial mediator of differentiation performance and IMT. In contrast, AsMT only appears significant in the Strategy and AMT relationship. They can only influence the differentiation performance through the presence of a differentiation strategy. It indicates that differentiation strategy is a complete mediator between differentiation performance and AsMT.

In addition, we evaluate the indirect effect of IMT on the differentiation performance in the following ways:

$$\text{Indirect impact of IMT} = 0.159 * 0.142 = 0.023$$

For instance, one unit increase in IMT is directly related with 0.142 unit rise in differentiation performance. At the same time, it is associated with 0.023 unit increases in differentiation performance through the effect of the differentiation strategy. However, we can see that the direct effect of IMT on differentiation performance is far larger than the indirect effect.

6.3.2.2 Testing Fit as Mediation on Cost Leadership Performance

Similarly, in equation 4, we notice that the cost leadership performance is significantly related with the cost leadership strategy, PPT and IMT. Also, equation 6 shows that the cost leadership strategy is significantly related with IMT. These strong associations mean that the cost leadership strategy is a partial mediator between the cost leadership performance and IMT. Their indirect impact on the differentiation performance could be calculated as:

Indirect impact of IMT=0.096*0.098 =0.009

Comparing with the coefficients of IMT in equation 4, we find that the indirect effect of IMT on cost leadership performance is weaker than its direct effect. Therefore, IMT mainly influences cost leadership performance through a direct approach.

6.3.2.3 Conclusions on fit as mediation

Through the linear regression analyses performed on the variables identified in the study, it is sustained that the notion that the fit between manufacturing strategy and AMT has the impact on the both differentiation and cost efficiency performance. In particular, IMT and differentiation strategy can directly influence differentiation performance according to equation 3. At the same time AsMT, PPT and IMT can influence differentiation performance through the use of a differentiation strategy. So we say IMT has both direct and indirect impact on differentiation performance. Similarly, PPT and IMT are the only two effective factors of differentiation strategy. IMT has both direct and indirect effects on cost leadership performance with the adoption of a cost leadership strategy.

Consequently, we come to the conclusion that IMT is partial mediator of both differentiation performance and cost leadership performance.

6.3.3 Fit as Matching

Test of fit as matching in this study mainly adopts a residual analysis approach. As Dewar and Werbel (1979) suggested, if fit exists between two variables X and Z, the residuals of regression on X (Strategy) by Z (AMT) would have significant influence on criterion variable Y (Performance).

Based on this perspective, we produce regressions on performances by the residuals generated previously. In Section 6.3.2, two residual variables have been developed:

1. Residuals of regression on Differentiation strategy by AMT
2. Residuals of regression on Cost leadership strategy by AMT

In the following analysis we will use Residuals (Differentiation Strategy ~AMT) to indicate the first type of residuals and Residuals (Cost leadership strategy ~AMT) to indicate the second one. Here we conduct two linear regressions:

Model 1: Differentiation performance ~

Residuals (Differentiation Strategy ~AMT) + Residuals(Cost leadership strategy ~AMT)

Model 2: Cost Efficiency performance ~

Residuals (Differentiation Strategy ~AMT) + Residuals(Cost leadership strategy ~AMT)

If any of the residuals are significant in the regression, we consider a fit effect exists on the performance. For instance, if residuals of regression on differentiation strategy by AMT were significant in Model 1, we consider a fit between differentiation strategy and AMT exists and such a fit has important impact on the differentiation performance of the surveyed companies.

Test results are shown in Table 6.17 and 6.18. Both models are highly significant. Regression on differentiation performance has a relatively low Adjusted R Square of .073 with significance value far less than 0.01 on the F-test. Residuals of regression on differentiation is the only significant explanatory variable (p<<0.01), which shows that fit between differentiation strategy and AMT has a significant influence on differentiation performance. Regression on the cost leadership performance is better. Its goodness-of-fit is 0.178 and F-statistic is 57.611 with p-value<<0.01. The regression model also indicates that residuals of regression on cost leadership strategy (p<<.01) is highly significant. It reveals that fits of cost leadership strategies with AMT has an important influence on cost leadership performance.

Table 6.17: Coefficients of Model 1

Coefficients(a,b)

	Unstandardized Coefficients		t	Sig.
Residual(DS~AMT)	.156	.034	4.641	.000

a Dependent Variable: Differentiation Performance
b Linear Regression through the Origin

Table 6.18: Coefficients of Model 2

Coefficients(a,b)

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Residual(CS~AMT)	.287	.038	.425	7.590	.000

a Dependent Variable: Cost leadership Performance
b Linear Regression through the Origin

6.3.3.1 Conclusions on Fit as Matching

As the analysis suggests, residuals of regression on differentiation strategy against AMT is the only significant explanatory variable for differentiation performance. Therefore, we think a fit between differentiation strategy and AMT (AsMT, PPT and IMT in particular) has significant impact on differentiation performance, which indicates that companies adopting a differentiation strategy should adjust their investment and integration in AsMT, PPT and IMT so as to achieve a higher differentiation performance.

On the other hand, cost leadership performance is strongly influenced by fit of cost leadership strategy with AMT. For instance, for companies adopting a cost leadership strategy, a high level of investment and integration in IMT are suggested. This AMT and strategy combination is helpful to improve cost leadership performance.

6.3.4 Fit as Profile Deviation

The test of fit as profile deviation approach considers that performance is negatively related to the deviation of a company to an ideal profile. Such an ideal profile should be built by the top 10% performers of the sample. Deviations are measured as the Euclidean distance between two companies on dimensions of strategy and AMT investment and integration. The more a company deviates from the ideal profile, the worse it performs on several or all dimensions.

To process the data, we first sort all companies (N=262) by their differentiation performance score, remove the lowest 10% samples (N=26) and extract the top 10% performers as the calibration sample (N=26). We then compute the mean score on each dimension and consider them as the ideal profile. Then we calculate the Euclidean distances of remaining samples to the ideal profile.

Table 6.19 provides the mean scores of the calibration sample and the remaining sample on each strategy and AMT dimension. It is seen that the calibration sample has a higher mean score on each dimension than the remaining sample. However, independent-sample t-tests only prove that the calibration sample has significantly higher scores on the differentiation strategy. IMT could be considered as significant, too. Also we find that the Euclidean distance to the ideal profile is not significantly related with remaining samples' differentiation performance, r=-.011 p=.436(1-tailed). It shows that although calibration companies have significantly higher differentiation strategy and IMT, their differentiation performances are no better than remaining companies.

Table 6.19: Comparison of Means for High-Low Differentiation Performers

	Calibration Sample	Remaining Sample	Sig. (2-tailed)
PDET	2.0048	1.6310	.154
PPT	1.9359	1.6246	.219
MHT	.5096	.4476	.641
AsMT	1.3846	1.2389	.454
IMT	*1.3558*	*.7607*	*.058*
Differentiation Strategy	*.8218187*	*-.0833597*	*.000*
Cost Leadership Strategy	.1257583	.0077785	.576

Similar data processing and analysis are also conducted on cost leadership performance scores. (See Table 6.20) It is noticed that the calibration sample has slightly higher scores on all dimensions except PPT. However the differences are only statistically significant for differentiation strategy and cost leadership strategy. Moreover, correlations between the cost efficiency performance scores and the Euclidean distance (r=-0.08, p=.124) show that there exists no significant relationship between cost leadership performance and individual's deviation from the ideal profile, either. Therefore, the profile deviation approach fails to identify any fit effect on cost leadership.

Figure 6.20: Comparison of Means for High-Low Cost Leadership Performers

	Calibration Sample	Remaining Sample	Sig. (2-tailed)
PDET	1.8462	1.6190	.244
PPT	1.3782	1.6437	.293
MHT	.6154	.4536	.240
AsMT	1.3205	1.2135	.583
IMT	1.0962	.7881	.280
Differentiation Strategy	*.3644402*	*-.0812213*	*.034*
Cost Leadership Strategy	*.6888270*	*.0027630*	*.000*

6.3.4.1 Conclusions on Ft as Profile Deviation

In the perspective of fit as profile deviation, fit is viewed as the adherence to an ideal profile. From our analysis above, we found out that significant differences exist in the level of investment and integration in IMT between companies with high and low differentiation performance. Simultaneously, adoption of a differentiation strategy has a decisive effect on the differentiation performance, too.

Also it is found that high cost leadership performers have used significantly higher cost leadership strategy and differentiation strategy. However, test of fit in this perspective fails to identify any association in performances and the use of AMT and strategy. It seems that deviation from the ideal profile has nothing to do with companies' performance.

6.3.5 Fit as Gestalts

Most other approaches test fit from variable perspectives by dimension reduction or regressions. In contrast, fit as gestalts aims to group samples into clusters—"gestalts" using Euclidean distance. Following this approach, all samples are clustered into three gestalts out of the consideration of the cluster effect and convenience of explanation by PDET, PPT, MHT, AsMT, IMT, differentiation strategy and cost leadership strategy attributes. Centers of the three clusters are shown in Table 6.21. From the total of 262 companies responded, there are 116 companies attributed to cluster one, 55 of them are assigned to cluster two, and the rest 91 are assigned to cluster three.

Table 6.21: Final Cluster Centers

	Cluster		
	1	**2**	**3**
PDET	1.74	2.77	.90
PPT	2.00	2.80	.47
MHT	.42	1.19	.10
AsMT	1.23	2.25	.63
IMT	.47	2.64	.09
Differentiation Strategy	.22795	.46941	-.57428
Cost leadership Strategy	-.14926	.41659	-.06152

From Table 6.21, we can see that cluster 2 has highest scores on all dimensions. Companies in cluster 2 tend to have highest input in AMT and are most likely to take a combination strategy—adopt both differentiation strategy and cost leadership strategy. Cluster 3 has the lowest scores on differentiation strategy and medium cost leadership strategy, which is a gestalt of companies with lowest-AMT input. Cluster 1 is a mixture of the previously two gestalts. It has the lowest cost leadership strategy, medium differentiation strategy and medium input in AMT.

Figure 6.7 and Figure 6.8 shows the mean scores of differentiation performance and cost leadership performance for each gestalt. It is noticed that gestalt 2 has the highest scores on both differentiation performance and cost leadership performance. Gestalt 1 performs worst on cost leadership performance, and gestalt 3 acts the worst in differentiation performance.

Figure 6.7: Mean Scores of Differentiation Performances of Each Gestalt

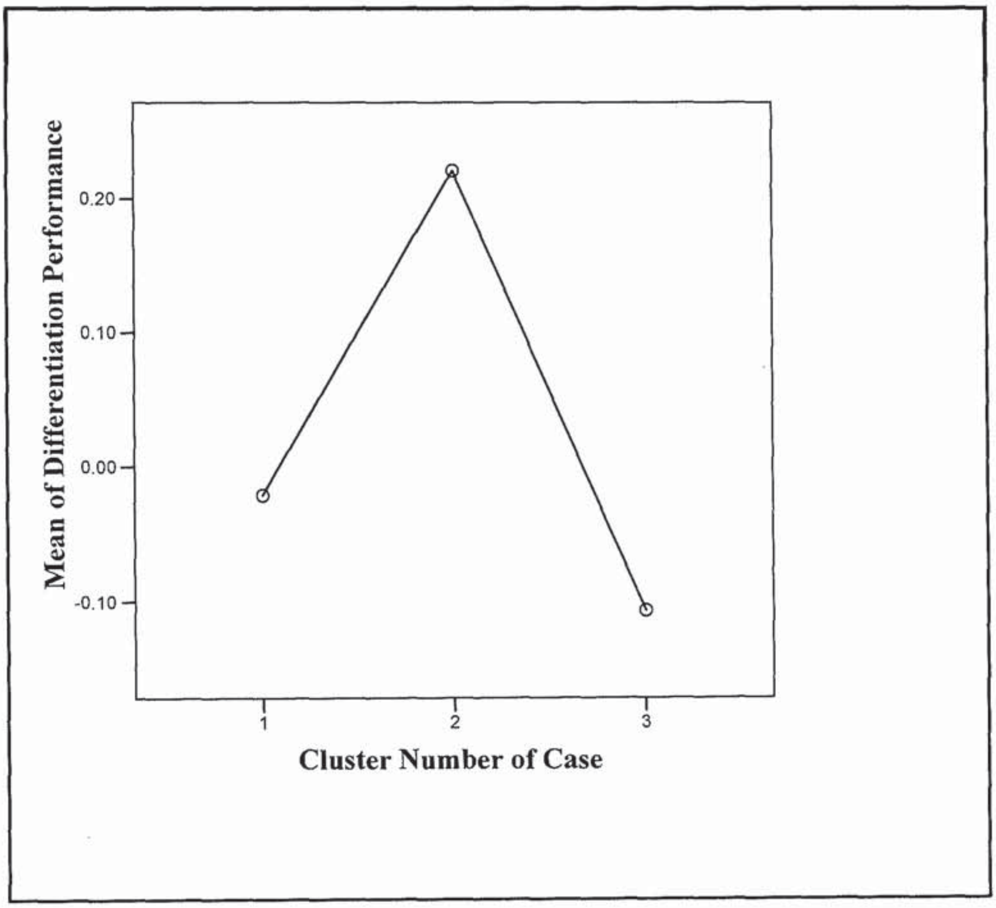
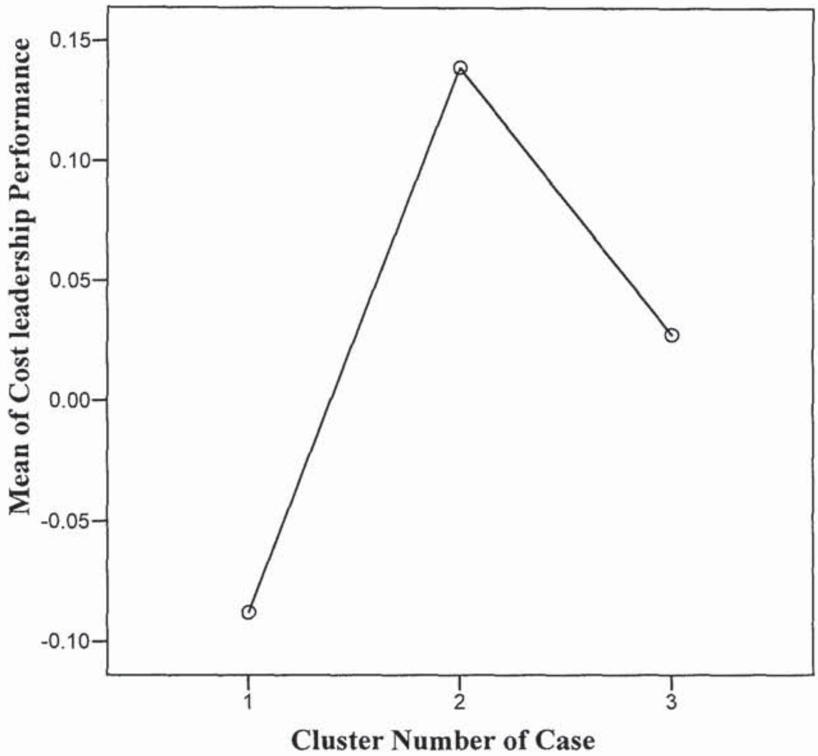


Figure 6.8: Mean Scores of Differentiation Performances of Each Gestalt



Through pair-wise comparisons on performance scores between gestalts, we find that Gestalt 2 has significantly higher differentiation performance over the other gestalts. However, the cost leadership performances between the three gestalts are not significantly different. Please refer to Appendix 13: Fit as Gestalts for more detailed test results.

