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A DECISION MODEL FOR MANUFACTURING BEST PRACTICE ADOPTION: LINKING PRACTICES TO COMPETITIVE STRATEGIES

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A Decision Model for Manufacturing Best Practice Adoption: Linking Practices to Competitive Strategies

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ABSTRACT

This thesis describes research that has developed a decision model for the analytical selection of manufacturing best practices.

The competitiveness and growth in the manufacturing sector is critical for Singapore economy. Design and improvement of manufacturing systems is imperative to sustain the competitiveness of manufacturing organisations in the country. It is common for companies to adopt manufacturing best practices in this design process to emulate the success and performance of their counterparts. However, practices should be adapted to the competitive environment and strategy of the company to yield the desired results. Therefore, linkages between best practices and their associated competitive priorities will present useful guidelines for action to help manufacturing organisations achieve superior performance.

The research programme has set out to define a decision model for best practice adoption. A broad taxonomy of manufacturing strategies and concepts has been used to identify and cluster a list of popular best practices commonly adopted. The decision framework for best practice adoption process is then formulated and a preliminary decision model constructed. This model is verified through semi-structured interviews with industry and academic experts. Validation of model is conducted via case study research on eight manufacturing organisations. Linkages between practices and competitive strategies are then constructed to establish the final decision model. Finally, this decision model is illustrated in the form of a guidebook to help practitioner in the best practice selection process.

This research has bridged the fields of manufacturing strategy and best practice research by establishing a comprehensive taxonomy of manufacturing strategies and concepts to classify the popular and commonly adopted best practices. A decision model that links best practices to competitive strategies has been developed to select the most appropriate practices for an environment. Thus, the work presented in this thesis has made a significant and original contribution to knowledge on the provision of analytical decision support for practitioners engaging in the manufacturing best practice adoption process.

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NOTATION

AHP	Analytical Hierarchical Process
AP	Agile Paradigm
CP	Craft Paradigm
DES	Discrete Event Simulation
DT	Decision Tree
DTI	Department of Trade and Industry
EDB	Economic Development Board of Singapore
ERC	Economic Review Committee of Singapore
FTA	Free-trade Agreement
GDP	Gross Domestic Product
IQS	International Quality Study
JIT	Just-in-time
LP	Lean Paradigm
MCP	Mass-customise Paradigm
MP	Mass Paradigm
POLCA	Paired-cell Overlapping Loops of Cards with Authorisation
QC	Quality Circle
QRM	Quick-Response Manufacturing
SBU	Strategic Business Unit
SCM	Supply Chain Management
SCOR	Supply-Chain Operations Reference-model
SMED	Single Minute Exchange of Dies
TBP	Time-based Paradigm
TPM	Total Productive Maintenance
TQM	Total Quality Management
WCM	World-Class Manufacturing

PUBLICATIONS

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Chapter 1: Introduction

A successful manufacturing industry can make a significant contribution to the prosperity of a nation as concurred with (Cohen and Zysman, 1987; Baines, 1995; Fingerton, 1999). For success, manufacturing companies have to develop and maintain a high level of coherence between their strategy and practices. One of the key mechanisms for the design and improvement of manufacturing system is the adoption of manufacturing best practices defined by popular manufacturing strategies and concepts. However, fragmented information on these strategies and concepts has often led to a strategic misalignment between the manufacturing practices and competitive strategies adopted. Thus has resulted in sub-optimal or poor performances of organisations. This Chapter introduces the background of the research, followed by an overview of the research aim, objectives and programme adopted. Finally, a summary of the research contributions is presented together with the illustration of the thesis structure.

1.1 Background to the Research

Today's manufacturing environment is complex as organisations are undergoing rapid and significant changes driven by the shift in the nature of manufacturing industries, changing customer/market demand and changing manufacturing goals (Storey, 1984; Bessant, 1991; St. John et al., 2001). One of these changes evident in Singapore is the shift from low value labour-intensive activities to the high value Information Technology enabled ones, which is coupled to the move to higher value product manufacture that focus on new competitive bases like innovation and service as opposed to the traditional cost base (Section 2.2). These changes have posed many challenges to manufacturing organisations in designing and improving their manufacturing systems to achieve superior performance as discussed by many researchers (see Hayes and Wheelwright, 1984; Hill, 1994; Schroeder and Flynn 2001; Swamidass et al., 2001). As global competition intensifies, achieving best practices and world-class performance is not just a desirable goal, but a necessity for survival (Schonberger, 1987; Elmore, 1998). Organisations need to decide on the most appropriate manufacturing strategy for their businesses, the best manufacturing practices to adopt and the priority of adoption with their limited resources to achieve global competitive advantage (Section 2.3). However, the lack of a holistic decision model to guide practitioners in a formal adoption process has often resulted in companies imitating blindly and eventually narrowing their strategic space (Hayes and Pisano 1994), resulting in sub-optimal or poor performances of many organisations (Schroeder et al., 1986; Swamidass; 1986; Swink and Way 1995; Ward and Duray 2000).

Evidence from literature has revealed that the emergence of manufacturing paradigms like the Mass or Lean paradigm is frequently associated with the emergence of radically different “best practices” (Section 3.2). For example, best practices like Total Quality Management (TQM), Total Productive Maintenance (TPM), Kaizen and Quality Circle are associated with Lean. However, such literature is often descriptive in nature and typically describes the type of practices that successful companies have in place (eg. Hanson and Voss, 1995; Alberto and Maurizio, 2002; Laugen et al., 2005), rather than supporting the analytical selection of manufacturing best practices. Vast majority of the literature is limited to the dissemination of best practices, without discussing in detail the necessary background to these practices. This is inadequate in helping companies to determine whether a best practice is appropriate for their environment (Davies and Kochhar, 2002). There are also relatively few large-scale studies that empirically link practices with performance as such relationships are assumed to be self-evident (Voss et al., 1997). However, trade-offs do exist between the competitive priorities of quality, cost, delivery and flexibility (Skinner 1969; Hayes and Wheelwright 1984) and it is critical that the practices implemented to achieve one competitive priority do not have an adverse effect on another. Thus, there is a need for a more holistic approach in defining the explicit linkages between best practices and performance; relating them to the competitive strategy they support to achieve the competitive advantage for sustainable growth and competitiveness (Section 3.4). The research aim and objectives have hence been formulated (Section 4.2) and an overview presented in the next section.

1.2 Overview of Research Aim, Objectives and Programme

As developed in Section 4.2, the aim of this thesis has been stated as:

> *"to develop a decision model for best practice adoption that links practices to competitive strategies and guide practitioners in the analytical selection of manufacturing best practices."*

In order to fulfil the research aim, 3 research objectives have been defined as to:

1. Develop a decision model for the adoption process of manufacturing best practices.
2. Validate the decision model with real-life industrial case studies.
3. Apply the decision model in the form of a guidebook for industrial application.

The research programme has thus been divided into 5 stages, which contribute to the attainment of these objectives described above.

The first objective is the development of a decision model, which is addressed in stages 1, 2 and 3 of the research programme. The lack of an existing holistic model requires the systematic gathering of existing knowledge in the field of manufacturing strategy and best practice research to form this decision model. Thus, the first stage is to define a decision framework and gather the requirements of the decision model by reviewing existing best practice adoption processes (Chapter 5). Based upon these requirements, the most appropriate modelling technique is selected and the decision model constructed (Chapter 6). As this decision model is based upon the analytical synthesis of theoretical findings in the literature, there is a need to verify the model constructed against experts' opinions to ascertain its accuracy with existing knowledge and concepts (Chapter 7).

The second objective is the validation of the decision model, which is addressed in stage 4 of the research programme. To measure the accuracy of the decision model in representing actual industrial scenario, this model will need to be validated. This is achieved through case study research on eight selected manufacturing organisations and is detailed in Chapter 8.

The final objective is to apply the decision model for industrial application. This forms the last and final stage (Stage 5) of the research programme. To aid managers and practitioners in the decision process of manufacturing best practice adoption, the final decision model is illustrated in the form of a guidebook (Chapter 9). Compatibility of practices, trade-off between competitive priorities and the priority of adoption is presented and explained in the guidebook to aid the analytical selection of manufacturing best practices.

1.3 Overview of Research Contribution

The research presented in this thesis makes two key research contributions to the subject of best practice adoption, namely:

- The creation of a decision model to provide a holistic and analytical aid for the best practice adoption process. This model defines the linkages between manufacturing best practices, manufacturing objectives and competitive strategies to guide practitioners in selecting the most appropriate best practices for their competitive environment.

- The new knowledge on the degree and order of criticality of best practices against strategic goals of an organisation. This guides the practitioners in prioritising best practice adoption plans for the design and improvement of manufacturing system.

1.4 Structure of the Thesis

The thesis structure is illustrated in Figure 1.1 and contains the following principal sections:

Chapter 2 Review of the industrial context to show the importance of manufacturing to Singapore's economy and the challenges faced by manufacturing organisations in Singapore. A case for best practice adoption is presented to help these organisations cope with the difficulties of manufacturing system design and strategic misalignment that impairs the attainment of superior performance. The challenges to best practice adoption are also discussed, which lead to the need and purpose for this research.

Chapter 3 Review of the literature to define the concepts of best practices and establishes a broad taxonomy to the disparate body of knowledge on manufacturing strategies and concepts that describes the existing best practices. A review of existing best practice adoption approaches is also conducted to establish the limitation and gaps in the current knowledge.

Chapter 4 Provides an overview of the research problem and develops the research aim, objectives and programme. Individual stages of the work are determined, and for each stage, a suitable research method is identified.

Chapter 5 Presents the execution of the first stage of the research programme by defining the decision process, criteria, variables and choices. This is achieved through the construct of a decision framework from existing manufacturing strategy literature. This framework then establishes the requirements of the decision model.

Chapter 6 Presents the execution of the second stage of the research programme by constructing the decision model. This is achieved through the review of decision modeling techniques against the requirements of the decision model established in Stage 1. A decision model is then constructed with the choice technique selected.

Chapter 7 Presents the execution of the third stage of the research programme by verifying the decision model constructed in Stage 2. This is achieved through interviews with academic and industrial experts in this field of study. The purpose is to assess how well the decision model constructed match up against the experts' opinion and process in making such decisions. The decision model is then refined with the experts' feedback.

Chapter 8 Presents the execution of the fourth stage of the research programme by validating the refined decision model in Stage 3. This is achieved through case study research on eight selected manufacturing organisations. The purpose is to validate the causal linkages established in the decision model against actual industrial scenarios. The final decision model is then established.

Chapter 9 Presents the execution of the fifth and final stage of the research programme by applying the final decision model from Stage 4 in the form of a guidebook for industrial application. The causal linkages between practices and competitive strategies are explained and drawn. This guidebook then serves as an aid for practitioners in the analytical selection process of manufacturing best practices.

Chapter 10 Concludes this thesis with discussions on the principal research findings against the research aim, contributions to knowledge, and limitations of the research programme and findings. It finally discusses the future research directions that could follow from this research.

This chapter provides an overview of the research background, the research aim, objectives and programme, a summary of the research findings and contribution, and the thesis structure. In the next chapter, an overview of the industrial context for best practice adoption in Singapore is presented.

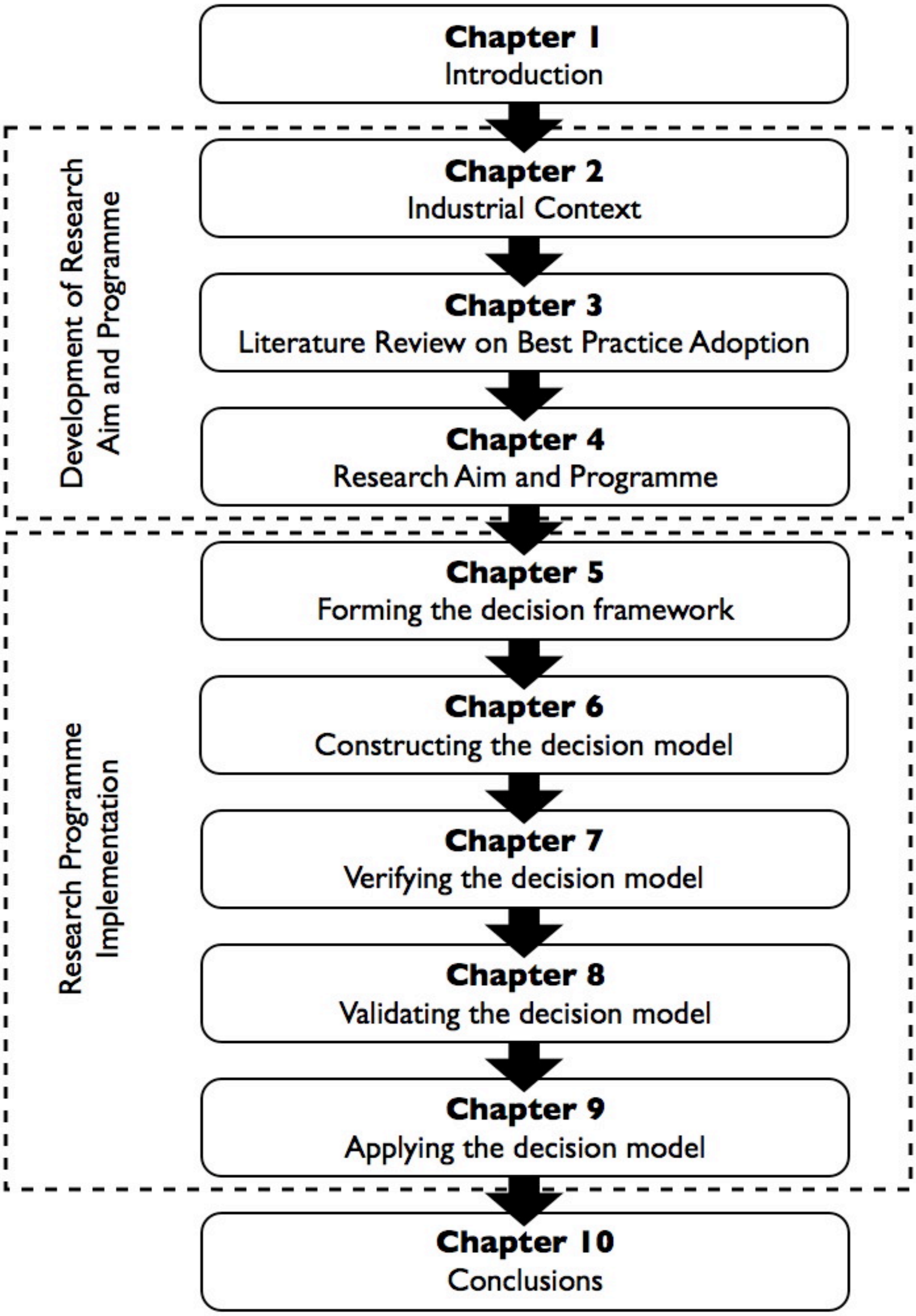

Figure 1.1 An Overview of the Research Programme

Chapter 2: Industrial Context

Chapter 1 has set out the background to the research, an overview of the research aim, objectives and programme, followed by a summary of research findings and contribution. This chapter deals with the industrial context of the research, emphasising the importance of manufacturing within the Singapore economy and the challenges faced by Singapore's manufacturing. Subsequently, the value of best practice adoption to Singapore is discussed, presenting a case for this research.

2.1 Manufacturing within the Singapore Economy

Manufacturing has been recognised as the key to future prosperity (Cohen and Zysman, 1987; Baines, 1995; Fingerton, 1999). It is also the largest single contributor to global economy accounting nearly three quarters of the World's trade (DTI, 2000). Manufacturing represents a leading sector in the economy of most developed countries. This is because manufacturing spurs demand for everything from raw materials to intermediate components to software to financial, legal, health, accounting, transportation, and other services in the course of doing business. Manufacturing is like an integral part of a web of inter-industry relationships that create a stronger economy as it sells goods to other sectors in the economy and, in turn, buys products and services from them (Fingerton, 1999).

The 'Manufacturing' economy encompasses manufacturing and also supports other industries, which depend on a strong manufacturing base, such as finance, telecommunications, wholesaling and accounting. Thus, it is a significant component of a nation's economy as it fundamentally affects the employment, wealth creation, international standing and quality of life of a country (ERC, 2002). This is evident from the growth of Singapore's Gross Domestic Product (GDP) where its share has grown from 11 per cent in 1960 to 27 per cent in 2005 (see Figure 2.1).