6.3.5.1 Conclusions on Fit as Gestalts

Through the test of fit via the gestalts perspective, it is revealed that high differentiation performances are found in companies that adopt dual strategies and have high levels of investment and integration in all AMT. Unfortunately, this approach fails to identify any fit effect on cost leadership performance. No matter which strategy a company chooses and how much it invests and integrates in AMT, their cost leadership performance does not differ much.

6.4 Conclusions

The study has confirmed that companies adopting a differentiation strategy tend to have higher levels of investment and integration in their PDET, PPT, MHT and IMT. Companies adopting a cost leadership strategy do not particularly emphasise investing in PDET, PPT and MHT to compete in the market. However, they could have some investment and integration in AsMT and IMT since they are positively associated with cost leadership strategy.

By examining the fit as moderator approach, differentiation performance is found significantly positively related with multiple AMT. Differentiation performance is stronger positively associated with AMT for companies adopting a high differentiation strategy. Companies with high cost leadership strategy have stronger positive correlations between AMT investment and both performances: differentiation performance and cost leadership performance. In particular for companies adopting a high cost leadership strategy, when they raise the level of investment and integration in PDET, PPT and IMT, differentiation performance could rise more rapidly; whilst, when they invest and integrate more in MHT, the cost leadership strategy increases faster. These findings based on subgroup analysis indicate that the fit effects between differentiation strategy and PPT, AsMT and IMT have significant influence in differentiation performance; on the other hand, the effective fits for cost leadership performance could be differentiation strategy and PDET, PPT and IMT, plus cost leadership strategy and MHT.

However, when the moderation approach adopts the regression method, it fails to identify any fit effect on differentiation performance. While it figures out that a combination of cost leadership strategy and MHT has significant positive effect on cost leadership performance, which coincides with the conclusions of sub-group analysis.

Fit as mediation perspective aims to test effectiveness of strategies as mediators between performances and AMT, through which we are convinced that differentiation strategy and cost leadership strategy are significant mediators of some AMT. For instance, differentiation strategy is the partial mediator of IMT and differentiation performance. It is also the complete mediator between differentiation performance and some AMT. e.g. AsMT and PPT. In addition, cost leadership strategy acts as the partial mediator between IMT and cost leadership performance. These relationships could be considered as fit effects.

Test of fit as matching perspective suggests that Differentiation strategy-AMT fit has a significant impact on differentiation performance. Moreover, cost leadership strategy –AMT fit is seen as significant on cost leadership performance.

The results of fit as profile deviation turn out to be less favorable, because it fails to identify any convincing fit effect on performances.

Fit as gestalts approach clusters all companies into three gestalts, which adopts various AMT and strategy combinations. We find that companies taking a dual strategy and high level of investment and integration in AMT have significantly better differentiation performance. Unfortunately, cost leadership is found not sensitive to strategy choice and AMT investments.

CHAPTER 7

DISCUSSION OF FINDINGS

7.1 Introduction

The last two chapters presented the statistical results based on the data collected from the study. This chapter will discuss the findings of the practice of the sampled companies in comparison with the current literature in the relevant area such as Operations and Production Management, Manufacturing Management, or Strategic Management etc.

The chapter begins with a brief recap of surveyed companies' profiles, followed by the discussion of findings. The discussion of findings consists of two major parts: the first part is focused on the findings of the practice of surveyed companies in relation to their manufacturing strategy orientations, their attitude towards AMT investment and integration, and their perceived manufacturing performance. The second part of the findings is concentrated on the statistical approach in defining fit between the manufacturing strategy and AMT and its implication on the manufacturing performance. The conclusion section recapitulates the chapter with the major findings of the study.

7.2 Surveyed Companies' Profiles

The survey was conducted via questionnaires to 2000 selected UK manufacturing companies with a response rate of 14 percent. In addition to the

15.7% of the informants who were directly responsible for the manufacturing function, another 76.6% of the informants were from the top management level and involved in some sort of decision making at the strategic level for the manufacturing function. All the informants have been in their respective position for an average of 11 years. These have enhanced the reliability and the creditability of the data collected in the study.

The study aims to find out UK manufacturing companies' behaviours on AMT diffusion in regards to their companies' manufacturing competitive priorities, and its impact on the manufacturing performance. The samples were taken from the UK manufacturing sectors which produce discrete products, covering companies from the fabricated metal products industry, which accounts for half of the sample, electronic and electrical equipment industry (18%), industrial machinery and equipment industry (17%), and others (16% which comprises of transport equipment industry, furniture industry, and other industry). This is representative of the current industry distributions of the UK manufacturing sector (DTI, 2007).

As the largest group of surveyed companies, electronic and electrical companies have the highest level of investment and integration in PDET, IMT and PPT, but the lowest AsMT. They also adopt the highest level of Differentiation Strategy. In contrast, fabricated metal production companies invest and integrate least in PPT, MHT and IMT. However, they adopt the highest level of Cost leadership Strategy with highest input in AsMT.

The largest industry, the electronic and electrical with large firms, has extensive investment and integration in CAD, CAE, MRP and MRPII. Similar to companies from all the other industries, companies from electronic industries put the highest weight in providing reliable products, followed by an on-time delivery strategy. In contrast, the electronic industry takes especially high strategy in product innovation, for instance launching new product lines and new models. The electronic and electrical industry adopts dominantly strategies such as providing reliable products and high performance products, cutting costs, having a wide product range, supplying excellent after sales services and customised products, and aiming at introducing new product lines and models.

On the other hand, companies from different industries share the same views on their performance. Generally, they perceived that they performed above the average industry level in all dimensions. In particular, they do the best in providing reliable and high quality products, providing good after sales services and customised products. In comparison, they are less particular with cost leadership performance dimensions, such as providing low price products and cost reduction.

The average employment in fabricated metal and industrial machinery is around the 100 level. As the median firm size across all industry sectors is around the 50 employee level, it indicates the presence of some very large firms which are pulling the whole sector average up. Yet, this is most stark in electronics and other manufacturing suggesting a few giant firms are present in the industry. This suggests that these two industries may have oligopolistic tendencies, i.e. dominated by a few giant corporations.

The majority of the companies being surveyed have been established for 30 to 50 years, which shows that these companies are mature in their life cycle. Being in their mature life cycle, these companies are unlikely to change their investment and strategy patterns drastically, i.e. their investment and strategy patterns are in a relatively stable state. This can be proven with their inclination to have the lowest intention of introducing new product lines and new product models among other counterparts. Interestingly, companies younger than 10 years have the strongest motivation to provide customized products. Compared with older companies, they invest and integrate the least in most AMT; PPT, MHT, AsMT and IMT in particular.

Among all the companies, 89% of them are privately owned, and half of which are small sized. Once again, this group of companies are more interested in providing customised products. Due to the rather relatively weaker financial strength – being small sized and privately owned, they have the lowest level of investment and integration in all AMT dimensions.

In contrast, the publicly owned companies (11%) are mostly middle sized. The different legal status of a company could influence their accessibility to the equity market and further affect its potential implication for investment capacity in the new technology and strategy orientation. They tend to invest and integrate most in PPT and adopt a higher quality strategy and flexibility strategy, which are the two dominant components of differentiation strategy.

Also, the share of foreign owned companies is different among the four typical industries. The fabricated metal industry is dominated by UK owned companies which have a share of over 90%. Compared with UK owned companies from the other industry, the fabricated metal industry invests and integrates the most in CAM and NC/CNC/DNC. In addition, they care least about introducing new product models and new product lines. In contrast, foreign companies take up to 17.4% of the stock of the electronic industry. The majority of foreign companies invest and integrate the most in PPT followed by PDET.

7.3 Manufacturing Strategy, AMTs and Manufacturing Performance

Manufacturing companies define the strategy to guide their manufacturing activities. It dictates how a product is manufactured, how resources are deployed in production, how the infrastructure necessary to support manufacturing should be organised (Hayes and Wheelwright, 1979), and how a company develops its competitive advantage against its competitors (Zahra and

Das, 1993). Companies can choose to develop their competitive advantage around the quality, cost, flexibility or delivery dimensions of the product against their competitors.

Companies can use AMT to enhance manufacturing capabilities and achieve the intended competitive advantage (Das and Narasimhan, 2001). However, the selection of the levels of investment and integration in AMT are often according to the nature and needs of the business (Tidd, 1994). For example, Raymond and Croteau (2009) in their recent work suggest that firms that follow different types of business strategy, will deploy AMTs differently. When these strategy patterns are fit with AMT, they could have some special impacts on the manufacturing performance (Grant et. al., 1991; Cook and Cook, 1994). Therefore, it is the basis of this research to find out the features of the surveyed companies' manufacturing strategies, their AMT investment and the manufacturing performance.

7.3.1 Facts of Manufacturing Strategies

There are several ways of defining manufacturing strategies that a company can pursue, for example, Slack et al (1995) identify four strategies, namely quality, flexibility, cost and delivery strategies. This study however, found that the surveyed companies can be grouped into 2 generic companies according to the two broader generic manufacturing strategies as proposed by Porter (1980), i.e. differentiation and cost leadership strategy, which is consistent with Parson (1983) and Kotha and Swamidass (2000). Companies that adopt the differentiation strategy aim to gain a competitive advantage by offering a unique product or service, in terms of its quality, flexibility and delivery dimensions of the products. The cost-related strategy is normally used by companies adopting cost leadership strategy, which aims to gain a competitive advantage by becoming the lowest-cost producer in the industry.

7.3.1.2 Cost Leadership Strategy

Concerning cost leadership strategy, companies from every industry consider that a cost-reduction strategy generally bears more importance than providing lower price than competitors. Interestingly, this study finds out that foreign companies value cost-reduction higher than local companies over all age bands.

The use of a cost leadership strategy is seen positively related with the level of investment of MHT. However, the level of integration seems low in all types of AMT. It is indeed in line with the literature on characteristics of companies emphasising a cost leadership strategy. As cost leadership companies emphasise on high-volume production and efficiency, it is apparent that they would invest more in MHT for efficient material handlings. Such companies employ mechanical or conventional technologies which do not require integration between those machineries to achieve economies of scale, and emphasise large size, high volume mass production, standardised products, and repeatability of specialised operations (Hayes and Wheelwright, 1979, 1984 and 1991). As quality is not a major issue for companies emphasising cost leadership strategy, precision or accuracy can be compromised by using these machineries.

Once again, the study also reveals that companies with a high emphasis on cost leadership strategy are strongly related with cost-related performance in a positive direction.

7.3.1.1 Quality Strategy

All the companies surveyed, regardless from which industry, agree that providing quality products is among the crucial manufacturing strategies. This attitude is not significantly influenced by any factors e.g. ownership, size, legal sector or age of the business. However, there are some groups of companies who do have higher tendency of adopting a quality strategy. For instance, companies in the band of 11 to 30 years adopt higher quality strategy.

Moreover, the level of quality strategy tends to increase with the size of a company—larger sized companies use the highest quality strategy, while small sized companies used the lowest level. It indicates that large sized companies are more tempted to provide quality products.

When we look into the relationship between the quality strategy and the investment and integration of AMT, it is noticed that it is significantly related with all AMT usage in a positive way. The higher quality strategy is adopted, the more are invested and integrated in AMT in all dimensions. In particular, AsMT is the most highly related to the quality strategy. However, this positive relationship is relatively weaker in MHT ($r=0.154$), even though it is still significant at 95% significance level. Without surprise, companies adopting a high quality strategy usually have higher quality performance.

7.3.1.3 Flexibility Strategy

The flexibility strategy is ranked with least importance among the four major strategy categories. It includes various strategy dimensions e.g. wide product lines, excellent after-sales, customised products, new model introduction and new product lines. These strategies are of different significance according to the industry of a company. For instance, companies in the fabricated metal industry provide materials to down-stream firms. Therefore, after-sale service is not required for companies in this industry. It is common for them to take a low strategy in the after-sales service dimension. In contrast, for companies from the industrial machinery sector or electronic sector, selling products is by no means the end of the transaction. In order to ensure that their products are properly installed, functional and well maintained, they place a high level requirement of providing excellent after-sales services. Therefore, companies in these sectors place particularly high attention to the after-sales strategy.

Quantity flexibility is another very important competitive advantage for most industries except machinery companies. However, introducing new product lines seems to be of minor importance for all industries.

We also find that the use of a flexibility strategy is positively related to all major AMT dimensions in a significant way, except AsMT. It is in fact true as the emphasis of these companies is not mass production or exclusiveness of product, the level of investment in AsMT is not essential for them to achieve their competitive advantages. In terms of the type of AMT, the positive relationship is the strongest between the flexibility strategy and PPT ($r=0.322$, $p<<0.01$). Companies with flexibility involved in changing over their production facilities more rapidly and hence need the help of the sophisticated PPT for planning their production scheduling. Also, the flexibility strategy is found positively related with flexibility performance. Higher flexibility performance is always associated with companies adopting high flexibility strategy.

7.3.1.4 Delivery Strategy

Delivery strategy is ranked the highest among the four major strategy dimensions. It is comprised of two basic dimensions: on time delivery and short time delivery. The study shows that none of the factors under research influence companies' delivery strategies significantly. Moreover, the adoption of a delivery strategy does not affect investment and integration in AMT, either. No matter what level of delivery strategy is used, companies' investment and integration in AMT keep unchanged. Interestingly, delivery strategy is seen strongly related with all performance dimensions in a positive way, which means adopting high delivery strategy is associated with strong improvement in performance in all aspects.

7.3.2 Facts of AMTs

The study uses the classification of AMTs based on its function in the context of manufacturing capabilities. The AMTs investigated in this study, i.e. a total of 14 types of AMTs, can be grouped into five domains based on the literature of AMT studies. The five domains are:

a. **a design and planning domain, i.e. Product Design and Engineering Technologies (PDET):** concerned primarily with design and engineering technologies, such as CAD, CAE, and CAM;
b. **a logistics-related domain i.e. Production Planning Technologies (PPT):** concerned with production and logistic planning, such as MRP, MRP II and ERP;
c. **a materials handling domain i.e. Material Handling Technologies (MHT):** which concerned with handling of materials, such as ASRS and AGVs;
d. **a manufacturing domain i.e. Assembly Manufacturing Technologies (AsMT)** – concerned with repetitive production technologies such as CAQCS, robotics and numerical control machines (NC/CNC/DNC);
e. **an integrated manufacturing domain, i.e. Integrated Manufacturing Technologies:** comprises of integrated and flexible manufacturing technologies such as FMS and CIM.

The measurement of the AMT derived from two perspectives: its level of investment and its extensiveness of integration. This study is one of its kind that incorporates the level of integration besides the level of investment of AMTs. As companies tend to use more and more AMT (Kotha and Swamidass, 2000), thus they increase the potential for integration among these technologies (Meredith, 1987; Dean and Snell, 1996). Four types of integration were used, i.e. no integration or a stand alone piece of technology; limited integration where integration within the manufacturing department; full integration refers to company-wide integration; and finally, extended integration which encompass the whole enterprise-wide integration, stretched over its supply chain (Das and Narasimhan, 2001).

7.3.2.1 Product Design and Engineering Technologies (PDETs)

Product design and engineering technologies are technologies used to assist designing and testing products, which include computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), and group technology (GT). This is the category of AMT which has been invested and integrated the most. Within this type of AMT, CAD is the most popular technology. In contrast, GT is the least favourable one. Because of economic strength restrictions, small sized companies invest relatively less in PDET than larger companies. Although most companies choose to have investments in PDET, few of them have PDET integrated. Even for CAM, which has been integrated the most among the four PDET, only 19 percent of all actual investors integrate CAM in their company.

The investment and integration in PDET is not significantly influenced by factors such as companies' industry and age band. However, there are some characteristics for companies that have high level investment and integration in PDET. For instance, larger companies are more likely to invest in PDET. Public companies invest and integrate more PDET than private companies. Moreover, companies from fabricated metal industry tend to invest and integrate more than the other industries.

Companies with a high level of investment and integration in PDET tend to adopt a higher quality strategy and flexibility strategy. These companies are usually seen having high flexibility performance. The finding is in contrast with the study undertaken by Das and Narasimhan (2001) which finds that PDET is associated with a cost leadership strategy.

7.3.2.2 Production Planning Technologies (PPTs)

As the second most invested technology, PPT has three technology dimensions—material requirement planning (MRP), manufacturing resources planning (MRP II) and enterprise resources planning (ERP). They are mainly used to assist in planning, scheduling and controlling of material and resources requirements for the production of manufacturing companies.

A very interesting finding about PPT is, for our surveyed companies, that their investments are still at an early stage of the material requirements planning tool, because they invest in MRP the most and ERP the least. However, it is noted that the younger a company is the less it invests in MRP. The survey also shows that investment in PPT still largely depends on the size of a company. The investment in ERP increases as the size of a company rises. In addition, foreign companies invest significantly more in PPT than UK companies.

According to the study, the level of integration in PPT increases with the age of the technology. Since MRP is the earliest version of PPT and has been applied for the longest time, the level of integration of MRP is the highest in the surveyed companies. Similarly, as the latest version of PPT, ERP is integrated the least.

Compared with companies from other industries, electronic companies tend to invest more in PPT. Still investment and integration of PPT increase with the companies' size. Also, we find that companies older than 50 years tend to invest and integrate more PPT than younger companies.

Companies with high PPT investment and integration are found using more quality strategy and flexibility strategy. These companies have higher flexibility performance, too.

7.3.2.3 Material Handling Technologies (MHTs)

Material handling technology is the least invested and integrated technology in this study. They are used by manufacturing companies to facilitate the handling of material in manufacturing operations.

From any point of view, MHT gets the least attention. Companies barely invest and integrate MHT in their companies no matter which industry they belong to and how old their businesses are. However, the investment and integration of MHT is noticed to be highly related with companies with a cost leadership strategy. It is perhaps that companies are using MHT to deal with their vast material handling to support their mass production facilities (Hayes and Wheelwright, 1979a, 1979b and 1984). Unfortunately, the investment and integration in MHT is not significantly related with any particular performance dimension.

7.3.2.4 Assembly and Machining Technologies (AsMTs)

Assembly and machining technologies (AsMT) are most widely applied for frequently repetitive functions. NC/CNC/DNC is the most widely applied AsMT. In particular, it is most applied in medium size companies. Moreover, investment in robotics and NC/CNC/DNC technologies increases with age bands.

The fabricated metal industry tends to have higher investment and integration in AsMT. The level increases with company sizes. Moreover, companies at the age of 51 to 70 are more likely to invest in and integrate AsMT. We find that the investment and integration of AsMT is significantly related with a quality strategy. For companies that have the quality strategy as their competitive advantage, where precision and accuracy are the important competitive edge, AsMT is used to achieve their objectives. Also, it is found positively related with quality performance in a significant way.

7.3.2.5 Integrated Manufacturing Technologies (IMTs)

Integrated manufacturing technologies (IMT) do not differ much across sectors. However, large companies tend to have higher investment in IMT due to their strong financial strength. In addition, except for the oldest and youngest age bands, investment of FMC/FMS and CIM, two types of IMT, decrease as their age band grows. The older a company is, the less it invests in IMT. Integration of IMT is at low level for both FMC/FMS and CIM and it does not differ much for each sector.

IMT is second least invested and integrated among the five major AMT types. Different sectors have indifferent levels of investment in IMT. The level increases with companies' size. On the other hand, companies between 51 to 70 years old tend to invest and integrate more IMT. The investment and integration of IMT is seen to be positively associated with multiple strategy dimensions, for instance, quality strategy, cost leadership strategy and flexibility strategy. Moreover, it is also positively associated with these dimensions of performance.

7.3.3 Facts of Manufacturing Performance

Generally, quality performances are considered the most important components of a company's service level and most surveyed companies are confident their quality performances are generally above the average level.

In comparison, companies surveyed in our study only consider their performance in cost control and reduction as at an average level. No significant differences are witnessed over industries, company sizes and legal status. However, an interesting phenomenon is companies younger than 10 years perceived that they are not performing as well as par, but companies in the age band of 71 to 100 years regarded themselves are doing the best in this aspect.

Flexibility performances are considered as being well performed by our surveyed companies, because they rank their performances in these aspects over 4 out of 5 on average. However, their performances are diverse within the category. They think they perform the best on product customization and worst on launching new product lines.

Companies under study are very confident on their timely delivery. But public companies turn out to be less content with their own delivery performance compared with private companies. Small companies turn out to be most confident on their performance on product customization. However, middle-aged companies (31yr-70yr) are least satisfied with their performance on launching new product lines and models.

Considering that the measurement of performances are based on managers' understanding of their companies' performance compared with the industry average, the level of performances actually reflects how they are satisfied with the performance of their company. This indicates that a manager will tend to rank the lowest on the type of performance that he/she considers worth the most improvement. When comparing the four types of performances, we notice that cost-related performances are ranked the lowest among the four types of performances, which means in general company managers wish their company can do better in cost control and cost reduction. This type of performance is the highest valued for most companies surveyed. In particular, young (younger than 10 yrs), small and public owned companies which provide industrial machinery and equipments are less content with their cost performance.

7.3.4 Relationship between Manufacturing Strategy and AMT

As mentioned earlier, the first objective of the study is to test the hypotheses developed from the literature, that, this study on AMT adoptions encapsulates the need for companies to employ appropriate levels of integration and investment of AMTs according to their manufacturing strategy.

Finding 1:

Thus, we can conclude that companies that adopting the differentiation strategy are significantly investing and integrating more of their PDET, PPT, MHT, and IMT. The results however show that whether a firm follows either a differentiation strategy or a cost leadership strategy, it will have similar levels of investment and integration in their AsMT, i.e. levels of investment and integration of AsMT are indifferent between those who adopt differentiation strategy and those who do not and hence AsMT is not significantly associated with differentiation strategy.

Finding 2:

Three out of five of the AMT are non-correlated with a cost leadership strategy. Investment in some AMT such as PDET, MHT and PPT does not affect the use of a cost leadership strategy. However, IMT and AsMT are associated with the cost leadership strategy in a positive way. Companies adopting a cost leadership strategy are found having a significant preference of investing and integrating in IMT and AsMT at all times.

Companies adopting a cost leadership strategy aim to reduce their cost during the production and delivery process so as to gain cost competitive advantage in the market. Therefore, any investment in AMT should help serve this purpose. MHT and AsMT are technologies that help to increase production efficiency when dealing with mass repeating work. Therefore, cost leadership is significantly accompanied by these AMTs.

7.4 The Measurement of Fit between Manufacturing Strategy and AMT and Its Implication on Manufacturing Performance

The study adopts the fit definition from various perspectives derived from the Strategic Management literature. This section lists the findings from each perspective and evaluates the pros and cons of each perspective and finally provides the conclusion of the most promising method in defining fit to study the co-alignment of two variables in the manufacturing context.

Table 7.1 Lists the Findings from Each of the Fit Perspectives:-

Fit definition	Statistical Techniques: how each test is performed	Strategy Vs AMT	Fit on differentiation performance	Fit on cost efficiency performance
Fit as moderation	Subgroup analysis: divide all the samples evenly into 3 groups according to their performance scores, then examine the correlations between strategies and AMT for high and low performers	Differentiation Strategy is significantly related with PDE, PPT, MHT and IMT. Cost leadership strategy is only significantly related with AsMT and IMT.	Fit between Differentiation Strategy and AMT (PPT, AsMT and IMT) Fit between cost leadership strategy and AMT (PDET, PPT and IMT)	Fit between cost leadership strategy and AMT (MHT)
	Conduct regression on performance against 'main effects' (AMT+strategy) and 'main effects and interactions' (AMT:strategy)		No fit effect.	Fit between cost leadership Strategy and MHT
Fit as mediation	Linear regression on performance against AMT and Strategy and linear regression on Strategy against AMT. Examine the effect of strategy as a mediator.		Fit between Differentiation Strategy and AMT (AsMT, PPT, and IMT)	Fit between Differentiation Strategy and IMT

Fit definition	Statistical Techniques: how each test is performed	Strategy Vs AMT	Fit on differentiation performance	Fit on cost efficiency performance
Fit as matching	Residuals analysis: Regression on performance against residuals of regression on strategy against AMT.		Fit between Differentiation Strategy and AMT (AsMT, PPT and IMT)	Fit between cost leadership Strategy and AMT(IMT)
Fit as profile deviation	Calculating the Euclidean distance between calibration sample and ideal profile. Regression on performance against the Euclidean distance.		No fit effect since deviation from ideal profile has not linear relationship with differentiation strategy. However, IMT and differentiation strategy are seen significantly different between calibration and remaining samples.	No Fit effect since only significant differences in the two strategy dimensions identified and deviation from ideal profile has no linear relationship with cost leadership strategy.
Fit as gestalts	Grouping clusters using Euclidean distance based on strategy and AMT dimensions, then testing the difference in performance scores between gestalts using pair-wise comparison.		Fit in dual strategy and all AMT.	No fit effect identified.
Fit as covariation	Omitted as no desired outcomes.		No link to differentiation performance	No link to efficiency performance

As mentioned by Bergeron et al (2001) that each approach to fit is theoretically and empirically different, thus the need for a clear theoretical justification of the specific approach adopted by the researcher.