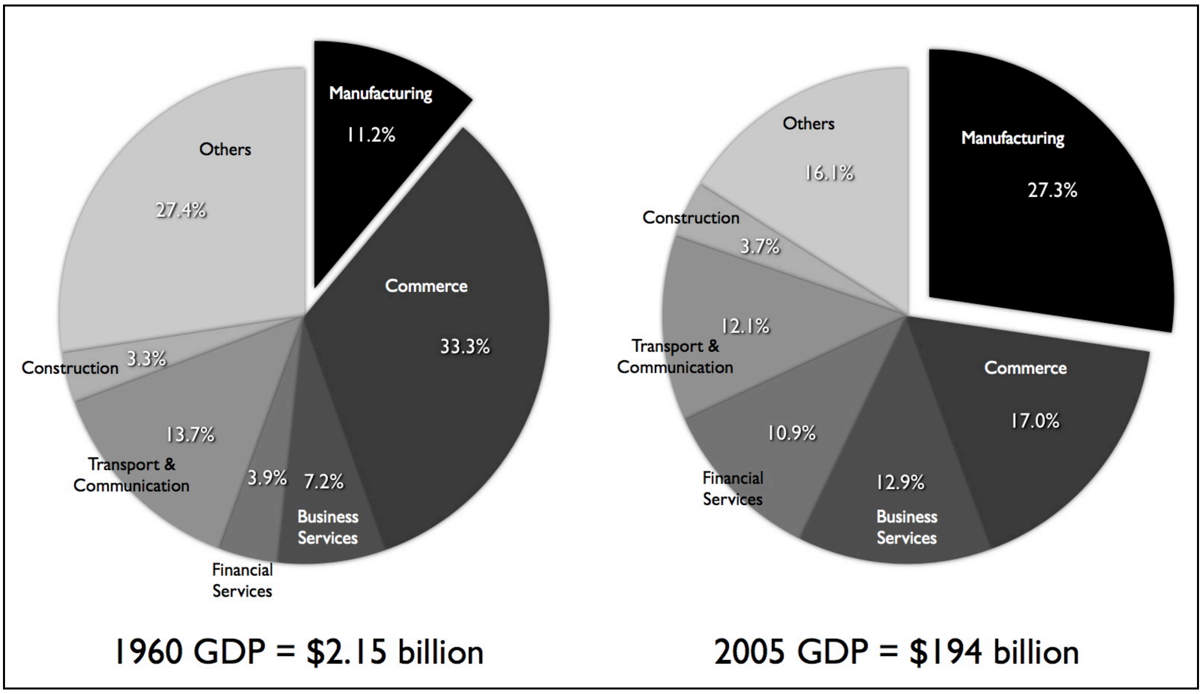

Figure 2.1 Singapore's Manufacturing Sector's Share of GDP (Source: Nah, 2006)

Total manufacturing output has also grew by about 7.7 per cent per annum from year 1991 to 2005 and performance of the sector has showed a rising trend during this period except 1998 and 2001 (see Figure 2.2). The contraction of the manufacturing output in 1998 was largely due to the shutdown of firms during the economic crisis, whereas the downturn in 2001 was attribute to sluggish global demand, particularly in electronics products. This trend is also reflected in the output of the major manufacturing clusters like Electronics, Chemical and Precision Engineering (see Figure 2.3)

Manufacturing has accounted for more than half of Singapore's exports and has generated many spin-offs for the economy and contributed to the development of the country's domestic support industries (ERC, 2002). Manufacturing diversifies the country's economic base, thereby increasing its resilience against cyclical fluctuations in the global economy. It also fuels the growth of the services sector, generates jobs at all skill levels and creates a robust platform for technology and innovation development. To-date, manufacturing has accounted for about 20% of the country's employment. With a projected growth to create 15,000 new manufacturing jobs from new manufacturing projects as well as 6,500 spin-off jobs in the services sector, it is expected that Singapore's total manufacturing output will reach $300 billion by 2018 (EDB Annual Report, 2005/6).

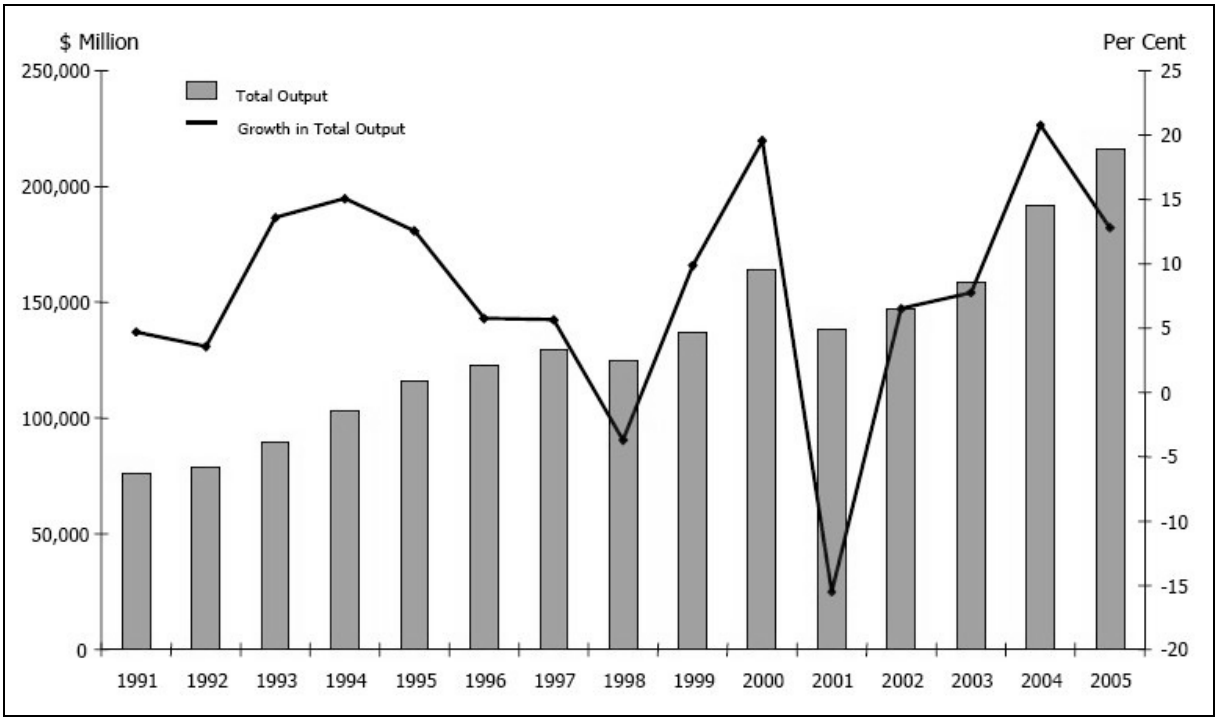

Figure 2.2 Performance of the Manufacturing Sector from 1991-2005 (Source: Nah, 2006)

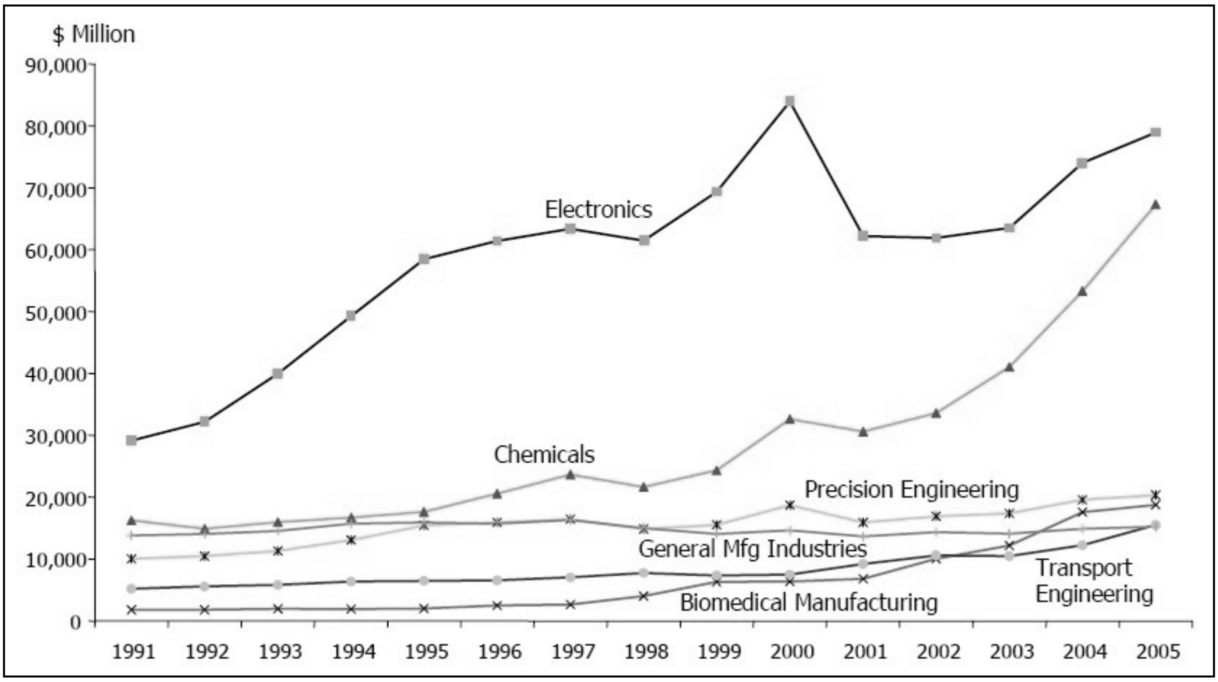

Figure 2.3 Output of the Manufacturing clusters from 1991-2005 (Source: Nah, 2006)

2.2 Challenges to Singapore's Manufacturing

Manufacturing has long been one of the prime engines of progress in Singapore as evident in the economic data presented in the previous section. Therefore, it is essential that manufacturing remains a vibrant, sustainable and substantial component of the country's economy for years to come. However, Singapore faces many challenges that are the result of changes taking place in both manufacturing industries at large, and in the socio-economic order in Asia. To keep the country's manufacturing competitive, Singapore must focus on providing an attractive business environment for value-added manufacturing, while adopting new technologies and developing new markets for its products (ERC, 2002).

In spite of the growth experienced, the percentage of workforce employed by manufacturing was down by 28% over the past decade (ERC, 2002). The best explanation for this is the shift in nature of the manufacturing industry in Singapore from lower value labour-intensive activities to high-value research and knowledge-based activities. This is evident in the general upward trend of labour productivity in the manufacturing sector from year 1991 to 2005 (see Figure 2.4), averaging at an annual growth rate of 4.4 per cent. In line with the output trend discussed in the previous section, productivity dipped in years 1998 and 2001, but registered strong growth in years 2000 and 2005. With China hollowing out the traditional manufacturing in many countries, as a result of low wages and operating costs, there is an even greater needs for Singapore to maintain if not increase this productivity growth to stay competitive as a viable manufacturing hub (ERC, 2002). The country needs to move towards producing more sophisticated and high value-added products, which needs the full complement of skilled workers. Therefore, there is also a need to engage in continuous training programme to upgrade the skills of the workforce to meet this new requirement.

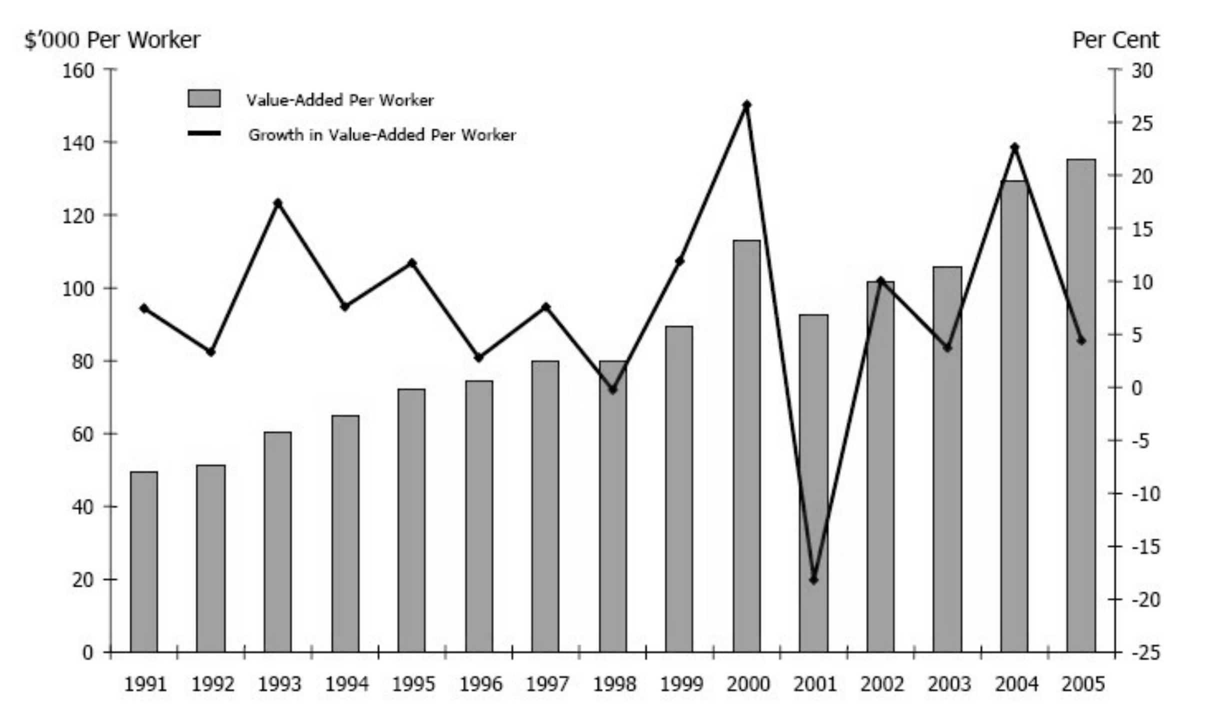

Figure 2.4 Productivity in the Manufacturing clusters from 1991-2005 (Source: Nah, 2006)

Skills of workforce are not the only concern for Singapore in moving up to higher value product manufacture. The country needs to provide an environment conducive for innovation, development and commercialisation of goods and services within industry clusters that span the entire product lifecycles. Singapore needs to make a transition from a 'fast follower' economy to a global leader in order to maintain the current GDP share of above 20 per cent by the manufacturing sector (ERC, 2002). Manufacturing value chain must be extended so that innovations in devices, processes and branding take place in Singapore. With competition from low cost countries like China, where the operating cost for manufacturing is relatively low, Singapore is in danger of being 'squeezed out' as it faces increasing competition from low cost manufacturing locations whilst lagging behind developed nations in the sophistication of technology and calibre of innovation (see Figure 2.5). The perception is that Singapore has become uncompetitive as a base for manufacturing, allied with the lack of market for products either within Singapore or the immediate neighbours. Tax and financial incentives offered to the multinational companies (MNCs) are no longer enough to retain them, if labour and operational costs are making the difference between profitability and liquidation (ERC, 2002). Thus, Singapore's manufacturing needs to move up the value chain and compete on other non-cost competitive bases like innovation, quality and service.

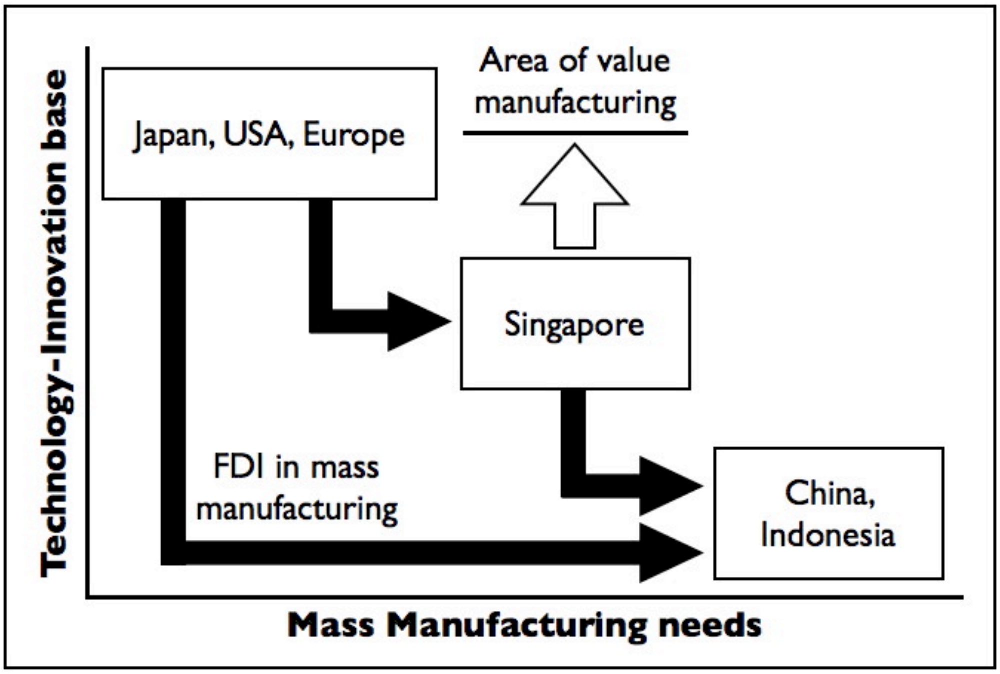

Figure 2.5 Singapore moves to value manufacturing (Source: ERC, 2002)

In summary, this section has presented the challenges faced by Singapore's manufacturing. With the rise of low cost industrialised nation like China in the region, Singapore is faced with increasing cost competition to retain and attract foreign investment in setting up manufacturing bases here. Moving up to higher value product manufacture, Singapore needs to transition from a 'fast follower' economy to a global leader. To retain the country's competitiveness as a manufacturing hub in the region, it has to adopt new technologies and best practices to develop new markets for its products and compete in other non-cost competitive attributes like innovation, quality and service.

2.3 Value of Best Practice to Singapore's Manufacturing

The significance of this research is totally dependent on the value of best practice adoption, in particularly to Singapore's manufacturing. Therefore, this section seeks to present the evidence that successful adoption of best practices could help to address the challenges faced by Singapore's manufacturing.

2.3.1 Needs for Best Practice

As global competition intensifies, achieving best practices and world-class performance is not just a desirable goal, but a necessity for survival (Schonberger, 1987; Elmore, 1998). With the growing interest in best practice, it was inevitable to measure the extent of its usage. Essentially, an approach taken was to compare or "benchmark" existing practices and performance with best-known standards drawn from empirical evidence accumulated within 'winning' organisation (Camp, 1989; Hanson and Voss, 1995). Such study has also lead to the worldwide trend of organisations adopting practices from best-in-class companies (Clarke and Mia, 1993; Sohal, 1996; Chia and Hum, 2000; Chiou et al., 2002) to achieve similar superior performance and success.