Depending on the statistical methods used, the five perspectives of fit could be grouped into two categories, the parametric method and the non-parametric method. Parametric methods require the data being studied should follow a certain type of distribution. In particular, perspective of fit as mediation and fit as matching applied parametric methods. When testing fit as a moderator with the regression approach, it also belongs to the parametric method. This is because regressions have an assumption of a normal distribution on the variables in the model. When such an assumption is not met, the credibility of the results will diminish. In contrast, no distribution information is required for perspective of fit as moderation (in the subgroup analysis approach), fit as gestalts and fit as profile deviation. These perspectives belong to non-parametric methods.

In this sense, comparisons between these two categories of perspectives of fit have become the discussion of parametric methods and non-parametric methods. Generally speaking merits and drawbacks of these two methods mainly concern fulfilment of distribution assumptions and precision of the results. Parametric methods can usually provide a model based on the data. Relationships between dependent variables and independent variables could be precisely measured by the coefficients. Predictions and statistical inferences can be made based on the fitted model. Due to these merits, parametric methods are always the more desirable methods in data analysis.

However, the distribution assumptions cannot always be satisfied and it is by no means rare to find out that the data is nothing like that required. Under such circumstances, nonparametric methods will function more properly. Although they can only conduct tasks like comparisons among groups, such information is more reliable and stable regardless of the distribution of the sample.

In our research we confirm that manufacturing strategies and performances follow the normal distribution with confidence. However, when examining the distribution of AMTs we find that they are following the normal distribution poorly. Large amounts of the observations concentrate on the left side of the distribution, which is mainly because most of the AMT are barely invested and integrated by most surveyed companies. These AMT variables have very a long tail in the left side of the distribution, which make them satisfying the normal assumption poorly. The less favourable distribution feature of AMT could make the credit of parametric analysis results compromised. It means in our study that nonparametric methods are relatively more likely to produce reliable results. Actually, the lack of credibility has already been revealed by the considerably low Goodness of fit measurement—Adjusted R Square of the regression models. Most of them are below 0.2, which means the regression model gain could only explain no more than 20% of the information of the dependent variables. However, a good regression model should explain at least 50% to 60% of the changes in dependent variable.

In this sense, perspectives of fit as mediation and fit as matching carries less credit even though they arrive at the same conclusion—the fit effect between differentiation strategy and some AMT (AsMT, IMT and PPT) have significant influence in differentiation performance; and fit between cost leadership strategy and IMT affect cost leadership strategy significantly. Both the mediation and matching approach involve fitting manufacturing strategy against AMT. For instance, once the differentiation strategy has been confirmed to be related with differentiation performance, they will secure the same fit effects, which are the AMTs significant in the regression function Differentiation Strategy ~AMT model—PPT, AsMT and IMT.

The perspective of fit as moderator from a regression approach fails to identify any fit effect on differentiation performance. However, it concludes that the cost leadership strategy accompanied by MHT has significant influence on cost leadership performance, which agrees with the same perspective tested from the subgroup analysis approach.

As a matter of fact, subgroup analysis turns out to be the best approach to test the effect of fit in our study. As non-parametric methods, fit as profile deviation fails to find out any fit effect on differentiation performance and cost leadership performance. The only sensible conclusion it made is the use of a differentiation strategy and IMT is significantly different between the calibrate group and the remaining group. If this can be considered as fit effect on differentiation performance, it has been included in the results of subgroup analysis.

On the other hand, fit as gestalts only figures out that the differentiation performance is particularly high for the surveyed companies which adopt a dual strategy and have extensive use of high levels of all AMT. It is a quite vague conclusion because we cannot distinguish the impacts of each of the AMT and strategies. The results largely depend on the choice of gestalts rather than the type of the investment and strategy pattern we are interested in. For example, none of the gestalts represent the type of companies that take a high cost leadership strategy and invest limitedly in all AMT but IMT.

In contrast, fit as moderation from the subgroup approach leads to the conclusion that differentiation strategy is influenced by the fit between differentiation strategy and AMT (PPT, AsMT and IMT) and the fit between the cost leadership strategy and AMT (PDE, PPT and IMT). When we combine these two types of fit together, we can find that they become a dual strategy with all AMT, which is the conclusion of fit as gestalts. This means subgroup analysis comes to the same results with the perspective of fit as gestalts and makes the conclusion more precise and clear. Also, fit between cost leadership strategy and MHT are seen influencing cost leadership performance significantly.

7.5 Conclusions

This study is the first to encompass the concept of 'fit' in empirical AMT research in such a comprehensive, systematic manner. The results reinforce Venkatraman and Van de Ven's contention that different conceptualisations, verbalisations, and methods of analysis of fit will lead to different results (Venkatraman and Van de Ven, 1989; Bergeron et al, 2001).

By comparing manufacturing strategies, AMT and performances by various factors, such as industrial sector, business age band, legal status and ownership, we find that public owned companies are more likely to adopt a differentiation strategy with large investments and integrations in multiple AMT. The fabricated metal production industry is keener on a cost leadership strategy and has the best cost leadership performance. In contrast, electronic and electrical industry adopts the highest differentiation strategy with large degrees of investment and integration in most AMTs. In addition, large sized companies are more likely to use high differentiation strategy with high level of input in all AMT, hence act the worst on cost leadership performance. However, interestingly, although companies younger than 10 years invest and integrate least in most AMT, they still have much worse cost leadership performance than the others.

The choice of perspective of fit depends on the nature of the sample. When distribution requirements are not met, the best approaches would be perspectives examined by non-parametric methods, such as fit as moderation (subgroup analysis), fit as gestalts and fit as profile deviation. Our analysis shows that fit as moderation is the best approach to provide reliable and sensitive results. It reveals that differentiation performances are significantly influenced by multiple fit effects—differentiation strategy and AMT (PPT, AsMT, IMT) and cost leadership strategy and AMT (PDE, IMT, PPT). Moreover, cost leadership performances are influenced by fit between cost leadership strategy and MHT.

CHAPTER 8

CONCLUSIONS AND IMPLICATIONS

8.1 Introduction

In the last chapter, we presented the research findings and assessed their significance and their association with the current literature. In this chapter, we highlight the conclusions and implications of the research. The chapter is organised into five sections. The first section provides conclusions about research issues and the research problem, i.e. to derive to the findings of the research. The second section highlights the implications for theory, which look at the contribution of the research to knowledge in its immediate discipline or field and the wider body of knowledge.

The following section summarises the implications of the research for policy and practice, which generally involves the top management team, or government bodies and other professional bodies dealing with manufacturing sectors. It is then followed by suggestions for future further research, and last but not least, an overview of the chapter concludes the final chapter of the thesis.

8.2 Conclusions About Research Issues and Research Problems

With the existence of various advanced manufacturing technologies, more and more functions or jobs are performed by these machineries instead of human labour. Generally, companies within the same industry face a common set of technological opportunities. However, it is apparent that technological differences exist among these companies. As Saren (1991) points out, these are attributed to a firm's competences, capabilities, and strategies, as these technologies are claimed to be able to achieve various benefits, some are said to be more successful in achieving certain benefits than the others.

In fact, a trawl of AMT studies often reveals that companies with a particular manufacturing strategy will invest in specific kind of AMT that can help them to achieve their intended manufacturing performance. For instance, companies that place emphasis on a cost leadership strategy, will tend to run their production in high volume, handling a large amount of inventory, and hence will tend to invest in AMTs that are capable of handling mass production such as robotics, and other automated production planning technologies.

However, the association of the various AMTs to the company's manufacturing strategy is unclear. There are mixed opinions from the literature. Thus, this study was undertaken in order to answer the first research question in regards to whether manufacturing strategies are associated with different levels of integration and investment of AMTs. The study partly confirms conclusions derived from the literature. It confirms that there is a link between the investment and integration of AMTs and manufacturing strategy. However, there is a rather interesting finding as to which AMTs are associated with certain types of the strategy.

The study confirms that the orientation of the manufacturing strategy seems sufficiently to determine the level of investment and integration of AMTs. The finding confirms that companies emphasise on a differentiation strategy are technology 'hogs' which basically use most or all AMTs to achieve their competitive advantage (Kotha and Swamidass, 2000). Thus the AMT usage is higher for firms pursuing a differentiation strategy than a cost leadership approach. However, the study finds that these companies do not particularly invest or integrate much of their assembly and machining technologies (AsMT) such as computer-aided quality control systems (CAQCS), robotics and numerical control machines (NC/CNC/DNC). This is a rather interesting finding.

While companies which emphasise on the cost leadership strategy, they are only concerned about the investment and integration in both assembly and machining technologies (AsMT) and material handling technologies (IMT). The findings are contradicting with the literature that cost leadership strategy companies would be less interested in investing and integrating any AMTs, i.e. the level of investment will be minimal and less integrated. The fact that they are investing in the AsMTs (such as computer-aided quality control systems, robotics and numerical control machines), and IMT (such as FMS and CIM) is a much surprising finding. With their cost consciousness mind, they would only invest and integrate in limited but essential technologies that would help them with their high volume production and handling large amounts of inventory, thus, it makes sense that these companies are associated significantly with these technologies

On the second issue, AMT studies often suggest that future study on AMT implementation should take a strategic view of AMT on the performance. For example, any further AMT studies should attempt to investigate strategic issues by simultaneously considering manufacturing performance, manufacturing strategy and AMT (Kotha and Swamidass, 2000). Thus, this forms the basis of the second research question which is what is the implication of the fit between the manufacturing strategy and AMT on the performance. In this study, we look at the manufacturing performance, as the pure measure of a technology's effectiveness in its ability to improve manufacturing rather than strategic or organisation performance (Chen and Small, 1994; Muhamad, 1997; Small and Yasin, 1997; Small, 1999; Das and Narasimhan, 2001).

In order to investigate into this research question, the contingency theory was used for the measurement of fit between the two dimensions, i.e. the AMT and the manufacturing strategy. However, there were mixed views of what is the definition of fit. So, the study examines the fit definition from five different perspectives, as suggested by the guru of Strategic Management, Venkatraman (1989).

This study is the first in the Production and Operations Management literature to encompass the concept of 'fit' in empirical AMT research in such a comprehensive, systematic manner. The results reinforce Venkatraman and Van de Ven's contention that different conceptualisations, verbalisations, and methods of analysis of fit will lead to different results (Bergeron et al, 2001).

The study finds that the more practical and feasible approach of defining fit is 'fit as moderation', as it provides reliable and sensitive results. The study also reveals that companies adopting a differentiation strategy and invest and integrate highly in PPT, AsMT and IMT will significantly achieve higher differentiation performance, moreover, adopting a high cost leadership strategy with high investment and integration in PDET, PPT and IMT also strongly improves differentiation performance; while companies adopting a cost leadership strategy and invest and integrate highly in MHT will significantly achieve higher cost leadership performance.

8.3 Implication for Theory

The wider contribution of this study to the theory is twofold. First, it adds to the accumulating conceptual and empirical work on the relationship between AMT-manufacturing strategy and manufacturing performance. It confirms that there is a relationship between the AMT and the manufacturing strategy, i.e. companies emphasising the differentiation strategy significantly invest and integrate in most of the AMT except AsMT; whilst companies adopting the cost leadership strategy are more likely to invest and integrate only in AsMT and IMT. The study also finds that the fit between the AMT and the manufacturing strategy affect the likelihood of achieving higher manufacturing performance.

AMT is often measured using the extent of use, or the level of investment. However, there is still lacking any study that uses the level of integration to measure the extensiveness of AMT usage in companies. The study uses the measurement of AMT derived from its level of investment and its integration. The mean score of each of the five categories is derived by taking the average of its investment score and integration score. This measurement is used due to the fact that all AMT can be integrated or linked to each other to achieve its ability to facilitate enterprise-wide integration (Cook and Cook, 1994; Wainwright and Waring, 2004). Thus, this study provides a different measurement option for AMT in terms of its level of investment and its level of integration.

This study provides a better understanding of the AMT diffusion in the UK manufacturing sector that produces discrete products, also this permits better comparison with the literature currently dominated by the US.

Secondly, we look at the contribution the study has made to the knowledge in terms of the contingency theory of fit. The study proposes the feasible and practical approach of defining 'fit' in the production and operations management area. There is no doubt that the choice of perspective of fit depends on the nature of the sample, i.e. when distribution requirements are not met, the best approaches would be perspectives examined by non-parametric methods, such as fit as moderation (subgroup analysis), fit as gestalts and fit as profile deviation.

Moreover, from a statistical point of view, highly correlated variables are always found in data collected from sampling survey, which will inevitably involve collinearity problems when conducting linear regression. This is also reflected in our study, shown as considerable low goodness of fit (R-square and Adjusted R-Square lower than 0.2). Although such a problem does not affect the general performance of model fitting, it generates seriously biased estimates from individual variables, e.g. AMT and strategies. Therefore, the study suggests that perspectives of fit via non-parametric methods are the most appropriate techniques in such research topics. In particular the study also shows that fit as moderation is the best approach in the production and operations management area in order to provide reliable and sensitive results.

8.4 Implications for Manufacturing Companies and Practitioners

This section considers the implications of the research findings for manufacturing companies, or more specifically the managers of those companies.

The most important implication of these results for manufacturing companies, is that AMT investment in manufacturing facilities is well worth pursuing. This is contrary to the conclusions reached by (Hayes and Wheelright, 1984; Jaikumar, 1986; Voss, 1988; Cooley, 1984; Bessant, 1993; Beaumont and Schroder, 1997; Demeter, 2003; Boyer et. al., 1996; Dean and Snell, 1996). The general finding is that the majority of the companies who have high investments and integration of AMT achieved high performance, both in differentiation and cost leadership performance.

It thus becomes clear that the top management team and indeed all those involved in the strategic decisions of the manufacturing company, develop a much more refined understanding of what AMT is, and that the successful implementation of an AMT requires a consideration of the link between the levels of investment and integration of AMTs and the company's manufacturing strategy, i.e. how the levels of investment and integration of each AMT enhance the manufacturing capabilities in order to support its manufacturing strategy. Only by acknowledging and understanding this link can managers hope to reap the full benefits of the new technologies.

Moreover, by understanding the link between manufacturing strategy and AMTs, t managers are better able to plan the deployment and implementation process. Once the company has decided on the manufacturing strategy to be followed, the managers will be able to identify the appropriate levels of investment and integration of AMTs in order to achieve the intended performance.

Such technology offers enormous potential to increase both effectiveness and efficiency of the manufacturing effort. It is capable of influencing strategic capabilities across manufacturing industries and allows companies to compete on a higher level of customer requirements (Das and Narasimhan, 2001). However, it needs to fit with the company's manufacturing strategy in order to be effective and capable of achieving the intended objectives. In the future, it will be increasingly important for manufacturing managers or directors to understand how the technology works – and know when to use a particular technology. . In short, the message for all manufacturing companies is their technology must match their strategy.

8.5 Implications for Government and Policy Makers

This section highlights the implications of the research for policy makers such as government agencies such as DTI, Manufacturing Advisory Servece (MAS), or Business support programmes and supports for investment such as Small Firm Loan Guarantee, and Regional Venture Capital Funds that provide funding opportunities to firms.

Given the positive impact on performance that can be achieved by successful integration of AMT, the primary implication of the research is that Government agencies and other funding bodies, should continue, and where possible, expand the financial support offered to companies who wish to pursue investment in AMT. Government agencies should seriously look into creating more funding opportunities or financial assistance to enhance the company's manufacturing capabilities through more advanced manufacturing technologies.

The research also highlights the importance of the integration of AMT, i.e. investment in AMT alone is no guarantee of success. Thus it is important that any funding initiatives aimed at increasing overall investment in AMT are made conditional upon the firm in question being able to demonstrate that they have given due consideration to how the new investment fits with their overall manufacturing strategy, and how would integrated with the existing company framework.

The manufacturing sector in the UK has contracted sharply over the past few decades, and in the increasingly global market place, manufacturing firms will only succeed if they can remain competitive. This thesis has shown successful investment in AMT, can allow companies to do this and thus encouraging investment in AMT is a means by which the UK government, and indeed any national government, can protect the capacity and employment levels within its own manufacturing sector.

Government agencies can thus enhance the importance of the role of the manufacturing sector in the UK economy by actively encouraging companies to switch to more high-technology enterprises by investing in more AMTs. It is indeed true for high-cost economies like the UK, that the activities that are likely to thrive are those that 'by their nature are complex and high-value adding', such as the high-technology sectors like aerospace, pharmaceuticals and computer manufacturing which enjoy a higher growth in the past year which have outstripped growth in low-technology sectors (see DTI report, 2007).

8.6 Limitations

The study focuses on AMT diffusion in UK manufacturing companies that produce discrete products. It looks at how a company chooses to invest and integrate its AMT in relation to its manufacturing strategy. The implication of the fit between the two variables: AMT and Manufacturing strategy, on the manufacturing performance, is then examined to answer the research questions set forth for the study. This study, like any other research, is not without its limitations. The limitations are as follows:-

- The performance measurement used for the study is the self-assessed and perceived performance which limits the objectivity of the performance measures. Companies were asked to rate their perceived performance in comparison with the industry average. This might have caused bias or inflated ratings contingent upon performance at the time of the ratings.

- Another limitation is concerned with 'generalisability'. This study focuses on discrete products in manufacturing industry. This is because these sectors are those that have been acknowledged to employ AMTs extensively. Moreover, they employ similar discrete manufacturing processes to manufacture products. Hence, given this limited choice of industry, the findings are generalisable only to this industry.

- The study is a cross-sectional research. It investigated the 'state' of fit between AMT and manufacturing strategy. The study also relied on cross-sectional data to examine strategy-AMT fit. Although the cross-sectional nature of this study is not a serious limitation, it does not permit the study to highlight the 'causal directions' between the variables: strategy-AMT-performance. Furthermore, it does not permit the examination of performance impact of AMT adoption over time.

- The study is concerned about the internal fit, based on the assumption that manufacturing strategy is derived from the business strategy which has already taken into considerations the external environment and internal organisational capabilities. Besides, it is also not necessary that AMT is the only means to achieve performance desired. There might be other factors, not resulting from the technologies invested or integrated (Grant et al., 1991).

- The study also ignores the learning effect, due to the duration the company has implemented the piece of AMT. In this case, we treated all the companies as the same – no matter how long the piece of the technology has been in use.

It is acknowledged that these limitations exist in the study. However, they do not detract from the significance of the findings, indeed they can provide sound platforms for future research.

8.7 Implications for Further Research

AMT diffusion is one of the important areas of research in the production and operations management literature. As the study confirmed that the selection of AMT in terms of its level of integration and investment is associated with the type of manufacturing performance, it would be interesting to see whether other factors or managerial interventions would affect its performance too. Perhaps, it would be a starting point for future research to look at the fit between the AMT with other managerial interventions like human resource management practice, or type of management style, or the market orientation which might affect the performance.

Another important avenue for further research would be to replicate and extend this research design to change the way some of the data was collected. For example, the performance data collected in the study was merely a subjective and self-reporting data from respondents of their perceived achievements in various manufacturing performance criteria. The objectivity of the data can be enhanced by using financial information that can be captured from the company's financial reports such as labour costs, turnover, sales, etc.

In addition, as the study relied on cross-sectional data to examine strategy-AMT fit, it was not possible to highlight the causal directions between the strategy-AMT relationship. Furthermore, it does not permit the examination of performance impact of AMT adoption over time. Given that: (a) firms rarely adopt all AMTs simultaneously (Twigg et al, 1992) and (b) the performance impact of AMT adoption may vary significantly over time (Dean and Snell, 1996), an evolutionary perspective that examines how firms adopt and utilize AMTs over time is needed. In this regards, a longitudinal study of research would enrich the research findings.

The way we gather the information will determine how we can interpret the findings, and the conclusions we can draw from research depend heavily on the particular research methods employed (Furlong, Lovelace, Lovelace, 2000).

Different types of research method draw different types of conclusions for the studies. The findings of the study were derived merely from the information gathered from the survey using a questionnaire, although a case study was conducted in the early stage, but its purpose was to validate the research instrument used for the main study. Thus it is proposed that future research may use a mixture of qualitative and quantitative studies, which involve both case studies and survey. The series of case studies will provide additional information in understanding 'the meaning and dimensions of linkage (i.e. the degree to which the AMT and manufacturing strategy reflect the manufacturing performance). This method should give a thorough insight and better understanding in exploring the issues.

8.8 Conclusions

In conclusion, this study has fulfilled its goal and expectations initially set for the study. Despite the limitations encountered in this study, it has made a significant contribution to the field of production and operations management, AMT implementation and strategic management. The study used the contingency theory to study the fit between AMT and manufacturing strategy and its implication on the manufacturing performance. It provides the empirical evidence crucially required to substantiate the anecdotal accounts on the proposed relationships.

The study confirms that the type of AMT to be invested and integrated in companies is associated with the type of the manufacturing strategy a company is adopting. The study also reveals that it is essential for a company to match its technology investment and its integration with its manufacturing strategy in order to achieve the intended manufacturing performance.

It is thus possible to conclude that a company that is adopting a differentiation strategy should invest and integrate its PPT and IMT more in order to significantly achieve a higher differentiation performance; while companies adopting a cost leadership strategy should invest and integrate in PDE and MHT more to achieve higher cost leadership performance.

The results reinforce Venkatraman and Van de Ven's contention that different conceptualisations, verbalisations, and methods of analysis of fit will lead to different results. The study finds that the more practical and feasible approach of defining fit is 'fit as moderation', as it provides reliable and sensitive results, and is more applicable in the manufacturing setting.

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APPENDICES

Appendix 1: Definition of AMTs Investigated

Type of Technology	Definition
Computer-aided design (CAD)	CAD is used to design and develop products, these can be goods used by end consumers or intermediate goods used in other products. CAD is also extensively used in the design of tools and machinery used in the manufacture of components. CAD is used throughout the engineering process from conceptual design and layout, through detailed engineering and analysis of components to definition of manufacturing methods (Kotha and Swamidass, 2000). It consists of the following component parts: CAD computer, computer peripherals, operations software, and user software. When CAD is integrated with CAE: Use of computers for drawing and designing parts or products and for analysis and testing of designed parts or products. It assists in the design and drawing process - new products or modifies existing products. It includes the direct graphic-interactive generation of two- or three-dimensional data models with subsequent graphic output, supporting activities such as calculations (e.g. the finite-element method) or simulations (see Maier, 1985).
Computer-aided engineering (CAE)	CAE software assists the engineer while examining and testing design from a structural or engineering point of view. This package is very similar to CAD software (Skinner, 1984).
Group technology (GT)	GT assists in designing and testing a product, from a structural or engineering point, controlling of manufacturing machinery, and also for part classifications and coding systems (Slack et al, 1995).
Computer-aided manufacturing (CAM)	Computer-aided manufacturing (CAM) refers to the use of specialised computer programs to direct and control manufacturing equipment. When CAD information is translated into instructions for CAM, the result of these two technologies is called CAD/CAM (Harrison, 1990). It encompasses the software to control manufacturing machinery. It produces the information required to determine the process of manufacture. For example, if the product is to be processed on a CNC, CAM will determine the movements of the tooling, cutting speeds, etc.

Type of Technology	Definition
Manufacturing Resource Planning (MRP, MRPII)	The application of computer aided systems in the planning and control of contract filling and manufacture as regards disposal and organisation, including determination and management of material needs, dates, and capacities; that is, the administration of bills of materials, operations scheduling, materials, and time as well as the recording of operating data, the planning of production and/or the management of customer orders (Harrison, 1990). It controls the entire manufacturing system from order entry through scheduling, inventory control, finance, accounting, accounts payable and so on (Harrison, 1990; Slack et al., 1995). **Material Requirement Planning (MRP)** – uses to determine and manage material needs, dates, and capacities by using bills of materials, operations scheduling, materials, and time as well as the recording of operating data. A useful tool for the planning of production and/or the management of customer orders (Harrison, 1990; Slack et al., 1995). When MRP is extended to other areas of the business to include the other various resources, it is called **Manufacturing Resource Planning (MRP II)** – planning of all the resources of a manufacturing company, i.e. manufacturing, marketing, finance and engineering. It is based on one integrated system containing a database which is accessed and used by the whole company according to individual functional requirements (Harrison, 1990; Slack et al., 1995).
Enterprise Resource Planning (ERP)	ERP is an extension of MRP II. ERP integrates business processes by using a centralised database. It contains modules to allow efficient reporting and decision making throughout the company, process data interactively and to be available in real time, and it also allows easier global integration (Slack et al, 1995).
Automated material handling (AMH) – Automated storage and or retrieval system (ASRS)	Automated materials handling system which use computers to direct automatic loaders to pick and place items. Storage automation is mostly effected by means of (elevated) shelf storages which are operated by automatic high-lift trucks. It can also include automatic identification of items and interfacing with automatic guided vehicles (AGV) (Slack et al, 1995).

Type of Technology	Definition
Automated Guided Vehicles (AGV)	Transport automation is in most cases undertaken by driverless transport systems, such as automated guided vehicles (AGVs) or rail-guided vehicles, also by suspended conveyors and roller conveyers or conveyor belts. AGVs are small independently powered vehicles which move materials to and from value-adding operations. They are usually guided by cables buried in the floor of the operation and receive instructions from a central computer. Variations on this arrangement include AGVs which have their own on-board computers or optical guidance systems (Harrison, 1990).
Computer-aided quality control	Computer-aided quality control systems - Automatic inspecting and testing performed on incoming materials and/or final product which carry out quality inspections performed by automation or robotics (Slack et al, 1995).
Robotics: simple pick and place robots or more complex robots	Robotics was first introduced for industrial applications in the early 1960s. It often has the appearance of one or several arms ending in a wrist. Its control unit uses a memorizing device and sometimes it can use sensing and adaptation appliances that take account of the environment and circumstances (Slack et al, 1995; Harrison, 1990). These multi-purpose machines are generally designed to carry out repetitive functions and can be adapted to other functions without permanent alteration of the equipment. The movement of robots is controlled in a similar manner to NC machine tools but most robots have many degrees of freedom. Robots can be classified based on their application as handling robots, process robots and assembly robots.
Computer Numerically Controlled machines (CNC) or numerical controlled machines (NC)	Machining tool which is directly linked to a computer that controls it. The information can either be stored on disk/ computer (CNC), or in a form of a punched paper tape (NC). This information controls the movements of its tools and the speed of the machine throughout the processing operation. The set of coded instructions and the computers attached to the machine have taken the place of the operator who would previously have controlled the machine by hand. Today, CNC controls are mostly applied for turning machines, boring and milling machines, horizontal boring machines, and machining centres. Other machining work holds a share of over 20% in NC/CNC machines, the principal share being held by grinding and erosion machines; but CNC controls exist for almost types of machining (Slack et al, 1995).