In Singapore, the Productivity Service Board (PSB) has partnered the National University of Singapore (NUS) to set up the NUS-PSB Centre for Best Practices (CBP). This centre aims to help the small and medium-sized enterprises (SMEs) to attain significant improvements in their business competitiveness and productivity through the adoption of best practices. Its tasks are to develop industry scorecards, best practice implementation models and assessment tools, document best practice cases and facilitate best practice networks and learning circles.

2.3.2 Importance of Best Practice to Singapore

It was reported that the links between best practices and improved performance is self- evident (Voss et al., 1997). Any investment of time or resources in a new practice will necessitate the provision of benefits in terms of improved performance. This statement is also supported by the International Quality Study (IQS), which reports, “the ultimate result of management practices of an organisation is performance – market performance, operational performance and financial performance”. Flynn et al. (1997) have used the term “world class manufacturer” to describe organisations which achieved a global competitive advantage through the use of their manufacturing capabilities as a strategic weapon. In the study, they had cited a number of critical best practices, including development of workforce, developing a technically competent management group, competing through quality, stimulating worker participation and investing in state-of-the art equipment and facilities. These areas of focus have also been the recommendations proposed by the Economic Review Committee, ERC (2002) to enhance the competitiveness of Singapore’s manufacturing.

ERC (2002) has also proposed a set of national initiatives to support the development of new technology industries to reduce the cost of operation and decrease the time to market for new products. One of them is a plug and play infrastructure whereby each industry has a common set of services that it requires, which are often unique to that industry but are used by all companies in the industry. As such, standards and world-class performance of these components is necessary and adopting best practices from industry leaders is one of the ways to achieve it.

Facilitating the flow of goods, information and people is key to the success of a global leader. Therefore, world-class logistics centres with best-in-class Supply Chain Management (SCM) services will attract companies to locate in Singapore both to support their operations, or as a part of the SCM community. ERC (2002) has recommended workgroups to further encourage specialisation of the SCM capabilities in Singapore, supported by the Government in maintaining the underlying infrastructure including the roads, ports and airport. Government established organisations, such as The Logistics Institute-Asia Pacific (TLI-AP), are maturing into thought leaders in Asia Pacific to encourage the sharing of best practice knowledge with academia and industry to spark innovations in SCM.

In order to overcome the challenge of a higher cost base, Singapore needs to be able to compete on different competitive bases such as quality. With the good branding that the country is enjoying, Singapore can strive to be the centre of excellence in the region through the adoption of best practices by learning and achieving the world-class standards and performance set by developed countries like Japan, US, UK and Europe.

Singapore's advantage is its proximity to low cost producing nation like Malaysia and Indonesia. We can leverage on this fact by shifting the low end manufacturing there while keeping the high value activity onshore. The concept of co-location, using Singapore for knowledge intensive and Riau for labour intensive activities, is a good one and needs to be capitalised upon. The current limitations include the lack of supporting industries and an insufficient logistics network between the two islands. In principle, manufacturing in the Riau islands of Bintan and Batam offers a novel solution to the challenge of value manufacturing by offering labour intensive production close by to Singapore, and the twinning initiative would benefit from the incorporation of Riau in more FTAs.

2.4 Issues with Adoption of Best Practices in Singapore

Adoption of these practices without understanding their associated competitive priorities can result in companies imitating blindly and eventually narrowing their strategic space (Hayes and Pisano, 1994), resulting in sub-optimal or poor performances of organisations (Swamidass, 1986; Schroeder et al., 1986; Swink and Way, 1995; Ward and Duray, 2000).

Acquiring best practice knowledge alone will not help organisations to develop world-class processes. They need to learn, adapt and apply the knowledge to their own processes, and renew the processes when superior practices emerge. For

Singapore to remain competitive, companies must continually face the challenges from low cost industrialised nation like China in the region. To retain the country's competitiveness as a manufacturing hub in the region, it has to adopt new technologies and practices to develop new markets for its products and compete in other competitive attributes like innovation, quality and service. Singapore needs to transition from a 'fast follower' economy to a global leader by moving up to higher value product manufacture. Therefore, an analytical guide to select the most appropriate best practices to adopt in relation to the competitive environment of the manufacturing organisation would improve its performance and competitiveness. The provision of such an analytical guide for best practice adoption is the purpose of this research.

2.5 Chapter Summary

This Chapter has set out the importance of the manufacturing industry to the Singapore economy. Challenges faced by Singapore's manufacturers have been discussed along with the identification of best practice adoption as the key mechanism for the industry to achieve superior performance and sustainable competitiveness for the country. Thus, there is little doubt that the adoption of best practices and the study to enable such adoption is a valuable research topic. In the next chapter, literature review on existing best practice adoption processes will be conducted in the process to develop the aim, objectives and programme for this research.

Chapter 3: Literature Review on Best Practice Adoption

Chapter 2 has established the importance and value of the study in best practice adoption to Singapore's manufacturing. In order to determine a precise aim and programme for this research, the full extent of the knowledge in the literature on best practice adoption must be established. The purpose of this chapter is therefore to introduce the concept of best practice, to define the terminology used in this thesis, to review existing manufacturing best practices, and to explore the issues that currently constrain the successful adoption process of these practices. This is realised by addressing the following questions through a review of the literature that has made a valuable contribution to knowledge in this field.

1. What is a best practice?
2. How is the best practice concept applied?
3. What are the existing manufacturing best practices?
4. How are the adoption decisions on these best practices made?
5. What are the current research issues associated with this adoption process?

3.1 Concept of Best Practice and its applications

The intention of this section is to answer the question of "What is a best practice?" as well as exploring how this concept is applied.

3.1.1 Concept of Best Practice

Camp (1989) defines best practices as those "that will lead to the superior performance of a company". Superior operating performance will in turn lead to superior business performance and competitiveness (Voss, 1995). Heibeler et al. (1989) had described best practices as "the best ways to perform a business process" while Hughes and Smart (1994) proposed a more detailed definition of best practice as "an activity or action which is performed to a standard which is better or equal to the standard achieved by other companies in circumstances that are sufficiently similar to make meaningful comparison possible".

Best practice is a relative term rather than an absolute standard as illustrated by the International Quality Study (IQS), which defines best practices as those that have aided the lower performing organisations to improve to medium performance, medium performers improve to higher performers, and higher performers to stay on top and achieve further benefits. This study has also stated that there are certain practices that are relevant to companies at particular points in their development, and thus for some companies individual best practices may not be appropriate at any particular point in time. Thus, best practices is context specific and Heibeler et al. (1989) had stated that in the experience of Authur Anderson:

> ***"...no single practice works for everyone in any given situation. Best is a contextual term. It means "best for you" – in the context of your business, your company culture, your use of technology, and your competitive strategies."***

Therefore, there is no single best practice, because best practice for one company may not be the best for another company.

3.1.2 Applications of Best Practice

In general, it is assumed that for companies to compete globally, they should emulate the practices of successful companies. Hayes and Wheelwright (1984) used the term "World Class Manufacturer" to describe organisation, which achieved a global competitiveness through the use of their manufacturing capabilities as a strategic weapon. Manufacturing best practice is then an approach that provides the significant improvement in measurable factors such as cost, quality, and time (Ungan, 2005).

Flynn et al. (1997) had cited a number of critical practices, including development of workforce, developing a technically competent management group, competing through quality, stimulating worker participation and investing in state-of-the-art equipment and facilities, all of which can be commonly associated with the Lean manufacturing paradigm or concept. Source of these best practices can be another company (e.g. customer, supplier, or an unrelated company) or another part of the organization (e.g. a sister company or another plant within a company) (Ungan, 2005), which can then be acquired through benchmarking.

3.2 Review of Existing Manufacturing Best Practices

Previous section has cited a number of critical practices, which are associated with the Lean manufacturing paradigm. In fact, the emergence of new manufacturing paradigms is frequently associated with the emergence of radically different ‘best practices’. Therefore, this section present the concept of manufacturing paradigm followed by a review of the existing manufacturing best practices through a historical account of six commonly identifiable manufacturing paradigms.

3.2.1 Concept of Manufacturing Paradigm

Manufacturing paradigms have been discussed by various researchers (William and Cleland, 1981; Manley, 1992; Allred, 1993; Buzacott, 1995; Kotha, 1995; Spina et al., 1996; Rogers and Bottaci, 1997; Tomiyama, 1997; Vonderembse et al., 1997; Naylor et al., 1999; O'Brien, 1999; Offodile and Abdel-Malek, 2002). However, only a few have offered explicit definitions (see Table 3.1), which vary somewhat. So, it is useful to revisit the general terminology in order to identify the most appropriate.

A paradigm can be thought of as a set of rules that establish boundaries as well as how to solve the problems within these boundaries. Morris and Brandon (1994) explain that these rules operate at the subconscious level and influence our perception, helping us to organise and classify the way we look at the world. A paradigm is also seen as a set of unquestioned and subconscious assumptions in the form of a model that helps us comprehend what we see and hear. In this way a new paradigm is taken to be a replacement for the prevailing modus operandi (Spina, 1998; Kuhn, 1996; Towill, 2001). Therefore, in a manufacturing context, the term paradigm can be defined as ‘a set of rules or principles based upon subconscious assumptions that a group of manufacturing organisations adopt to guide and define their design and production of manufactured goods from raw materials'.

Table 3.1 Manufacturing Paradigm definitions reported in the literature

Author	Manufacturing paradigms definition
William and Cleland (1981)	A top-down, command and control management structure that is supported by accounting and business information systems and primarily provides feedback on progress in meeting specified objectives and goals.
Spina et al. (1996)	Limited sets of new principles that underpin the techniques and pool together various manufacturing models of systemic and coherent combinations of practices companies adopt, adapt or autonomously develop, according to their internal and external environment, to suit their situation best.
Rogers and Bottaci (1997)	The underlying manufacturing principles, methods and associated business structures. On a wider point, it refers to the highly specialised and non-transferable nature of manufacturing knowledge.

3.2.2 From Craft to Mass Paradigm

Prior to the emergence of Mass Production, the common method of manufacturing was primarily Craft Production. This mode of production had existed prior to the industrial revolution, where early craftsmen had worked without the benefit of substantial mechanization. Craft Production has therefore commonly referred to the process of manufacturing by hand with or without the aid of tools. Key characteristics about this Craft Paradigm (CP) are highly unique end products, a highly skilled workforce acquiring the full set of craft skills required in designing and producing the product, the use of general-purpose machine tools, low production volume as well as the ability to customise each product to their individual owner (Womack et al., 1991). Manufacturing best practices were slow to diffuse during the industrial revolution. Many craft trade contained closely guarded trade secrets and skills, which were only passed down through apprenticeship. Thus, explaining the reason why the sharing and diffusion of best practices across the industry were slow. This form of manufacturing was dominant across most industries until the beginning of the 20th century when mass production took over, bringing about a paradigm shift through the work of industrialists such as Henry Ford in his automotive assembly lines.

Evidence of Mass Production had appeared as early as the 18th century in the UK textile industry where mechanisation for spinning yarn and weaving drastically increased the productivity of workers as well as the consistency of products. However, this Mass Paradigm (MP) only coalesced with Henry Ford's development of the first assembly line in 1908 to produce identical cars in large quantities. Key characteristics identifiable with MP are a very narrowly skilled workforce, standardisation of manufacturing processes and parts, use of dedicated machines, high production volumes as well as low product variety (Womack et al., 1991).

The MP is typically driven to produce at the lowest cost/price (Duguay et al., 1997) by drastically improving the productivity (Womack et al., 1991). This is achieved via the adoption of economies of scale (Duguay et al., 1997; Duray, 2002), which is associated with best practices like the use of interchangeable and standardised parts as well as the standardisation of works and products. To cope with the intended high volume production, best practices like division of labour and the specialization of machines or tasks were adopted to reduce the non-productive time of machine setup or product change over (Womack et al., 1991; Burgess, 1994; Wilson, 1995; Engstrom et al., 1996; Forza, 1996; Cooney, 2002). To further improve the productivity, mechanisation of the conveyor belt system was employed to move products through the production floor and minimise the movement of workers, leading to the association of continuous flow production system and the use of automated conveyor system as the other best practices in this paradigm. Finally, vertical integration was practiced to reduce the variability in supply and this also lead to adoption of a centralised hierarchical control system to manage and control the huge organisation resulted (Womack et al. 1991; Duguay et al. 1997).

These practices described were highly representative of Ford's innovative mass production system, which had replaced the prevailing modus operandi of craft production in the car industry. This brings about a dramatic cost reduction while increasing the product quality. Within 50 years of the diffusion of MP across the automotive industry in the USA, this paradigm had replaced most of the craft production activities in the industry.

3.2.3 From Mass to Lean Paradigm

Popularity of the Ford production system has inspired many to learn about the Mass Production way including Eiji Toyoda, then the next successor to the Toyota Motor Company. Together with Taiichi Ohno, they concluded that Fordism was not suitable for Japan's manufacturing environment and went on to design the Toyota Production System (Shingo, 1981; Monden, 1983; Ohno, 1988), which was ultimately called Lean Manufacturing (Womack et al. 1991) and will be referred to as the Lean Paradigm (LP) here. Key characteristics of LP include the continuous improvement to eliminate 'wastes' (wasted effort, materials, time, motion, etc.), Just- In-Time (JIT) concept, Kanban system (pull system) and autonomous work teams. The paradigm has also been the most widely studied and adopted mode of manufacturing from mid 20th century into the new millennium.

With the LP, there is a shift in focus from a cost-driven to a quality-driven production. This is evident in the many continual quality improvement programmes that are associated with this paradigm (Sohal and Egglestone, 1994; Forza, 1996; Katayama and Bennett, 1996; James-Moore and Gibbons, 1997; Cua et al., 2001; Karlsson, 2002; Shah and Ward, 2003; Hines et al., 2004), which includes best practices like Total Quality Management (TQM), Total Productive Maintenance (TPM), Kaizen and Quality Circle. The reason for this shift is the recognition of quality as the main source of problems for productivity. Poor quality products or parts will result in reworks/scraps that propagate down the production process, and so incur unnecessary production resources. These non-value-added activities are commonly referred to as waste, which were also addressed by some other activity or process related best practices like Single Minute Exchange of Die (SMED), lot size reduction and value stream mapping (Womack et al., 1991; Katayama and Bennett, 1996; Wilson, 2002; Shah and Ward, 2003). Material waste on the other hand is addressed by practices like demand-driven production and Just-in-Time related activities like procurement and inventory control (Schonberger, 1982; Neil and O'Hara, 1987; Harber et al., 1990; Singh and Brar, 1992; Clarke and Mia, 1993; Lawrence and Hottenstein, 1995; Ramarapu et al., 1995; Spencer and Guide, 1995; Dong et al., 2001; Shah and Ward, 2003). Finally, empowerment of workforce through practices like self-directed teams, multi-skilled workforces and ownership of processes address the organisational waste by unnecessary hierarchy of shop floor supervisors (Sohal and Egglestone, 1994; Forza, 1996; Karlsson and Ahlstrom, 1996; Katayama and Bennett, 1996; Shah and Ward, 2003). Central to the LP thinking was the continuous reduction of all forms of waste (Womack et al., 1991) through the best practiced described. Through them, it has brought about continuous improvement in productivity as well as product quality and has permeated beyond manufacturing to the other industries like service, construction and maintenance (Hines et al., 2004). Towards the end of the 20th century, when the popularity of LP was probably at its height (Mowery et al., 1993; Womack and Jones, 1994; Katayama and Bennett, 1996; Liker, 1998), other new manufacturing concepts emerge (Liles and Huff, 1990; Carter and Baker, 1992; Baker, 1994; Kaighobadi and Venkatesh, 1994; Owen, 1994; Kotha, 1995; Rosenfield, 1996; Spina et al., 1996; Mahaney, 1997). Most of these manufacturing concepts had originated from the USA and of them, the most popular were Quick-Response Manufacturing (Suri, 1998), Time-based Manufacturing (Blackburn, 1991), Mass Customisation (Davis, 1987) and Agile Manufacturing (Kidd, 1994).

3.2.4 The rise of Time-based Paradigm

Quick-Response Manufacturing (QRM) finds its roots in a strategy used by Japanese enterprises in the late 1980s (Schmenner, 1988; Stalk, 1988). This strategy later became known as Time-Based Manufacturing (Blackburn, 1991; Baker, 1994). In contrast to the LP, which emphasises on waste reduction, this Time-based Paradigm (TBP) strives on a relentless emphasis on lead time reduction. The key characteristics of the TBP are continuous improvements to reduce lead time in all aspects of a company’s operations, exploitation of system dynamics principles to define the best structures and policies for lead time reduction, a large variety of products with variable demand, and the POLCA (Paired-cell Overlapping Loops of Cards with Authorisation) system (Suri, 1998).

TBP shares many similarities with the LP especially in its associated best practices like the deployment of cross-functional teams (Q-ROC) and demand-driven production (POLCA system) (Suri, 1998). Quality improvement programmes are also evident in this paradigm (Blackburn, 1991; Koufteros et al., 1998). However, a key difference here is the emphasis of time as waste (Gehani, 1995; Kumar and Motwani, 1995; Bozarth and Chapman, 1996; Koufteros et al., 1998; Jayaram et al., 1999; Nahm et al., 2003). In LP, all waste is treated equally whether it is in the form of materials (scraps and inventories) or non-materials (time and non value-added activities). This is different from the TBP, where non-material wastes are treated with higher importance than material wastes. Such differentiation thus separates the two paradigms with the TBP being delivery-driven (Stalk, 1988; Lindsley et al., 1991; Gehani, 1995; Bozarth and Chapman, 1996; Jayaram et al., 1999; Ko et al., 2000) as opposed a quality driven LP. This is evident in the differences between the two key practices associated with each of these paradigms. POLCA (in TBP) is a combination of a pull and push system while Kanban systems (in LP) is a pure pull system (Suri, 1998). This implementation will encourage the holding of some inventories in TBP as a result of the push mechanism in order to reduce lead-time, at the expense of some material wastes.

In summary, instead of adopting practices for general waste reduction in LP, a more specific waste reduction activity in the form of lead time reduction is adopted for the TBP. Key best practices found here will therefore be similar to some of those found in the LP like quality programmes, self-directed and flexible workforce, value-stream mapping etc. (Kumar and Motwani, 1995; Bozarth and Chapman, 1996; Hum and Sim, 1996; Koufteros et al., 1998; Ko et al., 2000;; Tu et al., 2001; Nahm et al., 2003) except that the focus is very much on the shortening of time to delivery, even at the expense of non time-based attributes (excess inventory and production capacity etc.) if necessary. It is also noted that the manufacturers adopting the TBP are mainly producing high variety and highly engineered products (Gehani, 1995; Tersine and Hummingbird, 1995; Hum and Sim, 1996; Jayaram et al., 1999). Thus, to support the fast delivery of highly customised products, best practices like concurrent engineering, cross- function work teams, close customer involvement and rapid prototyping are also associated with this paradigm (Gehani, 1995; Kumar and Motwani, 1995; Tu et al., 2001; Nahm et al., 2003).

3.2.5 From Mass to Mass-Customise Paradigm

During the 1990s, a paradigm shift occurred again with mass-customised production systems (Kotha, 1995), termed here as the Mass Customisation Paradigm (MCP). Davis (1987) coined the term mass customisation where a mass- customised product is defined as a 'one-of-a-kind product, manufactured on a large scale' hence it embraces economies of scope as well as scale. Key characteristics of MCP are high product variety, modularised components to customise end products, and postponement strategy (Feizinger and Lee, 1997; Pilkington and Chong, 2000). MCP can be viewed as a reaction to the signs of weakness shown by MP with the mass production of standardised products at an affordable price for largely homogeneous markets. Since its identifications (Davis, 1987; Pine et al., 1993), MCP has received a considerable attention in the research literature (Feizinger and Lee, 1997; Gilmore and Pine, 1997; Alford et al., 2000; Silveira et al., 2001; Karlsson, 2002; MacCarthy et al., 2003; Alptekinoglu, 2004; Partanen and Haapasalo, 2004). Postponement strategy is a key practice in MCP (Feizinger and Lee, 1997; Duray et al., 2000; Duray, 2002; Su et al., 2005), which proposed that the customisation of the final product be postponed to as late a stage as possible in the assembly process so as to consolidate the inventories of the sub-components as well as leveraging on the economies of scale from the common sub-components shared by the final products. This strategy is only possible with a highly modularised product, such as the computer, where many varieties of end products share a high percentage of common sub-components. Therefore product and process modularisation (Pine, 1993; Feizinger and Lee, 1997; Gilmore and Pine, 1997; Duray, 2002) are also key best practices in this paradigm. This paradigm is also flexibility-driven (Pine, 1993; Feizinger and Lee, 1997; Gilmore and Pine, 1997), as evident from its flexible process and product configuration, thus offering fairly varied products at a reasonably low cost.

MCP typically exists in an environment of a high level of unique customer needs (Pine, 1993; Feizinger and Lee, 1997; Gilmore and Pine, 1997), such as the computer market. As such, a high level of market segmentation is the norm to cluster groups of customers sharing similarities in order to exploit the economies of scale. The environment also exhibits a medium level of variety or moderate degree of customisation (Pine, 1993; Feizinger and Lee, 1997; Gilmore and Pine, 1997) as compared to the highly customised products seen in TBP.

3.2.6 Agile Paradigm for the future

Agile manufacturing was coined during a US government sponsored research programme at Lehigh University and, latterly, MIT (Nagel et al., 1991). It seeks to cope with demand volatility by allowing changes to be made in an economically viable and timely manner (Kidd, 1994). It has been defined with respect to the agile enterprise, products, workforce, capabilities and the environment (Gunasekaran, 1998), that gives impetus to the development of the Agile Paradigm (AP). Some of the key characteristics of the AP are high quality and highly customised products, products and services with high value-adding content, mobilisation of core competencies, responsiveness to change and uncertainty, synthesis of diverse technologies as well as intra-enterprise and inter-enterprise integration (Youssef, 1992; Goldman and Nagel, 1993; Kidd, 1994).

AP has the key objective of coping with unexpected and rapid changes (Duguay et al., 1997; Quintana, 1998; Zhang and Sharifi, 2000; van Hoek et al., 2001; Brown and Bessant, 2003; Bruce et al., 2004; Coronado et al. 2004). Thus, effective change management processes are evident in this paradigm (Vastag et al., 1994; Zhang and Sharifi, 2000; van Hoek et al., 2001; Guisinger and Ghorashi, 2004). This is manifested in the form of these infrastructural practices adopted by the organisation in AP, for example, integration of product/production/business information, virtual enterprise, decentralised organisation, rapid partnership formation and outsourcing. All these practices are mechanisms to cope with the continuous changing market (Duguay et al., 1997; Quintana, 1998; Zhang and Sharifi, 2000; Coronado et al., 2004; Guisinger and Ghorashi, 2004). Strategic alliances, which leverage on sharing of resources to reduce risk from the dynamic environment, is also another key practices in this paradigm (Youssef, 1992; Gunasekaran, 1998).

Organisations adopting AP are typically global companies with worldwide operations (Vastag et al., 1994; Prater et al., 2001; Bruce et al., 2004; Coronado et al., 2004; Guisinger and Ghorashi, 2004). This is in line with the effect of globalisation, which has resulted in increased competition and volatile market demand, a condition that is addressed by the AP. The scope of operations for organisations adopting the AP is also large through alliances; this is in order to provide the customer with total solution products. Thus, the AP can be identified as service-driven.

In conclusion, the AP appears to be most suited to a highly volatile and dynamic market environment, typical of a globalised economy (Burgess, 1994; Vastag et al., 1994; Quintana, 1998; Prater et al., 2001; Brown and Bessant, 2003; Bruce et al. ,2004; Coronado et al., 2004; Guisinger and Ghorashi, 2004). Organisations adopting this paradigm typically have widely dispersed operations and are generally organised in a decentralised manner to serve the diverse needs of their large customer base (Prater et al., 2001; Coronado et al., 2004; Guisinger and Ghorashi, 2004). The competitive practices typically found here are strategic partnerships, outsourcing, virtual integration and self-managed knowledge workers who adapt to the rapid changes and uncertainty of the environment (Duguay et al., 1997; Quintana, 1998; Zhang and Sharifi, 2000; Coronado et al., 2004; Guisinger and Ghorashi, 2004)

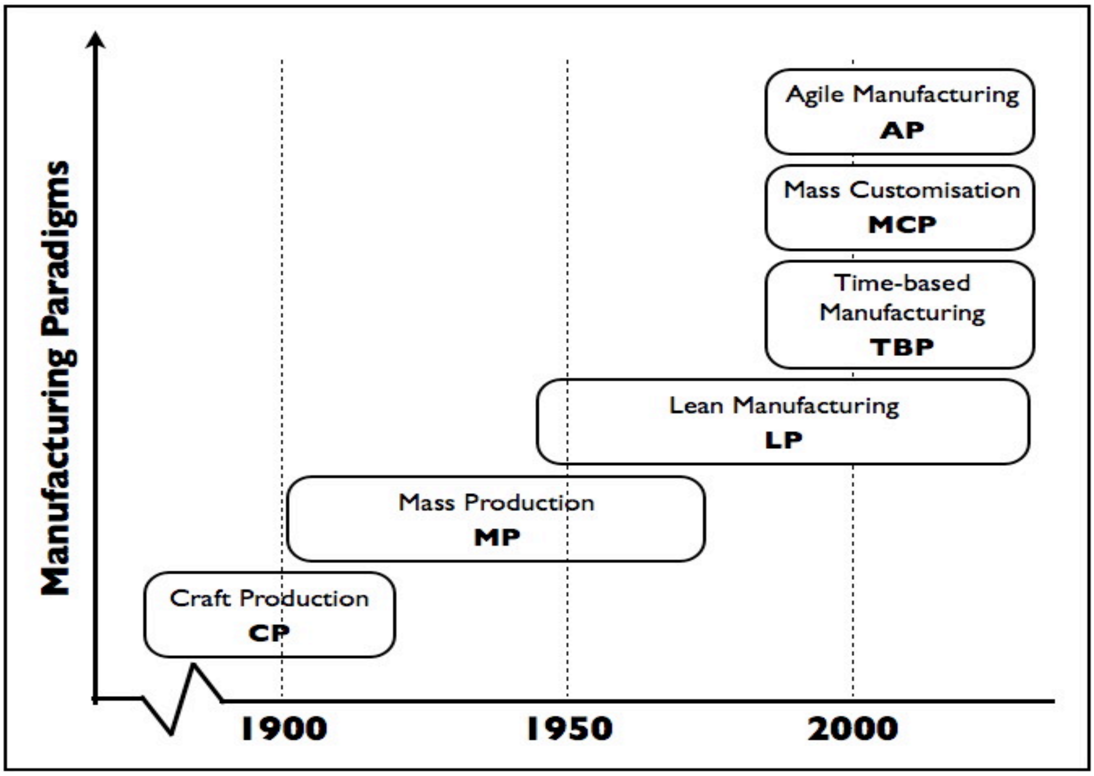

Figure 3.1 Emergence of Manufacturing Paradigm

In summary, six distinct manufacturing paradigms have emerged in the recent history of manufacturing and their associated key best practices had been identified and discussed in this section. These paradigms are illustrated in Figure 3.1 in a chronological map of their emergence.

3.3 Review of Best Practice Adoption

The previous section has presented a review of the existing manufacturing best practices through a historical account of six manufacturing paradigms. It is therefore the intent of this section to review and understand how the adoption decisions for these best practices are currently made. Two common adoption concepts frequently associated with best practices are identified in Section 3.1. They are World Class Manufacturing and Benchmarking. The former encompasses a variety of management practices that were derived from empirical facts and data collected from 'winning' organisations (Voss, 1995) while the latter refers to the search for industry best practices that leads to superior performance (Camp, 1989). These concepts share many similarities as well as subtle differences in their approaches to best practice adoption. Thus, a review on them will reveal the existing knowledge on the adoption approaches.

3.3.1 World Class Manufacturing

World-class manufacturing (WCM) and best practice are concepts that encompass a variety of management practices (Voss, 1995). In fact, Voss (1995) describes WCM as a subset of best practice. These concepts were initially applicable to manufacturing based functions. Later with the advent of techniques like concurrent engineering, customer care programmes and activity based accounting they got extended to functional areas such as design, marketing and costing.

Popularity of manufacturing best practices can be attributed to the quest for WCM status by organisations worldwide. Clark (1996) has reported that manufacturing best practices have gained wide acceptance and popularity in industries that some leading manufacturers are building their own plants based on them. One example is the Daimler Chrysler's Toledo North Assembly Plant, which represents the culmination of best practices from the company's worldwide manufacturing operations. Another evidence for their popularity is the launch of the programmes on manufacturing best practices that some industrialised countries such as the USA and Australia had actually conducted (Struebing, 1996). These programmes are industry and government cooperative efforts that intend to improve the competitiveness of those countries' industrial bases.

There are also many perfectly sound conceptual models for WCM reported in the publications of manufacturing authors, consultants and government reports. The high-level Quality templates from the Malcolm Baldrige American National Quality Award and the European Foundation for Quality Management are some of them. Hanson and Voss (1995) has provided a similar conceptual framework for world-class business operation (see Figure 4.2).

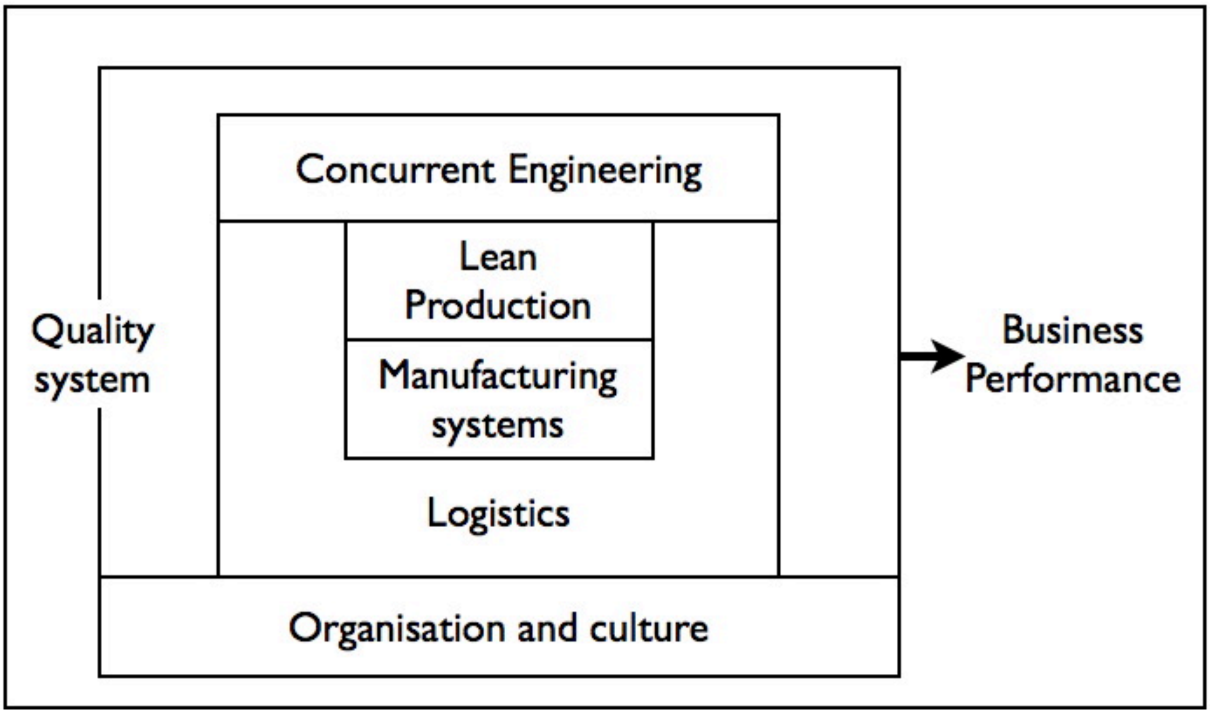

Figure 3.2 World Class Manufacturing – Best Practice Model (Source: Hanson and Voss, 1995)

The goal of achieving and maintaining world class manufacturing capability is a continuously moving target. However, through examining the elements in the model of best practice, Companies are able to measure, compare and evaluate the performance of existing processes, products or services against that recognised as world-class practices through benchmarking. Thus, brings forth the next adoption concept for review.

3.3.2 Benchmarking

The next common adoption approach of best practices is benchmarking. However, benchmarking is still not well defined as over 42 definitions were found by one source (Heib and Daneva, 1995) as cited by Sarkis (2001). The meaning of the word benchmark as defined by Merriam-Webster's Collegiate Dictionary (2003) refers to a point of reference from which measurement may be made; something that serves as a standard by which others may be measured or judged. Thus, benchmarking is defined here as the search for industry best practices that leads to superior performance (Camp, 1989). Pryor and Katz (1993) had refined it as “a process for measuring your performance against best-in-class companies, then using the analysis to meet and surpass the best-in-class companies”.

Benchmarking represents a continuous, systematic process for evaluating the products, services, and work processes of organisations that are recognised as representing best practices, for the purpose of organisational improvement (Sarkis, 2001). At the core of successful benchmarking lies a regular and documented worldwide scan for organisations that are skilled at what they do, regardless of industry (Garvin, 1993). Thus, benchmarking has been used as a goal-setting process to aid the setting of performance objectives for achieving performance improvements (Venetucci, 1992). It is also an effective tool for planning and implementing change processes that lead to organisational improvement when the knowledge gained is converted into a detailed action plan to improve competitive advantage (Pryor, 1993).

Benchmarking process has a number of levels that can be used in the analysis of an organisation (Camp, 1989):

- Internal benchmarking – benchmarking against internal operations or standards, usually in a multi-division or multinational enterprise.
- Industry benchmarking – benchmarking against other companies in the same industry, whether they are direct competitors or not.
- Process benchmarking – benchmarking generic processes (e.g. order receipt and dispatch process) against best operations or leaders in any industry.

Camp (1995) has later separated the industry benchmarking into "competitive" and "functional" benchmarking with direct competitor benchmarking fitting under the former category, and those from other industries within the latter. Pozos (1995) has also presented another category called strategic benchmarking, which is defined as the proactive analysis of emerging trends, options in markets processes, technology, and distribution that could affect strategic direction and deployment.