Type of Technology	Definition
Flexible manufacturing cells (FMC) or systems (FMS)	Consists of two or more NC/CNC machines which are interconnected by handling devices (such as robots) and transport system. A FMS can work on more than one different work piece simultaneously. It allows varying machining operations on different workpieces to be performed within a given area (Lindburg, 1992). The NC workstations perform the machining operations, robots which move parts to and from the work stations, transport/ material handling facilities which move the parts between work stations, and operated under the guidance of a central computer system. FMC – capable of single path acceptance of raw materials and single path delivery of a finished product; FMS- capable of multiple paths. May also be comprised of 2 or more FMCs linked in series or parallel.
Computer Integrated Manufacturing (CIM)	Incorporate CAD, CAM and also the control of FMS. It integrates all elements in the manufacturing process from product design to distribution (CAD/CAM, CNC, robots, AGV, production planning, logistics). It links beyond company departments by integrating computer systems, thus islands of computer application in the firms are integrated (Lay, 1990; Udo and Ehie, 1996). A variety of single elements are designed in a specific way to link already installed systems. With CIM, an uninterrupted digital information flow is created between all computer assisted technical and administrative departments of a plant; avoiding multi-programming and multi-keeping of the same data in the memories of the computer systems in different departments (Boaden and Dale, 1986).

Appendix 2: UK Standard Industrial Classification (UKSIC 2003)

Sub section	Industry
DJ	***Manufacture of basic metals and fabricated metal products***
27	Manufacture of basic metals: includes activities of smelting and/or refining ferrous and non-ferrous metals from ore, pig or scrap, using electrometallurgical and other process metallurgical techniques. Also cover the manufacture of metal alloys and super alloys by introducing other chemical elements to pure metals. The output of smelting and refining, usually in ingot form, us used in rolling, drawing and extruding operations to make sheet, strip, bar, rod or wire, and in molten form to make castings and other basic metal products.
28	Manufacture of fabricated metal products, except machinery and equipment: this division deals with the manufacture of 'pure' metal products (such as parts, containers and structure), usually with a static, immovable function, such as metal doors, tanks, casks etc.
DK	***Manufacture of machinery and equipment not elsewhere classified***
29	Manufacture of machinery and equipment not elsewhere classified: independently act on materials, either mechanically orthermally, or perform operations on materials (such as handling, spraying, weighing or packing). It includes their mechanical components which produce and apply force and any specially manufactured primary parts. This category includes fixed and mobile or hand-held devices, regardless of whether they are for industrial, construction and civil engineering, agricultural, military or home use. The manufacture of weapons and of special equipment for passenger or freight transport within demarcated premises also belong to this division. Examples of products: Compressor, pumps, valves, marine engine, bearing, gears, furnace burners, lifts and escalators, machine tools, machinery,
DL	***Manufacture of electrical and optical equipment***
30	Manufacture of office machinery and computers
31	Manufacture of electrical machinery and apparatus not elsewhere classified: Examples of products: motors, generators and transformers
32	Manufacture of radio, television and communication equipment and apparatus
33	Manufacture of medical, precision and optical instruments, watches and clocks, instruments and related products.
DM	***Manufacture of transport equipment***
34	Manufacture of motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment

Appendix 3: Questionnaire

Aston University
Aston Business School
Birmingham
B4 7ET
United Kingdom

ADVANCED MANUFACTURING TECHNOLOGY SURVEY OF UK MANUFACTURING FIRMS

The purpose of the study is to gain a better understanding of the diffusion of advanced manufacturing technology in UK manufacturing firms.
This questionnaire should take about 15 minutes to complete. Your answers are very important to this study and will be kept strictly confidential.
Please return the completed questionnaire at your earliest convenience using the pre-paid envelope provided.

Thank you for your support and cooperation.

SECTION A: BACKGROUND INFORMATION

Note: Please tick (✓) or circle an appropriate box

A1. Please indicate the MAIN products you manufacture.

____

____

A2. Which of the following best describes the manufacturing sector in which your company operates?

☐ Fabricated metal products	☐ Industrial machinery and equipment	☐ Electronic and other electric equipment
☐ Transportation equipment	☐ Instruments and related products	
☐ Other (Pls specify)		

A3. Year of establishment? State year:________________

A4. The formal status of this establishment?

A public limited company (PLC)	1
A private limited company (Ltd)	2
A partnership	3
A single proprietorship, i.e. owned by one person	4
Other (Please specify)	5

A5. Is your company?

An independent company, or the only establishment in the organisation	1
The overall company HQ, or the HQ for this country	2
A divisional or regional HQ	3
An operating site	4
Other (Please specify)	5

A6. The principal ownership of your company or group?

UK owned	1
Foreign owned	2
Joint foreign/ UK owned	3

A7. Please state how many full-time equivalent employees (1 part-time = ½ a full-time employee) you have?

____________________ employees.

SECTION B: MANUFACTURING STRATEGY

B1. In comparing your organisation with the competitors, indicate the importance of the following strategies.

1 – Not important, **3** – Moderately important, **5**- Absolutely critical, **N/A**- Not applicable

	Manufacturing Strategies	Not Important		Moderately Important		Absolutely Critical	Not Applicable
Q1	We offer products that are reliable.	1	2	3	4	5	N/A
Q2	We offer high performance products to our customers.	1	2	3	4	5	N/A
Q3	We offer product with zero defect error.	1	2	3	4	5	N/A
Q4	We offer prices as low or lower than our competitors.	1	2	3	4	5	N/A
Q5	We continuously concern for cost reduction in all possible sources.	1	2	3	4	5	N/A
Q6	We offer a wide range of product options to our customers.	1	2	3	4	5	N/A
Q7	We offer excellent after-sale service.	1	2	3	4	5	N/A
Q8	We offer customised products to our customers.	1	2	3	4	5	N/A
Q9	We introduce new models into our existing products.	1	2	3	4	5	N/A
Q10	We continuously launch new product line to new customers.	1	2	3	4	5	N/A
Q11	We provide on-time delivery of customer orders.	1	2	3	4	5	N/A
Q12	We make fast deliveries to our customers.	1	2	3	4	5	N/A

SECTION C: MANUFACTURING TECHNOLOGY

C1. Please indicate <u>the amount of investment</u> your manufacturing plant has in the following technologies. Please refer to the Glossary attached for detailed definition of each technology.

1- Little investment, **3** – Moderate investment, **5**- Heavy investment

	Manufacturing technologies	Little Investment		Moderate Investment		Heavy Investment	Not Applicable
Q1	Computer-aided design (CAD) – to design new products or modify existing products.	1	2	3	4	5	N/A
Q2	Computer-aided engineering (CAE) – to examine and testing design from a structural or engineering point of view.	1	2	3	4	5	N/A
Q3	Group technology (GT) – the parts and process classification, and coding systems that used to specify machine types that go into a cell.	1	2	3	4	5	N/A
Q4	Computer-aided manufacturing (CAM) – to control manufacturing machinery, by determining the process of manufacture, i.e. the movement, speed etc of the machinery.	1	2	3	4	5	N/A
Q5	Material requirement planning (MRP) – to plan production and raw materials requirements by working backward from the sales forecast.	1	2	3	4	5	N/A
Q6	Manufacturing resources planning (MRPII) – Extension of MRP. Planning of manufacturing resources, i.e. manufacturing, marketing, finance and engineering, based on one integrated system.	1	2	3	4	5	N/A
Q7	Enterprise resources planning (ERP) – extension of MRPII. Integrates business processes by using a centralised database. More functions such as reporting, decision making etc.	1	2	3	4	5	N/A
Q8	Automated storage and or retrieval systems (ASRS) -automated material handling system to help to to store or retrieve parts using computerised devices.	1	2	3	4	5	N/A
Q9	Automated guided vehicles (AGV) – to direct driverless vehicles to deliver materials in the plant.	1	2	3	4	5	N/A
Q10	Computer-aided quality control – to carry out inspection and testing on final products or incoming or in process materials.	1	2	3	4	5	N/A
Q11	Robotics – a reprogrammable, multifunctional machine to perform repetitive tasks such as pick-and-place or other complicated robots.	1	2	3	4	5	N/A
Q12	Numerical control machines (NC/CNC/DNC) – machining tools which is controlled by information stored on disk (CNC) or in a form of a punched paper tape (NC).	1	2	3	4	5	N/A
Q13	Flexible manufacturing cells/systems (FMC/FMS) – consist of a group of NC/CNC/automated workstations interconnected by a material handling system.	1	2	3	4	5	N/A
Q14	Computer-integrated manufacturing (CIM) – integrate CAD, CAM, and FMS, i.e. from design to distribution.	1	2	3	4	5	N/A

C2: Please indicate <u>the extent of integration</u> of the technologies implemented in your organisation:

1- No integration	2- Limited integration	3- Full integration	4- Extended integration
The technology is **control by a dedicated software/system, not link** to other application system within the production/ operations department.	The technology is **integrated within production/ operations functions,** ranging from product design, production planning to logistics.	The technology is integrated with other systems from other departments not directly involved in manufacturing (i.e. other than those in **2**).	The technology is integrated within the organisation, and extended to external organisations like suppliers and customers.
Example: use CAD only for engineering drawing, but not connected to any other part of production function.	Example: CAD links to materials, or planning, or warehousing, or logistic functions.	Example: CAD is link to marketing or finance/ HR departments.	Example: CAD is link to customer's system, or to suppliers' inventory systems.

Q1	Computer-aided design (CAD)	1	2	3	4	N/A
Q2	Computer-aided engineering (CAE)	1	2	3	4	N/A
Q3	Group technology (GT)	1	2	3	4	N/A
Q4	Computer-aided manufacturing (CAM)	1	2	3	4	N/A
Q5	Material requirement planning (MRP)	1	2	3	4	N/A
Q6	Manufacturing resources planning (MRPII)	1	2	3	4	N/A
Q7	Enterprise resources planning (ERP)	1	2	3	4	N/A
Q8	Automated storage and or retrieval systems (ASRS)	1	2	3	4	N/A
Q9	Automated guided vehicles (AGV)	1	2	3	4	N/A
Q10	Computer-aided quality control (CAQC)	1	2	3	4	N/A
Q11	Robotics	1	2	3	4	N/A
Q12	Numerical control machines (NC/CNC/DNC)	1	2	3	4	N/A
Q13	Flexible manufacturing cells/systems (FMC/FMS)	1	2	3	4	N/A
Q14	Computer-integrated manufacturing (CIM)	1	2	3	4	N/A

SECTION D: MANUFACTURING PERFORMANCE

D1. From the following list of statements, please indicate your organisation performance in comparison with your industry average.

1 – Well below par, **3** - Average, **5** – Well above par.

	Performance variables	Well Below Par		Average		Well Above Par	Not Applicable
Q1	Ability to offer products that are reliable.	1	2	3	4	5	N/A
Q2	Ability to offer high performance products to our customers.	1	2	3	4	5	N/A
Q3	Ability to deliver zero defect error products.	1	2	3	4	5	N/A
Q4	Ability to offer competitive or lowest prices through efficiency from all possible sources.	1	2	3	4	5	N/A
Q5	Ability to offer competitive or lowest prices through cost reduction from all possible sources.	1	2	3	4	5	N/A
Q6	Ability to offer a wide range of product options to our customers.	1	2	3	4	5	N/A
Q7	Ability to provide excellent after-sale service.	1	2	3	4	5	N/A
Q8	Ability to customise products according to customers' specifications and requirements.	1	2	3	4	5	N/A
Q9	Ability to offer new models into our existing products.	1	2	3	4	5	N/A
Q10	Ability to launch new product line to new customers.	1	2	3	4	5	N/A
Q11	Ability to deliver goods on time.	1	2	3	4	5	N/A
Q12	Ability to provide fast deliveries to our customers.	1	2	3	4	5	N/A

SECTION E: RESPONDENT'S PROFILE

E1. Please indicate your title of position held in the company?

____

E2. Years of holding the position in the company? _____________years.

FEEDBACK ON RESEARCH RESULTS

Would you be interested in receiving a summary report of the findings of this research?

Yes ☐ No ☐

If **Yes**, would you please complete the following:

Name:

____

Company:

____

Address:

____

____

Email Address:

____

Tel/Fax No:

____

Thank you for your assistance. This will be invaluable for our work.
Please return the completed questionnaire in the prepaid envelope provided.

If you have any queries please contact:
Ms Emmy Pong, Aston Academy for Research in Management, Aston University, Birmingham B4 7ET, Tel: 0121-2043154, Fax:0121-3335620, email: pongecm@aston.ac.uk.

Apendix 4: Letter Accompanying Questionnaire

<Salutation> <FirstName><Surname>
<Designation>
<Company Name>
<Address 1>
<Address 2>
<Town> <Postcode>

March 1 2005

Dear <Salutation> <Surname>

ADVANCED MANUFACTURING TECHNOLOGY (AMT) SURVEY OF UK MANUFACTURING FIRMS

A few weeks ago we sent out questionnaire to manufacturing companies throughout the UK, to participate in **a very important study** about AMT diffusion of UK Manufacturers. This study is aimed to understand the state of AMT adoption and its relations to UK manufacturers' competitive priorities. This study is important, as it will help to find the right AMT which allows your company to boost the productivity and help to achieve the competitive advantages. It will also serve as a reference when adopting AMT. Your company will be able to use the findings of this study to benchmark your current AMT adoptions.