In summary, the two common approaches to best practice adoption are reviewed. WCM defines a subset of best practices that are regarded as quintessential for the attainment of "World-Class" status by organisations worldwide. Thus, representing a goal for achieving and maintaining "World-Class" manufacturing capability. Benchmarking on the other hand presents a more practical and focused approach by relating industry best practices to specific performance targets. Both concepts although defers slightly in the definition of the end goal for the organisation, their approaches are similar in the setting up of exemplar best practice models to guide the adoption process. However, companies adopting these approaches do not result in attaining competitive advantage as they will only be as good as their toughest competitors (Hayes and Wheelwright, 1984). Thus, the next section will present and discuss the research issues related to such adoption process.

3.4 Current Research Issues in Best Practice Adoption

Previous sections have introduced the concept of best practice, a review of the existing manufacturing best practices and a review of the existing adoption approaches. Against this background, this section establishes the need for future research that focuses in the area of manufacturing best practices adoption.

3.4.1 Overview of general research issues

Much of the literatures in the area of best practice research is descriptive in nature, only describe the practices that successful companies have in place (Shingo, 1981; Schonberger, 1987; Ohno, 1988; Merrills, 1989; Womack et al., 1991; Voss, 1995; Engstrom et al., 1996; Feizinger and Lee, 1997; Magretta, 1998; Duray et al., 2000; Alberto and Maurizio, 2002; Laugen et al., 2005; Dangayach and Deshmukh, 2006). A vast majority of this literature is also limited to the dissemination of best practice without discussing in detail the necessary context to the practices, which is necessary to help companies in determining the most appropriate best practices for their competitive environment.

Studies of relationships between practices and performance in the area of manufacturing are also limited. Although studies such as (Swamidass and Newell, 1987; Womack et al., 1991; Voss, 1995; Flynn et al., 1997; Harrison, 1998) have been undertaken with the explicit aim of investigating the relationship between best practices and performance. The links between practices and performance are typically general and assumed to be self-evident (Voss et al., 1997). There is little cause and effect analysis of the impact of these practices on performance.

This field of research is also rather scattered with many articles focusing on only one or a limited set of practices (Swamidass and Newell, 1987; Hanson and Voss, 1995; Lawrence and Hottenstein, 1995; Spencer and Guide, 1995; Flynn et al., 1997; Rondeau et al., 2000; Cua et al., 2001; Fullerton and McWatters, 2001; Nahm et al., 2003; Shah and Ward, 2003; Banerjee, 2005). Studies taken place also vary in methodologies and results. Thus, there is a need for a more holistic model that will bring together these disparate pools of knowledge and encompasses a bigger set of practices for adoption consideration.

In summary, the three main research issues to best practice research are identified. They are the lack of study on practices in context of their applications, limited cause and effect analysis on the impact of practices on performance and the lack of holistic model that encompasses a bigger set of practices for adoption consideration. Therefore, it is the intent of the subsequent sections to identify the outstanding research issues with respect to these issues identified.

3.4.2 Research issues on best practice to performance relationship

There are relatively few large-scale studies that empirically link practices with performance. In many instances, the relationships between best practices and improved performance are assumed to be self-evident (Voss et al., 1997). However, the need to link practices to performance has become especially important for companies striving to achieve the goal of WCM and has been the subject of studies by IBM Consulting (1993, 1994) and Andersen Consulting (1993, 1994). Such studies indicate that operating performance is critical to the overall competitiveness, and that operating practice is critical to operating performance (Voss, 1995). Thus, the causal linkages between operational practices and performance are key to improving overall competitiveness.

Voss (1995) states that the introduction of new practices in manufacturing is normally associated with expected benefits in terms of improved performance in specified areas. However, trade-offs do exist between the competitive priorities of quality, cost, delivery and flexibility and this has been the underlying argument of much operations management literature (Skinner, 1969; Hayes and Wheelwright, 1984). The existence of these trade-offs makes it critical that the practices implemented to achieve one competitive priority do not have an adverse effect on another. In the same way that trade-offs must be managed, so must the effects of implementing practices. Thus, there is a need to determine which practices to use for improving a specific areas of performance, in addition to analysing any detrimental effects on other performance areas.

3.4.3 Research issues on best practice models

There is no scarcity of best practice models in the manufacturing literatures, with many of them based on the Japanese's "Lean" model, such as "The Machine that Changed the World" (Womack et al., 1991), "Lean Thinking" (Womack and Jones, 1996a), and "The Lean Enterprise Benchmarking Project" (Anderson Consulting, 1993). However, these studies focus on the dissemination of knowledge on "Lean" practices and provides little cause and effect analysis on the impact of these practices on performance. Thus, providing no indication of how these practices are prioritised.

Another example is the MRPII Class A best practice model (Tincher and Sheldon, 1997), which defines operational excellence in terms of key measures and target. It provides guidelines on what companies should be aspiring to achieve operational excellence. Although links have been made between basic practices and measures of performance, there is again no analysis on the priority of practices or any account for the cause and effect relationships and ease of implementation. Instead, it focuses on the improvement efforts for a set performance targets. For example, to achieve the target for inventory accuracy, it is recommended to limit access to the stores, adopt a "zero defects" attitude, implement a good transaction system, and introduce cycle counting as oppose to annual physical inventory (Wallace, 2001).

These failure to link practices to specific measurable objectives, to prioritise best practices and the lack of analysis on the necessary infrastructure required for the practices is often the reasons for disappointing results from the best practice implementation (Davies and Kochhar, 2000).

3.4.4 Research issues on adoption approaches of best practices

Earlier published materials show that benchmarking is closely associated with the financial result (Rigby, 2001), operational performance and business performance (Voss et al., 1997), and the capacity for change in strategic thinking and action (Drew, 1997). This subject has also attracted a diverse range of interest since the early 1990s, with academic literature ranging across a broad range of disciplines such as: strategic purchasing (Carr and Smeltzer, 1999), innovation practices (Ahmed et al., 1996), manufacturing practices (Magan et al., 1999), business process re-engineering (Talluri, 2000), logistics services (Millen et al., 1997), sales forecasting performance (Kahn, 1998), project management (Ramabadron et al., 1997), health and safety management (Fuller, 1997) and agile manufacturing (Sarkis, 2001). Despite these interests, substantial research evidence has also revealed that organisations are generally not willing to adopt or they are not successful in implementing their findings (Longbottom, 2000).

According to Ungan (2005), compatibility of practices, cost of adoption, the companies' satisfaction of existing practices and the pressure of operating environment have a significant impact on the adoption decision. Thus, these conditions must be considered in the adoption process to improve the adoption rate and outcome.

3.4.5 Summary of issues with Best Practice Research

Accepting that a research thrust in the area of best practice research is justified, it is appropriate to explore the issues that surround this research. From the discussion in the previous sub-sections, four major shortcomings of current research approaches are identified and summarised below,

1. This field of research are typically descriptive in nature and fragmented with many articles focusing on only one or a limited set of practices. Thus, resulting in varying methodologies and performance (Section 3.4.1).

2. There are limited cause and effect analysis on the impact of practices on performance, which is important to understand the trade-offs between practices (Section 3.4.2).

3. Existing best practice models lack the linkages between practices and objectives, the prioritisation of best practices for adoption and the analysis on the necessary infrastructure required by the practices, which are often the causes for disappointing results (Section 3.4.3).

4. Current adoption processes seldom consider the compatibility of practices, the cost of adoption, the companies' satisfaction of existing practices and the pressure of operating environment, which have significant impacts on the adoption decision (Section 3.4.4).

Another important shortcoming, which was not highlighted but implicit in the discussions, is the limited deployment of best practice as a strategic weapon to attain competitive advantage. Most discussions on best practices are in association with the attainment of operational excellence and competitiveness with the best-in-class. Thus, it only puts the company on par with the toughest competitor and does not yield sustainable competitive advantage. These research gaps will then guide the direction of the best practice research proposed and detailed in the next chapter.

3.5 Chapter Summary

This Chapter has discussed the concepts of best practice, its applications and the current issues constraining the successful adoption process. Firstly, the concepts of best practice were introduced to set the terminologies used. This is followed by a review of existing manufacturing best practices through a historical account of six commonly identifiable manufacturing paradigms. Subsequently, the best practice adoption concepts and processes were reviewed and discussed to identify the research gaps to guide the direction of best practice research.

Chapter 4: Research Aim and Programme

Chapters 2 and 3 have established the domain for the research. It is therefore the intention of this research to assist practitioners in the best practice adoption process. This chapter summarises the knowledge supplied from earlier chapters to generate a precise aim and programme that will fulfill this research intention. In the following sections, an overview of the research problem will be provided. This will lead to the development of the research aim and objectives. Subsequently, the research programme is described with discussion on the choice and rationale of the research methods. Finally, a conclusion of the chapter is presented.

4.1 Research Problem

Manufacturing is a leading sector in the Singapore's economy and plays a critical role in the country's growth as it supports many sectors in the economy, including many service industries, which could not exist without it (Section 2.1). However, Singapore's manufacturing is in danger of being 'squeezed out' as it faces increasing competition from low cost manufacturing locations like China whilst lagging behind developed nations like US and Japan in the sophistication of technology and calibre of innovation (Section 2.2). Thus, Singapore's manufacturing needs to move up the value chain and compete with other competitive attributes like quality and service as oppose to cost. To do that, manufacturing firms need to achieve best practices and world-class performance necessary for survival in the global competition (Section 2.3).

A limitation of best practice occurs where companies imitating blindly and eventually narrows their strategic spaces (Hayes and Pisano, 1994). Thus, in acquiring best practices, they need to learn, adapt and apply the knowledge to their own processes, and renew the processes when superior practices emerge (Section 2.4). However, best practices are context specifics (Section 3.1) and most of such programmes and studies are conducted in the western countries like US and Europe (Section 3.3). Therefore, there is a need for a more holistic approach to best practice adoption that is applicable to the Singapore's unique competitive environment (Section 2.4).

Relationships between best practices and improved performance are often assumed to be self-evident (Section 3.4.1), thus leading to the misconception of attaining superior performance by simply adopting practices of successful companies. This is apparently untrue as evident from the disappointing results reported for the implementation of best practices (Section 3.4.3). Limited application of best practice as a strategic tool has also lead to unsustainable competitive advantage achieved by many company adopting the common benchmarking methodologies (Section 3.4.5). Therefore, it is clear that some form of decision model that relate best practices to the competitive environment of the company will be valuable for practitioners engaging in best practice and its adoption processes. This will contribute to the competitiveness and growth of Singapore's manufacturing and economy as a whole.

4.2 Research Aim and Objectives

On the basis of the research problem defined above, the aim of this research is therefore,

"to develop a decision model for best practice adoption that links practices to competitive strategies and guide practitioners in the analytical selection of manufacturing best practices."

Realising this aim will provide practitioners with a structure to deal with the selection and prioritisation of manufacturing best practices to adopt instead of blindly imitating the successful companies. In order to fulfill this research aim, 3 key research objectives have been defined as to:

1. Develop a decision model for the adoption process of manufacturing best practices.

2. Validate the decision model with real-life industrial case studies.

3. Apply the decision model in the form of a guide for industrial application.

The research aim and objectives have been set out in this section. In the next section, the research programme and methods to execute this research will be proposed.

4.3 Development of Research Programme and Methods

To realise the above aim and objectives, a research programme was devised to direct the activities of this research in a sequence of stages. Further detail about the activities at each stage will subsequently be added, prior to the execution of the associated stage, so as to take advantage of knowledge gained from the execution of preceding stages. Hence, the remainder of this thesis will presents each research stage as a separate chapter, within which, the detailed research activity at that stage is discussed. This section begins with an overview of the research programme, followed by the discussion on the associated purposes of each stage and the guiding methods and policies necessary to realise them.

4.3.1 Overview of Research Programme

The research programme is a sequence of activities that are to be carried out to realise the aim of this research. Explicit in the research aim is an intention to develop a decision model for best practice adoption. Inherent to the development of a decision model is the formation and validation of the model. Therefore, the research programme proposed will address these 3 key processes of forming the decision model, validating the decision model and eventually applying this decision model as an aid for the analytical selection of manufacturing best practices. These 3 processes also coincide with the 3 research objectives defined.

Decision modelling involves the articulation of the decision problem, understanding the domain reality, and translating the abstracted solution provided by the decision model to concrete reality (Novosad, 1982). Taking a quote from Chesterton (2006),

"It isn't that they can't see the solution. It is that they can't see the problem."

The first step in this process is therefore to ask, "What is the Question?" Once the problem is clearly posed, the next step can then identify the key variables or parameters necessary for answering the question. Hence, Stage 1 of the research programme will be to form the decision framework. This stage will draw input from the knowledge gained in Chapter 2 and 3 to define the structure and contents for the decision model. This will set the requirement for the decision model to be constructed in Stage 2.

Following naturally after the forming of the decision framework is the model development. Hence, Stage 2 of the research programme will be the construct of the decision model. Domain expertise and sound knowledge of modelling tools are keys to selecting the relevant data for a problem. Decisions involved are how many independent variables to be chosen, and what should be the period over which the data needs to be examined. The trade-off is model complexity (too much data) versus model relevance (too little data). Taking a quote from Eigen (1973),

"A theory has only the alternative of being right or wrong. A model has a third possibility: it may be right, but irrelevant."

Thus, the requirements for the decision model established in Stage 1 will be used to evaluate the relevancy of the existing decision modelling techniques. The outcome of this stage is a preliminary decision model for best practice adoption.

The decision model constructed would necessarily make assumptions and these have to be tested. Hence, Stage 3 of the research programme will be the verification of the decision model. As evident in Section 3.4, the weakness in the existing best practice research reports limited links to strategy research. Hence, leading to the construct of the decision model via the systematic gathering of existing knowledge in the field of manufacturing strategy and best practice research. As Karlin (1983) quoted,

"The purpose of models is not to fit the data but to sharpen the questions."

Therefore, academic and industrial experts' opinion are consulted to verified if the decision model constructed is "fit-for-purpose" in the light of the problem defined. This is to ensure that the required level of confidence on the accuracy of the model representation to existing knowledge and concepts is achieved.

At the end of Stage 3, a verified theoretical decision model is formed. Naturally, the next step will be to test its validity against actual industrial scenarios. This will form the Stage 4 of the research programme. Artefacts pertaining to the study will be collected from the industrial case study for this validation process. On the basis of the results obtained, this theoretical decision model will be refined and the final decision model formed.

The final task of the research programme will be to apply this final decision model formed as an aid for the analytical selection of manufacturing best practices in the industry. This will be form the final Stage 5 of the research programme, which is the illustration of the decision model in the form of a guide to aid the best practice adoption process.

In summary, a 5-stage research programme is developed and presented in Figure 4.1. These stages will be given the following titles in the remaining of this thesis:

Stage 1: Forming the Decision Framework

Stage 2: Constructing the Decision Model

Stage 3: Verifying the Decision Model

Stage 4: Validating the Decision Model

Stage 5: Applying the Decision Model

Subsequent sub-sections will discuss about the associated objectives of each stage and the guiding methods and policies necessary to realise these objectives.

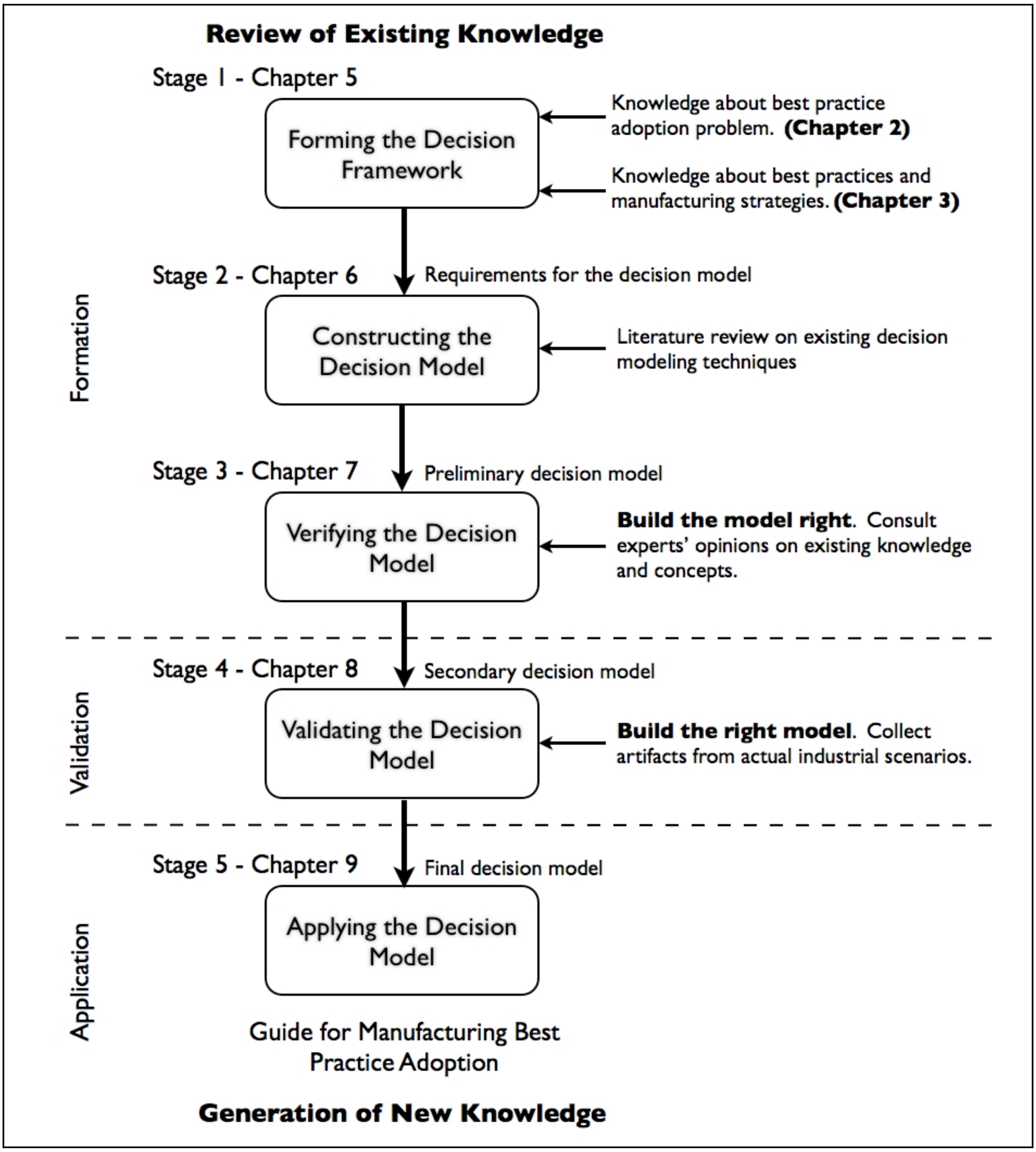

Figure 4.1 Overview of Research Programme

4.3.2 Stage 1: Forming the Decision Framework

The first task in the research programme is the articulation of the decision problem for the adoption process of manufacturing best practices in the form of a decision framework. This decision framework will be formulated through the analytical synthesis of the knowledge gained from Chapter 2 and 3 about the challenges of best practice adoption as well as the research in best practice and manufacturing strategy. The purpose here is to define and set the requirement for the decision model to be constructed in Stage 2. Therefore, the purpose of Stage 1 of the research programme is:

To establish the requirements of a decision model for the best practice adoption process.