Your company is one of the UK manufacturing companies randomly selected to participate in this study. It is essential that this questionnaire is completed by as many manufacturers in order to have a collective perspective. Your answers are completely confidential and will be released only as summaries in which no individual's answers can be identified. The code on the questionnaire is to assist us to conduct follow-ups on non-responses. A copy of the finidngs will made available to you by simply fill up your request at the end of the questionnaire. This survey is voluntary. However, you can help us very much by taking a few minutes to share your company's adoption experiences on AMT. If for some reason you prefer not to respond, please let us know by returning the blank questionnaire in the enclosed prepaid enveloped.

We greatly appreciate your help in furthering this research. If you require any clarification, or have any comments or suggestions with regard to this study, please do not hesitate to contact us. We look forward to receiving your completed questionnaire soon.

Thank you very much for helping with this important study.

Yours sincerely,

Dr Peter Burcher
PhD Supervisor

Emmy Pong
PhD Reseacher
Tel:0121-2043154
Email:pongecm@aston.ac.uk

Appendix 5: Reminder Letter

<Salutation> <FirstName><Surname>
<Designation>
<Company Name>
<Address 1>
<Address 2>
<Town> <Postcode>

22nd March 2005

Dear <Salutation> <Surname>

SURVEY OF IMPORTANT UK MANUFACTURING FIRMS
ADVANCED MANUFACTURING TECHNOLOGY

A few weeks ago I circulated a questionnaire to you, hoping that as one of the leading Manufacturing Companies in the country, you would be able to help me in my PhD reasearch project looking at Advanced Manufacturing Technology (AMT).

Just in case you have either not received the original or perhaps it has not yet been passed to you, I have enclosed a second copy and trust that you can find the time to complete the simple questionnaire and return it to me in the stamped addressed envelope provided

The research that I am conducting concerns an analysis of the critical factors in the successful implementation of AMT and its impact on subsequent business performance. Of course your response will be treated in the strictest confidence and the data sanitised to protect your company identity.

Naturally in return for your participation a copy of my findings will be made available to you once the research report has been completed.

I would like to thank you in advance for your assistance in helping me with my

PhD project and look forward to receiving your completed questionnaire.

Yours sincerely

Emmy Pong

Appendix 6: Factor Analysis on Manufacturing Strategies

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.574
Bartlett's Test of Sphericity	Approx. Chi-Square	49.875
	df	6
	Sig.	.000

Total Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.507	37.664	37.664	1.316	32.891	32.891
2	1.047	26.163	63.826	1.237	30.936	63.826
3	.741	18.526	82.352			
4	.706	17.648	100.000			

Extraction Method: Principal Component Analysis.

Rotated Component Matrix(a)

	Component	
	1	2
Quality Strategy	.731	.223
Cost Strategy	-.103	.848
Flexibility Strategy	.824	-.066
Delivery Strategy	.681	.302

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Component Transformation Matrix

Component	1	2
1	.765	.644
2	-.644	.765

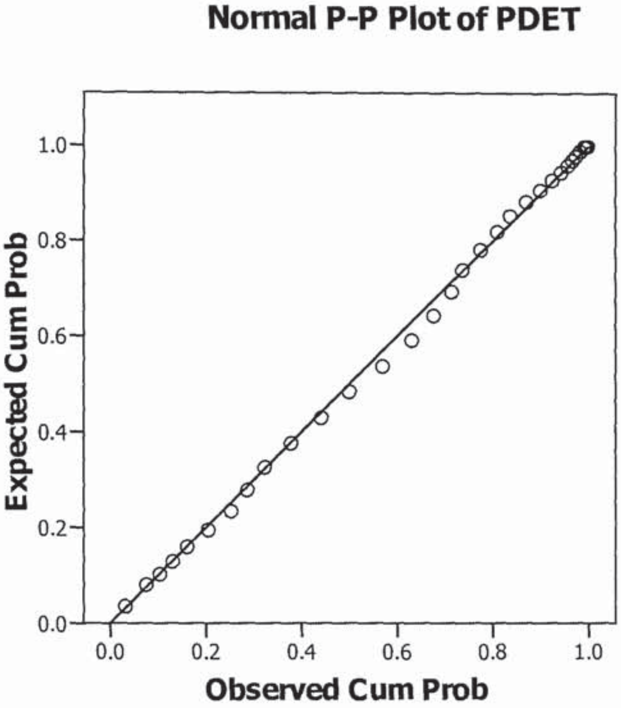
Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

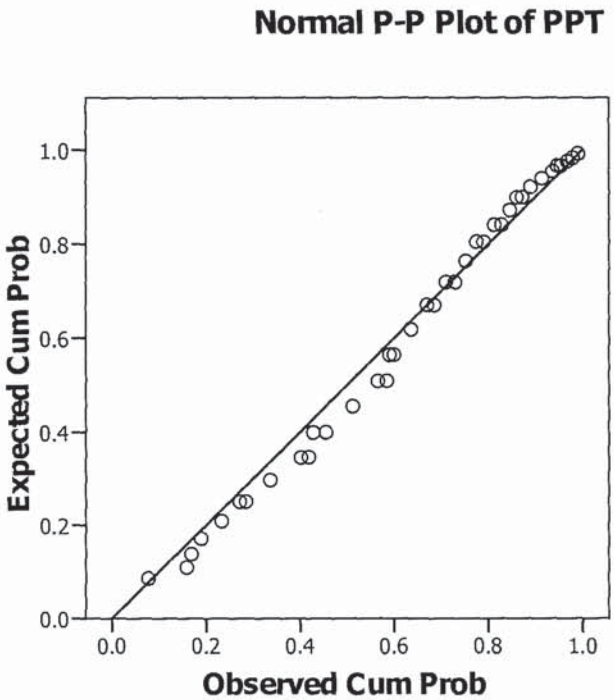
Component Score Coefficient Matrix

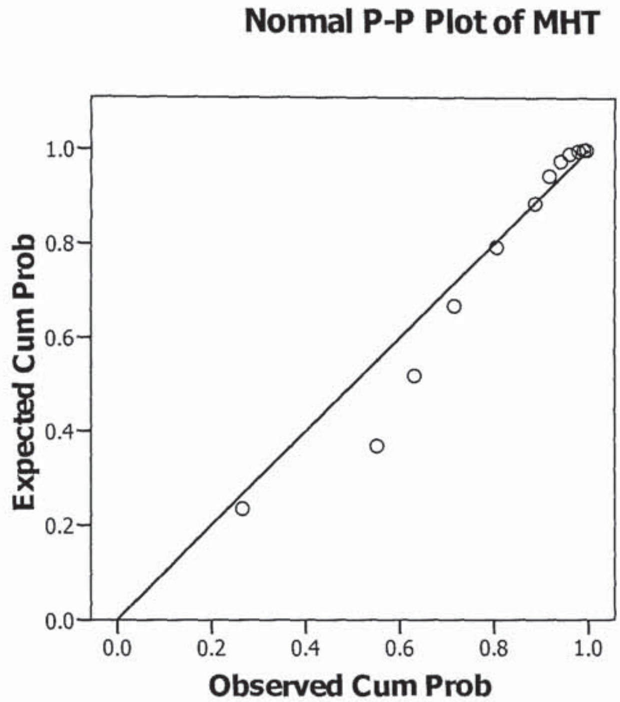
	Component	
	1	2
Quality Strategy	.542	.081
Cost Strategy	-.203	.723
Flexibility Strategy	.656	-.174
Delivery Strategy	.525	.139

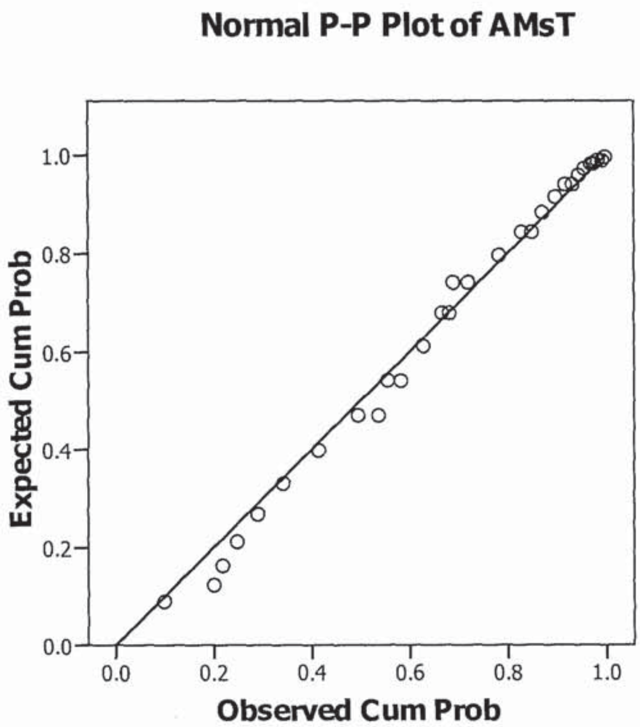
Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Component Scores.

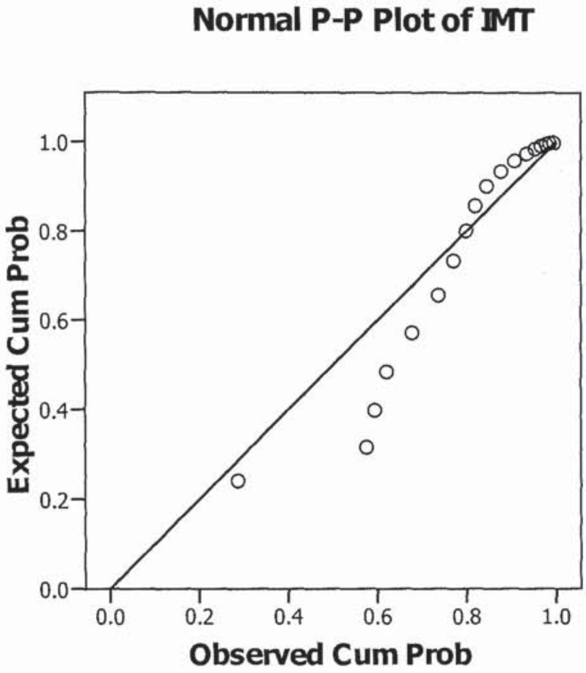
Appendix 7: Normal PP Plot of AMTs






Normal P-P Plot of MHT
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


Normal P-P Plot of AMsT
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


Normal P-P Plot of IMT
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

Appendix 8: Fit as Covariation

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.458
Bartlett's Test of Sphericity	Approx. Chi-Square	28.3687
	df	21
	Sig.	.13

Perspective of fit as Covariation fails to pass the KMO and Bartlett's Test, which is an indication of suitability of factor analysis.

Appendix 9: Fit as Moderation

Comparisons of correlation coefficients between high and low differentiation strategy adopters

Paired Samples Test

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
Pair 1 Differentiation Performance	-.08720	.02206	.00987	-.11459	-.05981	-8.838	4	.001
Pair 2 Cost-leadership Performance	-.08640	.08814	.03942	-.19584	.02304	-2.192	4	.093

Comparisons of correlation coefficients between high and low cost-leadership strategy adopters

Paired Samples Test

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
Pair 1 Differentiation Performance	.16640	.09463	.04232	.04890	.28390	3.932	4	.017
Pair 2 Cost-leadership Performance	.13420	.11824	.05288	-.01261	.28101	2.538	4	.064

Appendix 10: Fit as Mediation

Differentiation strategy~AMT

Model Summary(e,f)

Model	R	R Square(a)	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
3	.307(d)	.094	.084	.95542059	.683

ANOVA(e,f)

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	24.577	3	8.192	8.975	.000(d)
	Residual	236.423	259	.913		
	Total	261.000(b)	262			

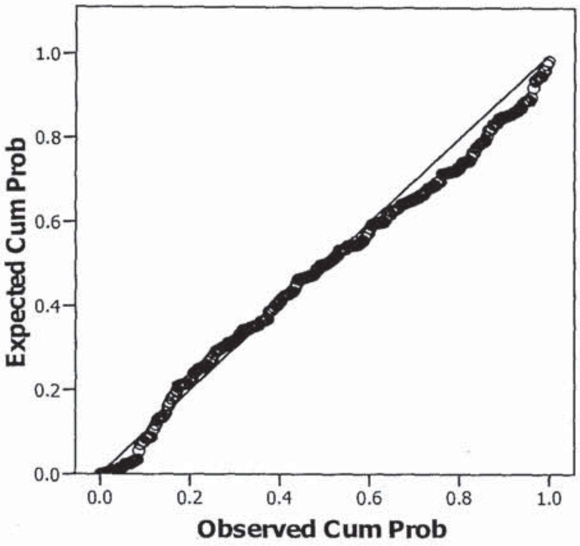
Coefficients(a,b)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
3	PPT	.194	.051	.395	3.800	.000
	AMsT	-.254	.071	-.393	-3.581	.000
	IMT	.142	.067	.197	2.123	.035

a Dependent Variable: Differentiation Strategy
b Linear Regression through the Origin

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Differentiation Strategy



Cost-leadership Strategy~AMT

Model Summary(g,h)

Model	R	R Square(a)	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
5	.136(f)	.019	.015	.99070191	.113

ANOVA(g,h)

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	4.831	1	4.831	4.922	.027(f)
	Residual	256.169	261	.981		
	Total	261.000(b)	262			