The method of realising this is to first carry out an activity to form the decision framework pertaining to the subject matter. This will define the structure of the decision problem. Subsequently, this framework will be populated and verified with contents from the literature. Finally, a detail set of requirements for the decision model is established from the structure and contents of this decision framework.

Previously described weaknesses in the literature (Section 3.4.5) are threefold and affect the manner in which this work should proceed. Firstly, a prescriptive tool that explores best practices in context to the competitive environment is not apparent. Secondly, the linkages between practices to objectives to strategic targets are limited and empirically weak, which inhibit the use of best practice as a strategic instrument. Last but not least, existing models only captures a limited set of practices and are limited to the choices described in the models rather than the creation of new and customised practices specific to the unique environment of the organisation. Existing methods to address the adoption of best practices are world class manufacturing models and benchmarking (Section 3.3). These methods are limited in their exploration of best practices in context and the provision of best practice as a strategic instrument (Section 3.4.3 and 3.4.5). Therefore, there is a need to develop a fundamentally new adoption approach that provides the linkages between practices to the context of the competitive environment and the strategic goals of the organisation.

To do so, there are basically three approaches to develop this new solution. The first approach is to completely ignore existing knowledge, allowing an uninfluenced development of an adoption model to proceed, and in this way, it may be possible to deliver a fundamentally new adoption model. The concerns here are, considerable effort may be expended only to arrive at an adoption model that already exists and the absence prior knowledge to the development of an unsupported conceptual solution is a subject for criticism. A second approach is to develop an adoption model on the basis of the existing knowledge about best practice in the literature. However, weakness in the existing literature may mislead research efforts and deliver a sub-optimum solution. Moreover, best practice research are seldom related to strategy research (Section 3.4.5), thus such approach is limited to derive and associate the strategic component required for the new adoption model. The final approach is to first critically assess the strategy research literature, in particularly manufacturing strategy, to derive a strategy model, which includes the best practices component. The danger here is the potential risk of out of scope to this research where the focus is biased towards strategy development around a set of existing best practices adopted rather than adoption of the required practices in support of the existing strategy.

Based on the above argument, none of these three approaches is suitable for execution of the first research activity. However, on closer examination, a combination of the second and third approaches will strike a good balance in the scope of the research work. Section 3.2 has reviewed the existing manufacturing best practices through an historical account of manufacturing paradigms. Therefore, the concept of manufacturing paradigm can be adopted to classify existing best practices and relate them to the concept of manufacturing strategy. That way, the association linkages between best practices and strategy are established. On this basis, a decision framework is constructed. This framework is then verified through the in-depth population from existing manufacturing strategy literatures, and the requirements of the decision model established.

4.3.3 Stage 2: Constructing the Decision Model

Following naturally after the construct of the decision framework is the model development. The requirements for the decision model established in Stage 1 will be used to evaluate the relevancy of existing decision modelling techniques for the construct of the decision model. Eventually, a decision model for the best practice adoption process is constructed. Therefore, the purpose of Stage 2 of the research programme is:

To model the decision process for best practice adoption

The method of realising this is to shortlist some suitable decision modelling techniques for evaluation. This is necessary because an exhaustive list of modelling techniques would require too much resource to test their relevancy and ineffective in modelling the decision problem. On this basis, three decision modelling techniques are shortlisted for evaluation, which include Decision Tree, Discrete Event Simulation and Analytical Hierarchical Process. These techniques are then analytically evaluated against the model requirements to select the best technique for the construct of the decision model. Finally, a preliminary decision model is constructed and presented.

4.3.4 Stage 3: Verifying the Decision Model

As evident in Section 3.4, the weakness in the existing best practice research reports limited links to strategy research. Hence, leading to the construct of the decision model via the systematic gathering of existing knowledge in the field of manufacturing strategy and best practice research in Stage 1 and 2. Model verification is to substantiate that the model is transformed from one form into another, as intended, with sufficient accuracy (Balci et al., 1997). Therefore, there is a need to verify the construct of the decision model formed with experts in this field. This is to ensure that the required level of confidence on the accuracy of the model representation to existing knowledge and concepts is achieved.

So, the purpose of Stage 3 of the research programme is:

To verify the model accuracy against existing knowledge and concepts.

Model verification deals with building the model right (Banks, 1998). The method in realising this is through the conduct of semi-structured interviews to seek the feedbacks and opinions from both academic and industrial experts in this field. Academic experts will provide the input on the accuracy of the structure and contents of the decision model against theoretical models and concepts. Industrial experts on the other hand will provide the input on the applicability and accuracy of the model for industrial application. The outcome is a secondary decision model ready for industrial testing in the next stage.

4.3.5 Stage 4: Validating the Decision Model

On the completion of Stage 3 of the research programme, we will have a verified decision model ready for industrial testing. Model validation is to substantiate that the model, within its domain of applicability, behaves with satisfactory accuracy (Balci et al., 1997). Thus, this validation stage will check for the accuracy of model representation against actual industrial scenarios and the purpose of this stage is:

To validate the model accuracy against real-life industrial scenario.

Model validation deals with building the right model (Banks, 1998). The typical method to test such causal linkages hypothesised in the decision model is a full-scale industrial wide survey followed by a statistical analysis of the results. However, on closer examination, there are some characteristics about the data required for analysis, which may result in large discrepancies and errors from such survey method and hinder the effective analysis of the results.

The first is the subjectivity issue on the competitive strategies adopted by a company, which may defers depending on the person that the survey is directed to. Even at the senior management level, it is common to have differing views about the competitive strategy that the company should adopt or is adopting. The second is the difficulty to obtain a complete overview of the best practices adopted by the company from one surveyed person in the company because it consists of detailed data collection across different functions in the company. Finally is the confidentiality of such information sought. Even if these information are available, they are often regarded as trade secret by the company for their competitiveness and thus unlikely for them to reveal through an industrial wide survey.

In view of these challenges faced in conducting an industrial-wide survey to validate the causal linkages, case study method was considered to be more suitable. This is because personal involvement of the researcher in case studies can ensures the objectivity of the data collected as well as the normalisation of the results for a more accurate analysis. Focus and personal engagement with a selected few companies also built trust and openness between the researcher and the company to promote the sharing of sensitive information sought. The outcome is a final decision model, validated against the industrial settings, for application in the next stage.

4.3.6 Stage 5: Applying the Decision Model

This is the final stage of the research programme and it deals with the application of the final decision model formed. This is achieved through the illustration of the decision model in the form of a guide to aid managers and practitioners in decision process of manufacturing best practice adoption. Causal linkages portrayed in the model will be detailed in a step-by-step manner to guide the analytical selection of manufacturing best practices. Compatibility of practices, trade-off between competitive priorities and the prioritisation of practices for adoption will be explained and discussed in the guide as depicted by the final decision model.

To summarise, the purpose for this stage is:

To apply the decision model as an aid for the analytical selection of manufacturing best practices.

4.4 Chapter Summary

This Chapter has set out the research problem, and proposed a solution to assist practitioners involved in the activity of manufacturing best practice adoption. Subsequently, the research aim and objectives for the thesis was established. A five-stage research programme has been proposed that would satisfy the academic rigour and industry relevance. Stages 1 to 3 have been planned to enable the researcher to review relevant literature and verify against experts in the field of best practice adoption, with the aim of constructing a decision model to represent this activity. Stage 4 will enable the researcher to validate the causal linkages represented in the model with real-life industrial case studies. In stage 5, this decision model will then be operationalised through the illustration of a guide to aid practitioners engaging in the selection and adoption process of manufacturing best practices. In the next chapter, Stage 1 of the research programme, namely forming the decision framework, is presented.

Chapter 5: Forming the Decision Framework

In Chapter 4, the research aim, objectives and programme have been set out. The aim of this research is to develop a decision support tool for best practice adoption that links practices to competitive strategies and guide practitioners in the analytical selection of manufacturing best practices. This chapter deals with the first stage of realising this goal, by constructing a decision framework of the best practice adoption process. The chapter first presents the purpose and method for this stage of research (Section 5.1), followed by the construct of a decision framework to define the structure of the decision problem (Section 5.2). Subsequently, this framework is populated (Section 5.3) and verified (Section 5.4) with contents from the literature. Finally, a detailed set of requirements for the decision model is established from the structure and contents of the decision framework constructed and presented in Section 5.5.

5.1 Stage 1: Purpose and Method

The purpose of this stage of the research is to establish the requirements of the decision model for the best practice adoption process, against which the performance of decision modelling techniques can be plotted in the next stage. This is necessary to limit the universe of discourse for the problem to ensure the relevancy of the decision model constructed. Furthermore, the research activity should commence by considering the existing knowledge gained about best practices and manufacturing strategies in Chapter 2 and 3 to form a decision framework. This will then defines a structure for the decision model, which details the relevant decision stages, variables and alternatives. Subsequently, this framework will be verified through the in-depth population of its contents from manufacturing strategy literature. Finally, the requirement set of the decision model is established. Figure 5.1 presents an overview of the research activities in this chapter.

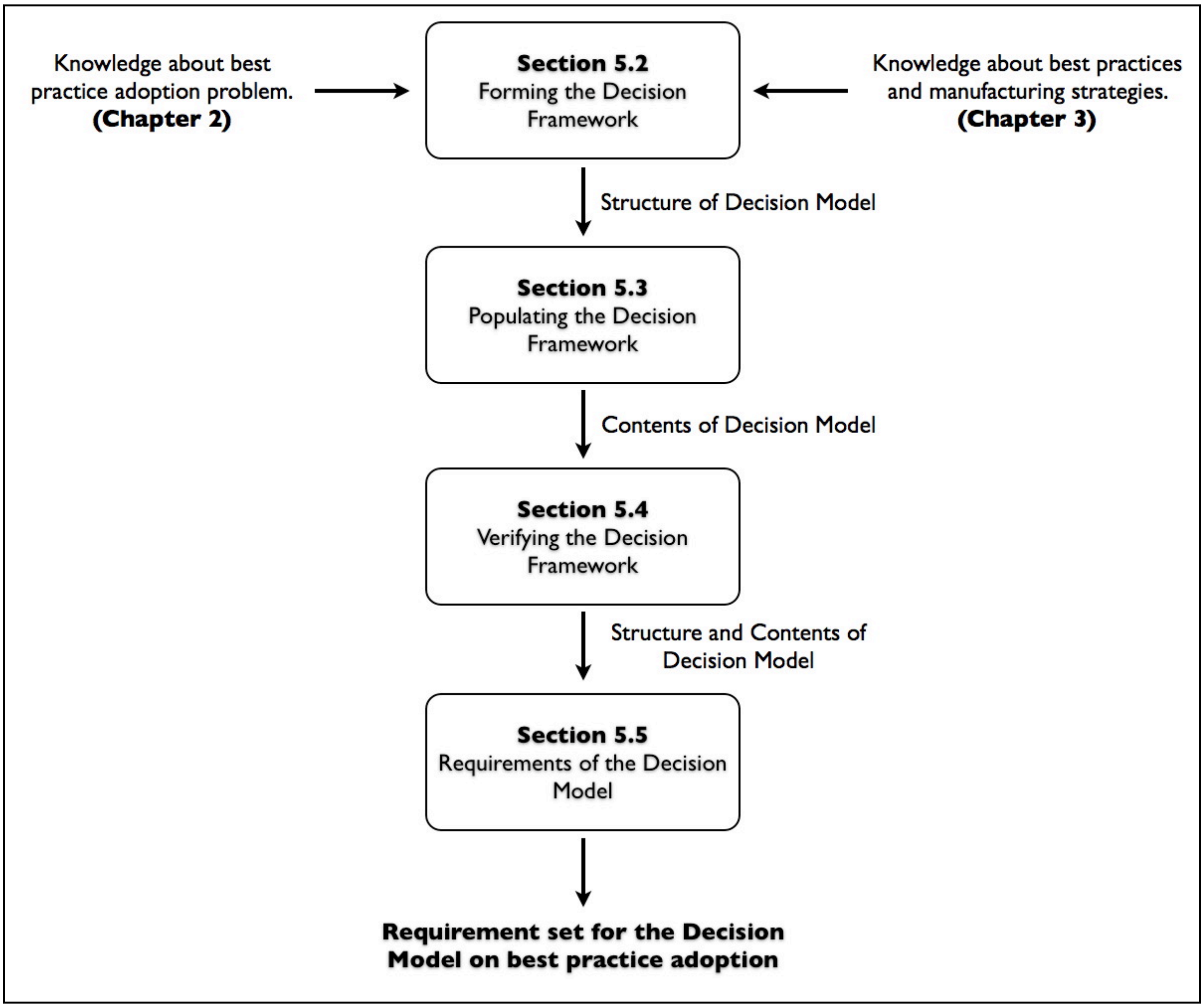

Figure 5.1 Overview of Stage 1's research activities

In Section 2.4, the challenges of best practices adoption in Singapore are made. These challenges define what is needed to drive the best practice adoption process, which sets the decision criteria. One of the main reasons for sub-optimal or poor performances of organisation despite the adoption of best practices is the poor understanding of the associated competitive priorities of the best practices adopted (Hayes and Pisano, 1994). This has lead to companies imitating blindly without realising the mismatch or incompatibility of the adopted practices to the intended competitive strategy pursuit by the company. To achieve competitiveness, the company needs to understand the competitive landscape they are operating in and the effective competitive strategy to adopt (Porter, 1980). Therefore, one of the activities in this stage is to understand the key external drivers that define the competitive landscape and the options of competitive strategies available.

The next step is to link these competitive strategies to the options of manufacturing best practices available. Heibeler et al. (1989) argues that best practices are context specific as 'best' is a contextual term in itself. It is only defines as "best for you" in the context of your business, your company culture, your use of technology, and your competitive strategies. Therefore examining of all practices in top-performing companies is inadequate to define the list of best practices required in this research. Moreover, access to all these top-performing companies are also limited to the few privileged and thus such information is rarely public access. Thus, literatures become the main source for the data required. Section 3.2 has identified the emergence of manufacturing best practices in association with new manufacturing paradigm. Thus, through an account of these paradigms identified, existing manufacturing best practices can be picked out and classified.

Finally, a decision framework will be formed to define the structure for this decision problem. Data collected from the literatures are then used to populate this framework for analytical verification. Subsequently, the requirement set for the decision model is established. This requirement set will then be used as a basis to select the most appropriate decision modelling technique for the construct of the decision model in the next stage.

5.2 Forming the decision framework

The first research activity in this stage is to form a decision framework that defines the structure of the decision model. This is achieved by the analytical synthesis of existing knowledge gained in Chapter 2 and 3 about the challenges of best practice adoption as well as the research in best practice and manufacturing strategy.

The emergence of new manufacturing paradigms is frequently associated with the emergence of radically different 'best practices' (Section 3.2). Thus, it is logical to take this paradigm approach for the construct of the decision framework. However, the term manufacturing strategy is also popular in the literature (see Skinner, 1969; Hayes and Wheelwright, 1984; Hill, 1989; Swamidass and Newell, 1987) and it worthwhile to differentiate the two. A consistent interpretation is that manufacturing strategy deals with the coordination of practices and policies across the structure and infrastructure of the manufacturing operation (Platts and Gregory, 1990). On the other hand, a manufacturing paradigm is accepted to be a set of underlying principles and assumptions that a group of manufacturing organisations adopt to guide their manufacturing function (Section 3.2.1). Therefore, it is reasonable to consider a manufacturing paradigm to be a generic set of closely related manufacturing strategies.

Manufacturing strategy is formed to achieve business goals (Platts and Gregory, 1990) and these goals are predominantly defined in terms of competitive priorities (eg: quality, cost, time, etc) (Frohlich and Dixon, 2001). For the case in relation to the manufacturing function, these priorities then define the manufacturing objectives to be achieved. Intrinsic to these priorities is the link to the competitive strategy of the Strategic Business Unit (SBU), which can be the manufacturing function. Often, this requires the SBU to choose a market strategy of either focus, cost leadership or differentiation (Porter, 1980). On this basis, manufacturing practices and competitive strategy are clearly linked and Figure 5.2 illustrates the usual arrangement prevailing in the literature.

To realise competitive manufacture, the practitioner has to interpret the linkages shown in Figure 5.2 and translate them into shop floor practices. However, the understanding of such linkages is fragmented (Section 3.4) and can lead to confusion and strategic misalignment. This has resulted in sub- optimal or poor performance of the organisation (Section 2.4). Adoption of practices without understanding their associated competitive priorities can result in companies imitating blindly and eventually narrowing their strategic space (Hayes and Pisano 1994). Therefore, there is a need to relate the manufacturing practices and objectives to the strategic direction of the business. Hence, it is critical to provide the structure and depth to this framework.

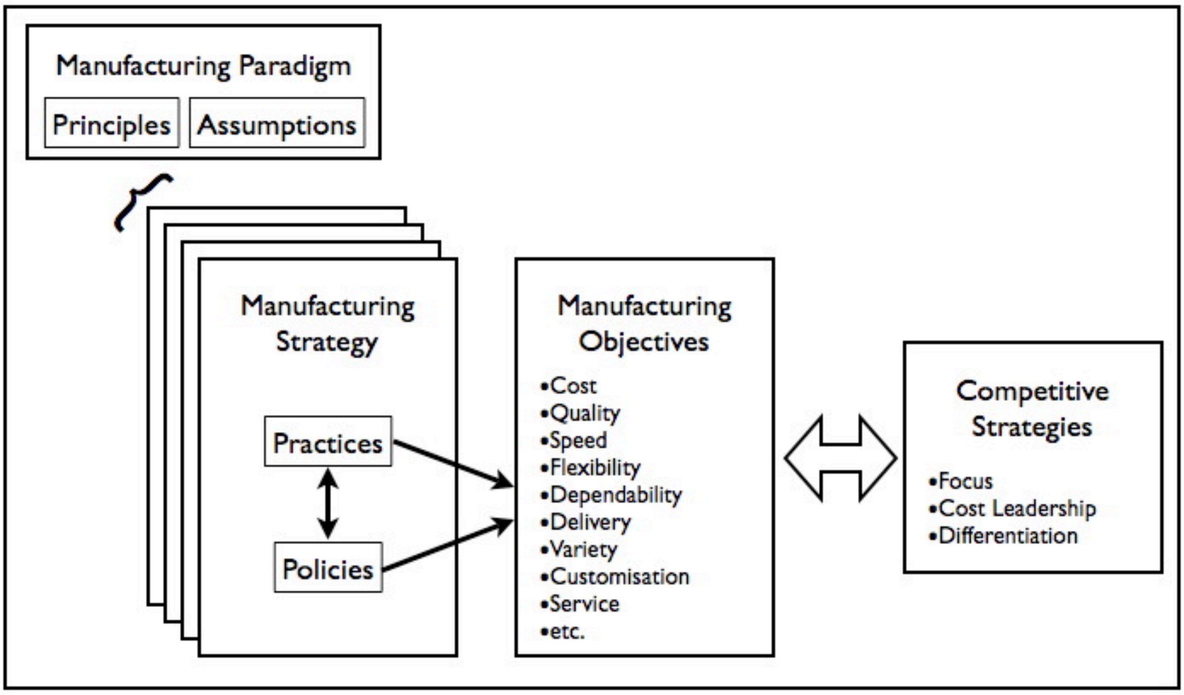

Figure 5.2 Linkages between Manufacturing Practices and Competitive Strategy

First component of the framework is the principles and assumptions associated with a manufacturing paradigm. In Section 3.2.1, these principles are also referred to as rules that guide and define the design and production of manufactured goods from raw materials. Thus, they can be linked to a common set of manufacturing practices. Assumptions on the other hand are commonly referred to as our perceptions of the surrounding (Morris and Brandon, 1994). For the case of this problem, it is how the company view their internal and external environment. Internally, it refers to as the manufacturing requirements that the organisations need to achieve. Externally, it refers to the market conditions in which the organisations are operating. Together, these assumptions define the competitive landscape of a company and influence the choice of competitive strategies and manufacturing objectives adopted.

The second component of the framework is the practices and policies associated with the generic manufacturing strategy. Skinner (1969), Fine and Hax (1985), Hayes et al. (1988), Hill (1989), Schroeder and Lahr (1990), and Platts and Gregory (1990) have grouped these practices, techniques and policies into a set of structural and infrastructural decision areas, which is presented Table 5.1. Classification of manufacturing practices in these decision areas will enable the ease of data collection for the population of the conceptual framework subsequently.

Table 5.1 Structural and Infrastructural decision areas of manufacturing operations (Adapted from Platts and Gregory, 1990)

Decision areas	Descriptions:
STRUCTURAL	
Facilities	The factories, their number, size, location, focus.
Capacity	The maximum output of the factory
Processes & Technologies	The transformation processes and technologies (metal cutting, mixing, assembly, etc.) and most critically the way in which they are organised.
Span of processes	The degree of vertical integration
INFRASTRUCTURAL	
Quality	The means of ensuring that products, processes and people operate to specification.
Control Policies	The control policies and philosophies of manufacture
New Products	The mechanisms for coping with new product introduction, including links to design.
Human Resources	All the people-related factors, including both the personal and the organisational level.
Suppliers	The methods of obtaining input materials at the right time, price and quality

The third component of the framework is the manufacturing objectives. As depicted in Figure 5.2, a manufacturing paradigm should support a cluster of manufacturing objectives, which are consistent with the competitive strategies. An example list of possible objectives is compiled from the work of Van Dierdonck and Miller, 1980; Hayes and Wheelwright, 1984; Hayes et al., 1988; Platts and Gregory, 1990; Youndt et al., 1996 and presented in Table 5.2. These objectives can also be referred to as the manufacturing or competitive objectives and link directly to the competitive strategy of the SBU.

Table 5.2 Competitive Objectives (Adapted from Frohlich and Dixon, 2001)

Competitive Objectives	Defined as the capabilities to:
Price:	
♦ Low Price	♦ Compete on price
Flexibility:	
♦ Design Flexibility	♦ Make rapid design changes and/or introduce new product quickly
♦ Volume Flexibility	♦ Respond to swings in volume
♦ Broad Product Line	♦ Deliver a broad product line
Quality:	
♦ Conformance	♦ Offer consistent quality
♦ Performance	♦ Provide high performance products
Delivery:	
♦ Delivery speed	♦ Deliver products quickly
♦ Dependability	♦ Deliver on time
Service:	
♦ After-sale service	♦ Provide after-sales service
♦ Broad Distribution	♦ Distribute the product broadly

Finally, the last component of the framework is the competitive strategy adopted by the company. In this case, Porter's (1980) view of competitive strategies is adopted. He proposed the idea that all strategies are variants of the 3 generic strategic choice between overall cost leadership, differentiation and focus (Figure 5.3). Thus, the priorities on the manufacturing objectives, which an organisation placed, will be related to the market scope or the basis of the competitive advantage.

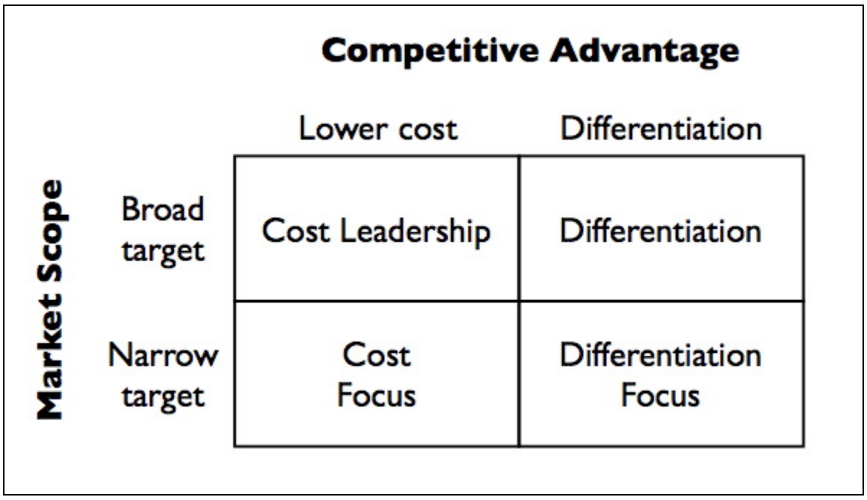

Figure 5.3 Generic Competitive Strategies (Adapted from Porter, 1980)

In summary, a conceptual decision framework is formed and presented in Figure 5.4. This conceptual framework defines a structure for the decision process of best practice adoption, linking practices to competitive strategy. Subsequent sections will populate and verify this framework to derive the requirement set for the decision model.

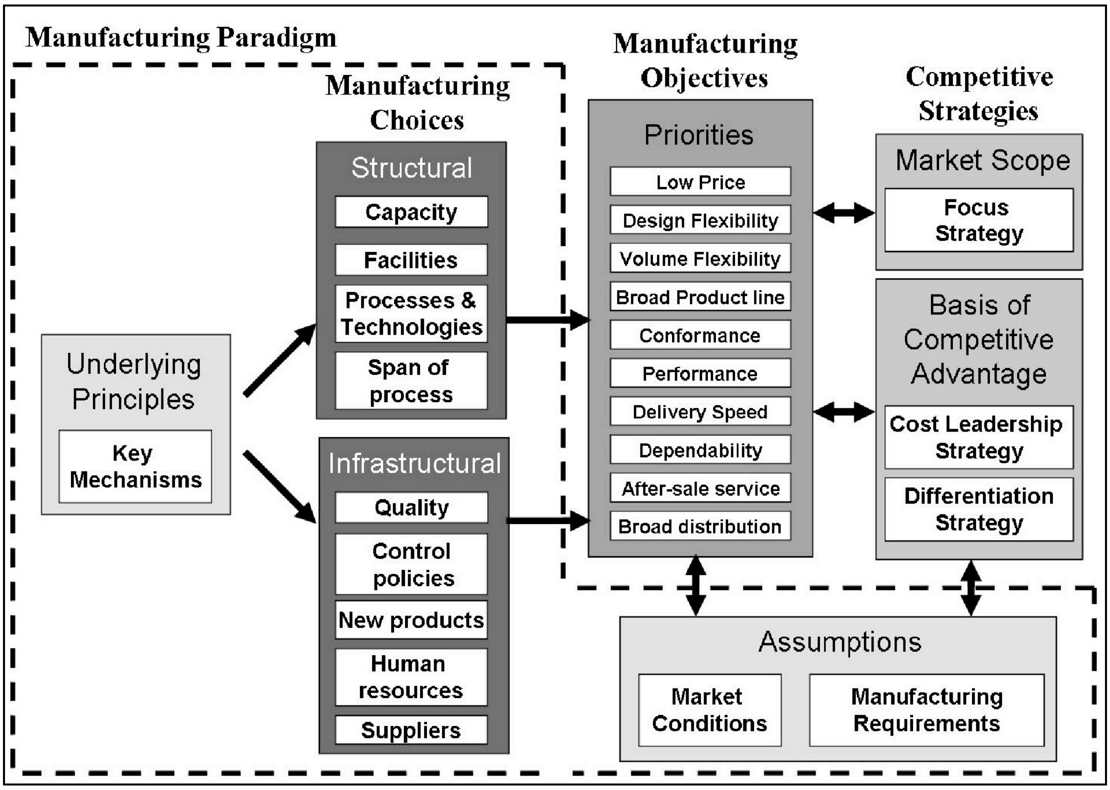

Figure 5.4 Conceptual Decision Framework

5.3 Populating the decision framework

The second research activity in this stage is the population of the decision framework to derive the contents of the decision model. This is achieved by systematic collection of inputs from the relevant literatures.

Section 3.2 has identified six distinct manufacturing paradigms through a chronological map. However, we are mindful that these paradigms identified are not exhaustive. Thus, our approach has been to focus on popular paradigms that are widely discussed, adopted and reported in the literature so as to acquire an in-depth understanding of their associated practices and their links to the competitive strategies adopted. For the purpose of this research, five of these six popular manufacturing paradigms (MP, LP, TBP, MCP, AP) identified will form the scope for the literature review.

The literature review carried out was structured around the work of Dangayach and Deshmukh (2001) on a contemporary review of the existing body of knowledge on manufacturing strategy. As it was essential that only relevant and high quality contributions were considered, articles identified have to meet the following criteria. First, they had to be published in one of the top five journals for manufacturing strategy research identified by Dangayach and Deshmukh (2001). These journals are International Journal of Operations and Production Management (IJOPM), Journal of Operations Management (JOM), Production and Operations Management (POM), California Management Review (CMR), and Harvard Business Review (HBR). Second, they had to be relevant to the five paradigms identified. Within this scope, a total of 86 papers were reviewed. The distribution of these papers across the journals and topic are shown in Table 5.3 and 5.4. Similarly, Table 5.5 summarises the principal contribution of each paper with respect to the paradigms discussed and their content types in terms of Practices/Techniques/Policies, Principles/Mechanisms, Manufacturing Objectives/Competitive Priorities, and Market conditions/Manufacturing requirements as defined by the conceptual framework in Figure 5.4.

Once these papers had been compiled, their findings were catalogued in a tabular form that reflected the decision framework. This is illustrated in Tables 5.6, 5.7, 5.8, 5.9 and 5.10, which depict the contents of the conceptual framework for each paradigm.

Table 5.3 Distribution of reviewed article in various journals

Journal Titles	Number of Papers	Percentage (%)
International Journal of Operations & Production Management (**IJOPM**)	51	59.3
Journal of Operations Management (**JOM**)	16	18.6
Harvard Business Review (**HBR**)	14	16.3
California Management Review (**CMR**)	4	4.6
Production and Operations Management (**POM**)	1	1.2
Total	86	100

Table 5.4 Distribution of paradigms articles with respect to various journals

Paradigms	Number of Papers					Total
	IJOPM	JOM	HBR	CMR	POM	
Mass Production (MP)	8	0	0	0	0	8
Lean Production (LP)	27	7	6	0	0	40
Time-Based Manufacturing (TBM)	11	7	4	0	1	23
Mass Customisation (MC)	4	3	4	1	0	12
Agile Manufacturing (AM)	12	0	0	3	0	15
Total	62	17	14	4	1	98

Table 5.5 Survey summary of literature reviewed

#	Researchers	Year	Journal	Paradigm	Content Types			
					Practices/ Techniques/ Policies	Principles/ Mechanisms	Mfg Obj./ Comp. Priority	Market Conditions/ Mfg Req.
1.	Lee	1989	IJOPM	MP LP			●	●
2.	Duguay et al.	1997	IJOPM	MP AM	●	●	●	
3.	Neil and O'Hara	1987	IJOPM	LP	●		●	●
4.	Sohal et al.	1989	IJOPM	LP	●	●	●	
5.	Harber et al.	1990	IJOPM	LP	●	●		●
6.	Singh and Brar	1992	IJOPM	LP		●	●	
7.	Banerjee and Golhar	1993	IJOPM	LP	●	●	●	
8.	Clarke and Mia	1993	IJOPM	LP	●		●	●
9.	Ramasesh	1993	IJOPM	LP	●	●	●	
10.	Sohal et al.	1993	IJOPM	LP	●		●	●
11.	Baker	1994	IJOPM	LP		●	●	
12.	Sohal and Egglestone	1994	IJOPM	LP	●	●	●	
13.	Spencer et al.	1994	IJOPM	LP	●	●	●	
14.	Ramarapu et al.	1995	IJOPM	LP	●	●		
15.	Spencer and Guide	1995	IJOPM	LP	●	●		
16.	Wilson	1995	IJOPM	LP MP	●	●	●	●
17.	Boyer	1996	IJOPM	LP	●			●
18.	Engstrom et al.	1996	IJOPM	LP MP	●			●
19.	Forza	1996	IJOPM	LP MP	●	●		
20.	Karlsson and Ahlstrom 1996	1996	IJOPM	LP	●	●		
21.	Katayama and Bennett	1996	IJOPM	LP	●	●		●
22.	Sohal	1996	IJOPM	LP	●			●

Table 5.5 Survey summary of literature reviewed (cont.)

23.	James-Moore and Gibbons	1997	IJOPM	LP	●	●	●	
24.	Lewis	2000	IJOPM	LP	●	●		
25.	Cooney	2002	IJOPM	LP MP	●	●		●
26.	Wu	2003	IJOPM	LP	●	●		
27.	Bruce et al.	2004	IJOPM	LP AM	●			●
28.	Hines et al.	2004	IJOPM	LP		●	●	
29.	Daugherty and Pittman	1995	IJOPM	TBM	●	●	●	
30.	Gehani	1995	IJOPM	TBM	●	●	●	
31.	Kumar and Motwani	1995	IJOPM	TBM	●	●	●	
32.	Tersine and Hummingbird	1995	IJOPM	TBM		●	●	●
33.	Bozarth and Chapman	1996	IJOPM	TBM	●		●	●
34.	Hum and Sim	1996	IJOPM	TBM	●	●	●	●
35.	Rohr and Correa	1998	IJOPM	TBM	●		●	●
36.	Jayaram et al.	1999	IJOPM	TBM	●		●	●
37.	Ko et al.	2000	IJOPM	TBM	●		●	●
38.	Perry and Sohal	2001	IJOPM	TBM	●		●	
39.	Hui	2004	IJOPM	TBM	●	●	●	
40.	Ahlstrom and Westbrook	1999	IJOPM	MC		●	●	●
41.	Duray	2002	IJOPM	MC MP	●	●	●	●
42.	Brown and Bessant	2003	IJOPM	MC AM	●		●	●
43.	Burgess	1994	IJOPM	AM MP	●		●	●
44.	Vastag et al.	1994	IJOPM	AM	●		●	
45.	Quintana	1998	IJOPM	AM		●	●	●
46.	Zhang and Sharifi	2000	IJOPM	AM	●	●	●	
47.	van Hoek et al.	2001	IJOPM	AM MC	●	●	●	●
48.	Prater et al.	2001	IJOPM	AM		●	●	●

Table 5.5 Survey summary of literature reviewed (cont.)