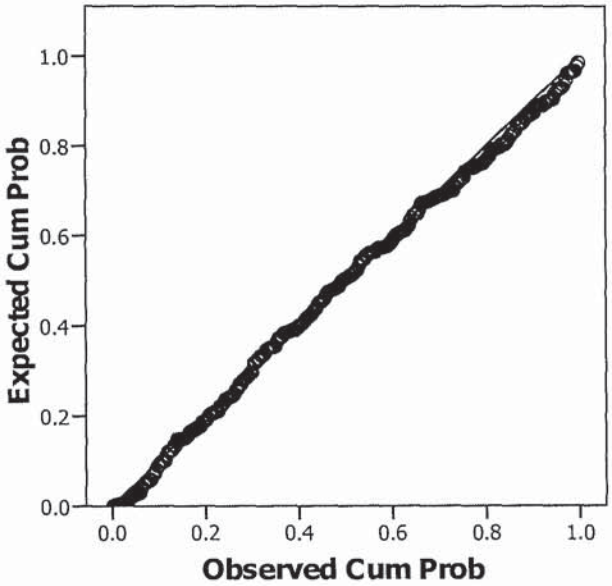
Coefficients(a,b)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
5	IMT	.098	.044	.136	2.219	.027

a Dependent Variable: Cost-leadership Strategy
b Linear Regression through the Origin

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Cost-leadership Strategy



Appendix 11: Fit as Matching

Model 1: Differentiation performance ~

Residuals (Differentiation Strategy ~AMT) + Residuals(Cost-leadership strategy ~AMT)

Model Summary(d,e)

Model	R	R Square(a)	Adjusted R Square	Std. Error of the Estimate
	.276	.076	.073	.51821

ANOVA(d,e)

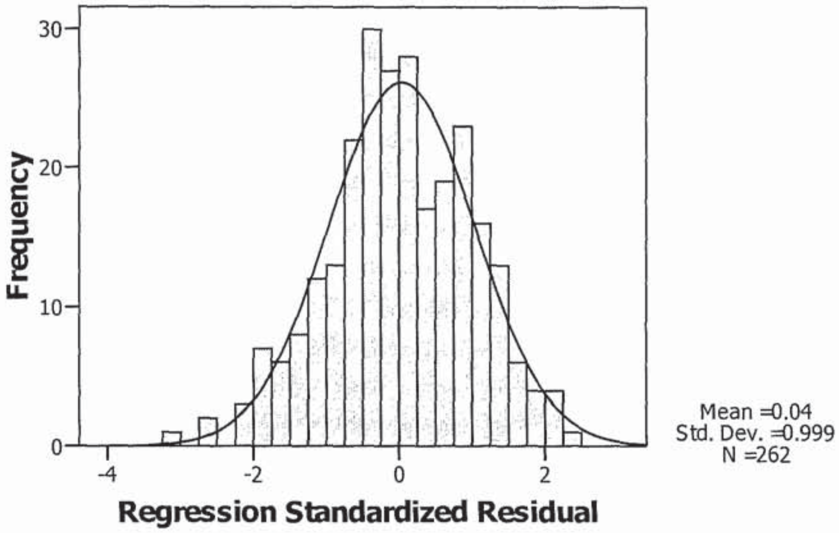
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	5.783	1	5.783	21.536	.000
	Residual	70.090	261	.269		
	Total	75.874	262			

Coefficients(a,b)

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta	B	Std. Error
	Residual(DS~AMT)	.156	.034	.276	4.641	.000

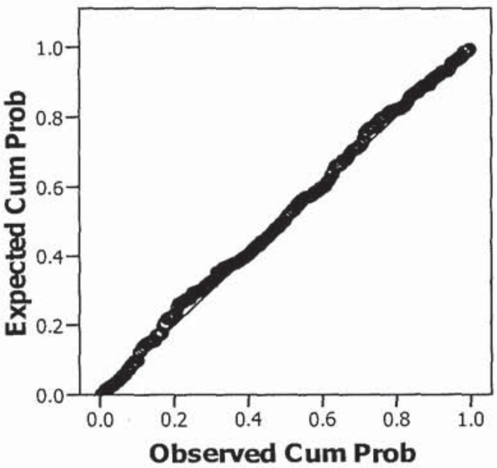
Histogram

Dependent Variable: Differentiation Performance



Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Differentiation Performance



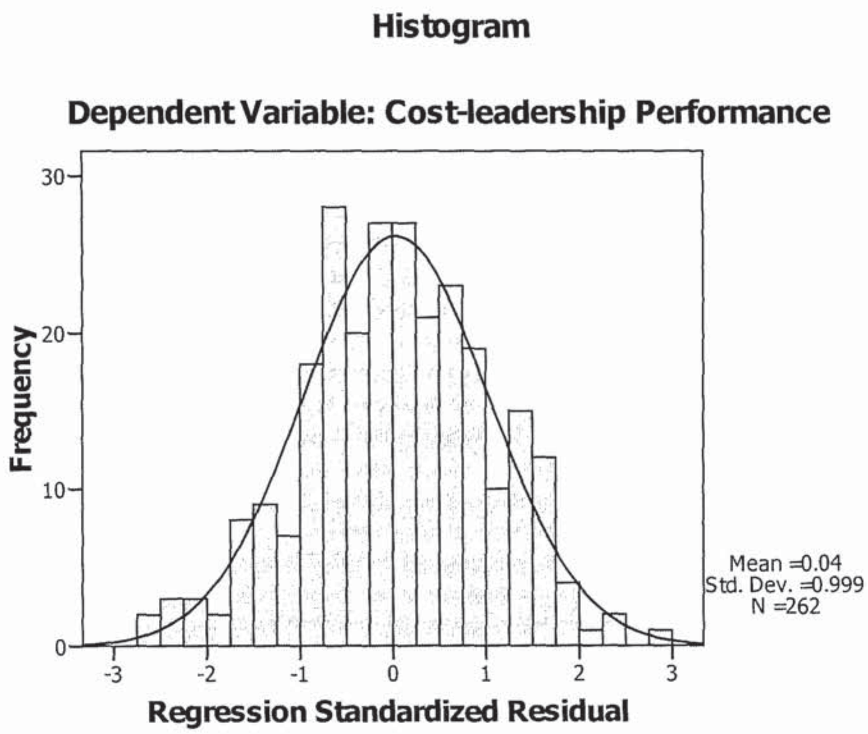
Model 2: Efficiency performance ~
Residuals (Differentiation Strategy ~AMT) + Residuals(Cost-leadership strategy ~AMT)

Model Summary(d,e)

Model	R	R Square(a)	Adjusted R Square	Std. Error of the Estimate
	.425(c)	.181	.178	.60611

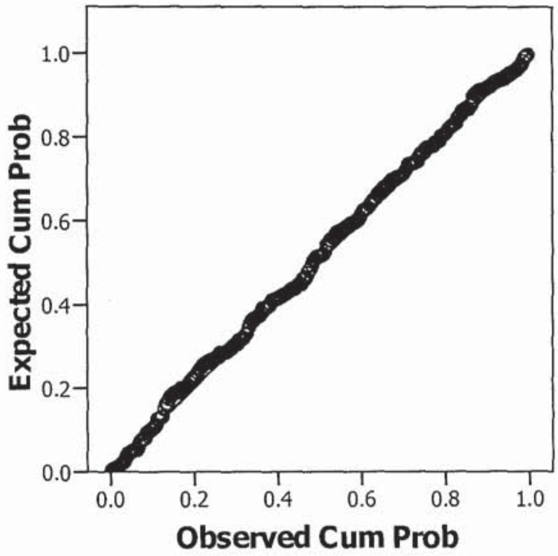
ANOVA(d,e)

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	21.164	1	21.164	57.611	.000
	Residual	95.882	261	.367		
	Total	117.046	262			



Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Cost-leadership Performance



Appendix 12: Fit as Profile Deviation

Independent Samples Test
Sorted by Differentiation Performance

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
PDET	Equal variances assumed	8.107	.005	1.945	234	.053	.37386	.19219
	Equal variances not assumed			1.464	28.036	.154	.37386	.25535
PPT	Equal variances assumed	3.294	.071	1.233	234	.219	.31129	.25240
	Equal variances not assumed			1.040	29.131	.307	.31129	.29938
MHT	Equal variances assumed	1.181	.278	.466	234	.641	.06200	.13298
	Equal variances not assumed			.422	29.990	.676	.06200	.14696
AMsT	Equal variances assumed	.011	.916	.751	234	.454	.14573	.19416
	Equal variances not assumed			.740	31.284	.465	.14573	.19681
IMT	Equal variances assumed	9.095	.003	2.503	234	.013	.59505	.23777
	Equal variances not assumed			1.971	28.438	.058	.59505	.30187
Differentiation Strategy	Equal variances assumed	.516	.473	4.534	234	.000	.90517839	.19963435
	Equal variances not assumed			4.967	33.332	.000	.90517839	.18223411
Cost-leadership Strategy	Equal variances assumed	1.436	.232	.561	234	.576	.11797982	.21044520
	Equal variances not assumed			.519	30.306	.607	.11797982	.22728538

Independent Samples Test
Sorted by Cost-leadership Performance

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
PDET	Equal variances assumed	1.210	.272	-1.168	234	.244	-.22711	.19452
	Equal variances not assumed			-.977	29.049	.337	-.22711	.23246
PPT	Equal variances assumed	.000	.985	1.055	234	.293	.26545	.25171
	Equal variances not assumed			1.062	31.634	.296	.26545	.25002
MHT	Equal variances assumed	1.795	.182	-1.179	234	.240	-.16181	.13727
	Equal variances not assumed			-.975	28.920	.338	-.16181	.16603
AMsT	Equal variances assumed	.075	.785	-.550	234	.583	-.10702	.19465
	Equal variances not assumed			-.549	31.488	.587	-.10702	.19497
IMT	Equal variances assumed	4.828	.029	-1.295	234	.197	-.30806	.23787
	Equal variances not assumed			-1.101	29.228	.280	-.30806	.27970
Differentiation Strategy	Equal variances assumed	.488	.485	-2.133	234	.034	-.44566143	.20895784
	Equal variances not assumed			-2.341	33.376	.025	-.44566143	.19037323
Cost-leadership Strategy	Equal variances assumed	3.922	.049	-3.502	234	.001	-.68606404	.19590539
	Equal variances not assumed			-4.808	40.798	.000	-.68606404	.14269905

Appendix 13: Fit as Gestalts

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Differentiation Performance	.293	2	259	.746
Cost-leadership Performance	1.161	2	259	.315

Differentiation Performance

		N	Subset for alpha = .05	
	Cluster Number of Case	1	2	1
Tukey HSD(a,b)	3	91	-.1066	
	1	116	-.0211	
	2	55		.2209
	Sig.		.564	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 79.383.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Cost-leadership Performance

		N	Subset for alpha = .05
	Cluster Number of Case	1	1
Tukey HSD(a,b)	1	116	-.0878
	3	91	.0278
	2	55	.1392
	Sig.		.083

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 79.383.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Appendix 14: Treatments to missing values:

Due to various reasons, some of the respondents failed to complete all the survey questions in the questionnaire. However, it is not very feasible to simply delete all the incomplete entries, because the effective samples could be seriously reduced by doing so. In some cases, especially when the sample size (number of companies surveyed) is small, deleting all the incomplete entries could make statistical tests impossible. Therefore, we need better methods to deal with missing value in a survey.

There are several types of treatments to missing values depending on the different types of survey questions. Generally, we will find some value to replace the missing value, which will not bias the analysis. i.e. mean of the series, mean of nearby points, median of nearby points, calculating the value by interpolation or linear trend at this point. In our research, for questions which provide the option 'Not applicable', all non-responded answers will be treated as 'not applicable'; for the other questions with no option like 'Not applicable', which have been answered by most respondents, missing values will be replaced by the mean of the entire series. However, there are also some questions, whose answers are based on previous questions. For example, questions C5 to C9 are only answered by respondents who enter 'Yes' in Question C4. Therefore, this type of unanswered questions deserves no extra treatment. In what follows are the detailed treatments to the unanswered questions (missing values).

Replacing unanswered questions as 'Not Applicable'

Answers in Section B1

RELIABLE (reliable products), HIGHPF (high performance products), ZERODEF (zero defect error), LOWPRICE (low price), COSTRED (cost reductions), WIDERGE (wide product range), AFTSALES (excellent after sales service), CUSTOMSD (customized products), NEWMODELS (new models introduction), NEWPDT (new models introduction), ANYQTY (new product lines), ONTIMEDEL (on-time delivery), SHORTDEL (short time delivery)

Answers in Section C2

CADINV (CAD investment), CAEINV (CAE investment), GTINV (GT investment), CAMINV (CAM investment), MRPINV (MRP investment), MRPIIINV (MRPII investment), ERPINV (ERP investment), AMHINV (AMH investment), AGVINV (AGV investment), CAQCINV (CAQC investment), ROBOTICSINV (Robotics investment), NCCNCINV (NC/CNC/DNC investment), FMCSINV (FMC/FMS investment), CIMINV (CIM investment)

Answers in Section C3

CADINT (CAD integration), CAEINT (CAE integration), GTINT (GT integration), CAMINT (CAM integration), MRPINT (MRP integration), MRPIIINT (MRPII integration), ERPINT (ERP integration), ASRSINT (ASRS integration), AGVINT (AGV integration), CAQCINT (CAQC integration), ROBOTICSINT (Robotics integration), NCCNCINT (NC/CNC/DNC integration), FMCSINT (FMC/FMS integration), CIMINT (CIM integration)

Replace missing value by mean of the entire series.

Answers in Section D1:

PFRELI (performance on product reliability), PFHGQTY (performance on high quality products), PFZEDEF(performance on zero defect), PFLWPRI(performance on low price), PFCOSRE(performance on cost reduction), PFWIRGE(performance on wide range of products), PFAFTSAL(performance on after sales), PFCUSTO(performance on product customization), PFNWMO(performance on new models), PFNWPRD(performance on new product lines), PFANYOUT(performance on change output volume quickly), PFTMDEL(performance on timely delivery), PFSHODEL(performance on short delivery time).