49.	Sharifi and Zhang	2001	IJOPM	AM	●	●	●	●
50.	Coronado et al.	2004	IJOPM	AM	●	●		●
51.	Guisinger and Ghorashi	2004	IJOPM	AM	●		●	●
52.	Schonberger	1982	JOM	LP	●	●	●	
53.	Lawrence and Hottenstein	1995	JOM	LP	●		●	●
54.	Wilson	1998	JOM	LP	●		●	●
55.	Cua et al.	2001	JOM	LP	●		●	
56.	Dong et al.	2001	JOM	LP	●		●	
57.	Fullerton and McWatters	2001	JOM	LP	●		●	●
58.	Shah and Ward	2003	JOM	LP	●		●	
59.	Lindsley et al.	1991	JOM	TBM	●		●	
60.	Upton	1995	JOM	TBM		●	●	
61.	Koufteros et al.	1998	JOM	TBM	●	●		
62.	Rondeau et al.	2000	JOM	TBM	●		●	
63.	Tu et al.	2001	JOM	TBM MC	●	●	●	
64.	Nahm et al.	2003	JOM	TBM	●	●		
65.	Droge et al.	2004	JOM	TBM	●		●	
66.	Duray et al.	2000	JOM	MC	●	●	●	
67.	Su et al.	2005	JOM	MC	●		●	
68.	Zipkin	1991	HBR	LP		●	●	
69.	Hayes and Pisano	1994	HBR	LP	●		●	
70.	Womack and Jones	1994	HBR	LP		●	●	
71.	Womack and Jones	1996b	HBR	LP	●	●		●
72.	Swank	2003	HBR	LP	●	●		
73.	Womack and Jones	2005	HBR	LP		●	●	●
74.	Huge	1979	HBR	TBM	●	●		
75.	Stalk	1988	HBR	TBM		●	●	
76.	Merrills	1989	HBR	TBM	●		●	

Table 5.5 Survey summary of literature reviewed (cont.)

77.	Stalk and Webber	1993	HBR	TBM	●		●	●
78.	Pine et al.	1993	HBR	MC	●	●		●
79.	Feizinger and Lee	1997	HBR	MC	●		●	●
80.	Gilmore and Pine	1997	HBR	MC		●	●	
81.	Magretta	1998	HBR	MC	●		●	●
82.	Swaminathan	2001	CMR	MC	●	●	●	
83.	Bahrami	1992	CMR	AM		●	●	●
84.	Pascale	1996	CMR	AM		●	●	
85.	Thomke and Reinertsen	1998	CMR	AM	●	●	●	
86.	Tang and Tang	2002	POM	TBM	●	●	●	
Total					70	54	66	38

Table 5.6 Tabulated Decision Framework for Mass Paradigm (MP)

Mass Production (MP)					
Underlying Principles	**Key Mechanisms**	**Practices/ Techniques/ Policies**	**Manufacturing / Competitive Priorities**	**Market Conditions/ Manufacturing Requirements**	**Competitive Strategy supported**
• Cost driven • Economies of Scale • Resource Specialisation	• Any initiatives or investment with the primary objective of cost reduction. • Suppliers are made to pit against each other to obtain the best possible deal. • Cost reduction through the increase of production volume over the same set of manufacturing resources. • Lower or control the product varieties to generate the economies of scale required. • Produce at maximum capacity to ensure maximum utilisation of manufacturing resources. • Use dedicated machine to ensure maximum utilisation. • Job division with different groups of workers performing unique set of simple task. • Anticipate, reduce and eliminate all sources of change that may engender additional cost. • Job division to allow interchangeable of workers to reduce variability. • Product standardisation to allow interchangeable of parts to reduce variability. • Manage changes through the use of inventory and the development of sophisticated software such as MRP. • System designed so that operating staff have relatively little and strictly limited influence on the quality and volume of work performed. • Arrange the material and machinery to simplify operations so that practically no orders are necessary. • Mechanisation of conveyor belt system to move products in the production floor and minimise machines or workers' movements.	• Centralised hierarchical control system • Command-and-control factory • Continuous flow production • Continuous production • Division of labour • Forecasting • Hierarchical organisation • Interchangeable parts • Interchangeable workforce • Inventory to buffer changes • Make-to-stock • Mechanisation • Mechanistic organisation structure • Moving assembly line • Narrowly skilled workforce • Paced assembly line • Product specialisation • Simplification of work or task • Specialised machines • Standardised design • Standardised work • Vertical integration	• Cost • Volume • Utilisation • Productivity	• High staff turn over • High volume production • Long product life cycle • Low variety • Mass markets • Price competition to increase market share • Repetitive production • Stable demand • Standardised products	• Cost leadership
Reference No. (Table 5.3)	2, 16, 19, 25, 41	2, 16, 18, 19, 25, 41, 43	1, 2, 16, 41, 43	1, 16, 18, 25, 41, 43	

Table 5.7 Tabulated Decision Framework for Lean Paradigm (LP)

Lean Production (LP)					
Underlying Principles	**Key Mechanisms**	**Practices/ Techniques/ Policies**	**Manufacturing / Competitive Priorities**	**Market Conditions/ Manufacturing Requirements**	**Competitive Strategy supported**
• Quality driven • Waste Reduction • Empowerment of workforce	• Any initiatives or investment with the primary objective of improving quality. • Root cause analysis to find out the source of the problem to achieve quality at source. • Collaboration with suppliers and customer to reduce variability and improve quality. • Integrated information technology to minimise error in information exchange. • Product and process simplification to minimise production errors and improve quality. • Demand driven production to reduce the unnecessary inventory produced. • Demand driven purchase to reduce unnecessary raw materials stocked. • Just-in-time purchase and production to reduce unnecessary activities and resources deployed. • Just-in-time practices to minimise cost by restricting expenditure in any form until the last possible moment. • Enhance value (or perceived value) to customers by adding product or service features and/or removing wasteful activities. • Product and process simplification to remove unnecessary product features and production processes. • Remove unnecessary hierarchy of the shop floor supervisors by empowering the workforce directly. • .Encourage employee participation to drive continuous improvement programme • Form multi-skilled work teams to drive continuous improvement programme	• Accounting Information System (AIS) • Bottom-up decision making • Cellular manufacturing • Close participation of suppliers • Clusters of remote suppliers • Competitive benchmarking • Computer Integrated Manufacturing (CIM) • Constant work-in-process (CONWIP) • Cross training/education • Cross-functional teams • Decentralisation of authority • Defect prevention • Electronic Data Exchange (EDI) • Empowerment of workforce • Focused factory production • Group problem solving • Group technology • Intermediate bond warehouse in close proximity to manufacturing site • Inventory management • Just-in-time (JIT) • Kaizen (Continuous improvement) • Kanban/Pull system • Level scheduling (heijunka) • Line balancing • Long-term contract agreements • Lot size reduction • Made-to-order • Mixed model scheduling • Multi-skilled workers • One-piece flow • Ongoing training • Ownership of processes • Preventive maintenance • Product flow layout • Product mix neutral • Production smoothing • Quality at the source • Quality circles (QC) • Quality leadership • Quick changeover techniques • Reusable packaging • Scrap reduction • Self-directed teams • Setup time reduction • Small batches • Sole sourcing • Standardised work • Stockless production • Streamline processes • Supplier certification • Task rotation • Team briefing • Total Productive Maintenance (TPM) • Total quality control (TQC) • Total Quality Management (TQM) • U-shaped cells • Value stream mapping • Workplace organisation • Zero inventory	• Cost • Quality • Flexibility • Inventory reduction • Productivity	• Availability of raw materials is high • Flexible suppliers and customers • High volume • Large manufacturer to enforce consistent acceptable product quality and purchase price on suppliers • Large manufacturer who has considerable bargaining power and get their suppliers to deliver in ultra-small lots • Long-term contractual agreement with suppliers and customers • Low complexity of product structure • Low setup time and cost • Medium variety • Newly industrialised countries • Product are not unique or customised • Relatively stable demand • Repetitive batch manufacturing • Risk of late delivery is low • High senior management commitment • Slow product and process innovation • High staff retention	• Cost leadership • Focus
Reference No. (Table 5.3)	4-7, 9, 11-16, 19-21, 23-26, 28, 53, 69, 71-74	3-5, 7-10, 12-27, 53-59, 70, 72, 73	1, 3, 4, 6-13, 16, 23, 28, 53-59, 69-71, 74	1, 3, 5, 8, 10, 16-18, 21, 22, 25, 27, 54, 55, 58, 72, 74	

Table 5.8 Tabulated Decision Framework for Time-based Paradigm (TBP)

Time-based Manufacturing (TBM)					
Underlying Principles	**Key Mechanisms**	**Practices/ Techniques/ Policies**	**Manufacturing / Competitive Priorities**	**Market Conditions/ Manufacturing Requirements**	**Competitive Strategy supported**
• Delivery driven • Leadtime Reduction • Product Customisation	• Any initiatives or investment with the primary objectives of improving the reliability and speed of delivery. • Time as the key measurement of performance. • Focused on response-sensitive customers. • Reduction of lead time in all aspects of a company's operations. • Employing information technology for the efficient exchange of information to reduce leadtime. • Optimise the flow of information and merchandise between channel members in order to maximise customer's satisfaction. • Rapidly designing and manufacturing products customised to the diversity of customer needs. • Design for ease of manufacturing and assembly to reduce the leadtime for production • Employ computer software to aid design and increase productivity	• Cellular organisation • Close supplier relationship • Compact process flow layout • Computer-aided design (CAD) • Computer-aided engineering (CAE) • Computer-aided process planning • Computer-aided quality control • Concurrent engineering • Co-operation with customers • Cross functional teams • Design for manufacturability and assembly (DFMA) • Electronic Data Interchange (EDI) • Electronic orders processing • Electronic reorder • Empowerment for frontline decision making • Engineer-to-order • Enterprise-wide integration of learning • Excess capacity • Flexible information flow • Flexible manufacturing system • Flexible workforce • Group Technology • Integrative decision-support systems • Just-in-time (JIT) • Long-term contract with carriers and vendors • Sole sourcing • Multi-skilled workers • Point-of-sale system • POLCA system • Preventive maintenance • Process flexibility • Product planning with customer • Product succession planning • Quality circle (QC) • Quality function deployment (QFD) • Quick Response Office Cell (Q-ROC) • Reduced managerial layers • Relational database system • Self-managed teams • Setup time reduction • Share product information with trading partner • Short cycle cut planning • Skill-based pay system • Small lot sizes • Supplier development • Supplier partnership • System-wide measures of time • Time-based supply management • TQM • Training and education of all employees • Unit production system • Universal product code • Value analysis	• Innovation • New product development time • New product introduction • Quality • Reliability • Responsiveness • Speed • Variety	• Broad product line • Customers work under high level of uncertainty • Fashion oriented firms • Fashionable products • Fast paced innovation • Frequent new product introduction • Highly engineered products in small batches • Large variety • Offer the most technological advanced products • Rapid increase of the technological sophistication of product • Seasonal change • Variable demand	• Differentiation • Focus
Reference No. (Table 5.3)	29-32, 34, 39, 61, 62, 64, 65, 75, 76, 87	29-31, 33-39, 60, 62-66, 75, 77, 78, 87	29-39, 60, 61, 63, 64, 66, 76-78, 87	32-37, 78	

Table 5.9 Tabulated Decision Framework for Mass-customise Paradigm (MCP)

Mass Customisation (MC)					
Underlying Principles	**Key Mechanisms**	**Practices/ Techniques/ Policies**	**Manufacturing / Competitive Priorities**	**Market Conditions/ Manufacturing Requirements**	**Competitive Strategy supported**
• Flexibility driven • Postponement strategy • Product modularisation	• Any initiatives or investment with the primary objectives of achieving design and volume flexibility. • Using flexible processes and organisational structures geared to producing varied and individually customised products and services at the low cost of a standardised, mass-production system • Postpone the task of differentiating a product for a specific customer until the latest possible point in the supply network, through the integration of the designs of products, processes, and supply networks • Product modularity and component standardisation to enable mix and match of component for increased variety. • Customer involvement to identify the degree and type of customisation to be provided • Using information technology to enable fast information exchange for effective change process.	• "Pay-for-performance" compensation systems • Adaptive customisation • Assemble-to-order • Automated decision support systems • Close proximity of suppliers • Collaborative customisation • Cosmetic customisation • Customer involvement • Customer membership program • Dependable suppliers • Diversity in modules • Dynamic network of autonomous operating unit • Fast cycle segmentation • Flexible manufacturing system • Flexible workforce • Highly skilled workforce • Information sharing • Modular design of manufacturing processes • Modular design of products • Outsourcing • Parts standardisation • Parts flexibility • Postponement strategy • Preventive maintenance • Process standardisation • Procurement standardisation • Product standardisation • Quality Improvement • Reengineering setup • Self-directed work teams • TBM practices • Tightly coordinated supply chain • Transparent customisation • Virtual Integration	• Cost • Customisation • Flexibility • Quality • Responsiveness • Speed • Variety • Volume	• Changing customer needs • Diminishing product life cycle • Dynamic product change • High level of market segmentation • High level of unique customer needs • High product variety • High volume • Moderate degree of customisation • Stable process change	• Focus
Reference No. (Table 5.3)	40, 41, 48, 64, 67, 79, 81, 83	41, 42, 48, 64, 67, 68, 79, 80	40-42, 48, 64, 67, 68, 80-83	40-42, 48, 79, 80, 82	

Table 5.10 Tabulated Decision Framework for Agile Paradigm (AP)

Agile Manufacturing (AM)					
Underlying Principles	**Key Mechanisms**	**Practices/ Techniques/ Policies**	**Manufacturing / Competitive Priorities**	**Market Conditions/ Manufacturing Requirements**	**Competitive Strategy supported**
• Service driven • Change Management • Strategic Alliances	• Any initiatives or investment with the primary objectives of coping with the unexpected and rapid changes to provide the required service. • Exploiting changes and take advantage of changes as opportunities • Changes the rule of the game in the market place through innovation. • Change management through integration of strategies, technology, people & systems. • Enriching the customer by providing total solution products. • Leveraging of resources through co-operation to reduce risk. • Master change and uncertainty by leveraging the impact of people, information and technology. • Using information technology to enable fast information exchange for effective change management. • Knowledge worker form various networks centred on organisational processes for effective change management. • Technological changes are linked to the corporate strategy and are closely co-ordinated with organisational changes to allow the workforce to adapt the fluctuations of production and other processes. • Replace functional departments by task forces whose creation results from customer opportunities. • Competencies outside the core must be exchanged and/or acquired through alliance. • Performance evaluation aim at spurring and sustaining both innovation and continuous improvement. • Constant evolution supported by an entrepreneurial organisational structure. • Deployment of virtual companies in the form of a dynamic organisational strategy.	• Business network redesign (BNR) • Business process redesign (BPR) • Cluster and networking • Computer Integrated Engineering (CIE) • Computerisation for information sharing • Concurrent engineering • Continuous training • Core competence management • Decentralised organisation • Electronic commerce • Flat organisation structure • Flexible human resources • Flexible manufacturing system • Flexible specialisation • Flexible workforce • Fluid clusters of network associates • Increase product information content • Integrated product / production / business information systems • Job rotation • Knowledge workers with skills in IT and multi-lingual abilities • Logistics infrastructure • Outsourcing • Physically distributed teams and manufacturing • Postponement strategy • Rapid partnership formation • Supply chain integration • Teamwork and cross-functional management teams • Value-based pricing strategies • Virtual enterprise	• Cost • Customisation • Dependability • Flexibility • Proactivity • Quality • Responsiveness • Service • Speed	• Continuous and unpredictable change • Exploitation of change as opportunities • Flexible volume • Fluctuating demand • Full service • Global competition • High degree of customisation • High level of impulse purchase • High volatility demand • Large variety • Low predictability demand • Reconfigurable • Short product lifecycle • Turbulence and uncertainty in the business environment	• Differentiation • Focus
Reference No. (Table 5.3)	2, 45-51, 84-86	2, 27, 42-45, 47, 48, 50-52, 86	2, 42-50, 52, 84-86	27, 42, 43, 46, 48-52, 84	

5.4 Verifying the decision framework

The third research activity in this stage is the verification of the decision framework. This section thus discusses and verifies the contents of the decision framework for each manufacturing paradigm.

5.4.1 Mass Paradigm

The Mass paradigm (MP) is typically driven to produce at the lowest cost/price (Duguay et. al., 1997) by drastically improving the productivity (Womack et. al., 1991). This is achieved via the adoption of economies of scale (Duguay et. al., 1997; Duray, 2002) as a key principle and economic tool for cost reduction where the total overhead of the manufacturing resources is shared among a large volume of products. In order to cope with this intended high volume production, machine and product standardisation (resource specialisation) (Burgess, 1994; Wilson, 1995; Engstrom et. al., 1996; Duguay et. al., 1997; Duray, 2002) is deployed as the key practices to reduce the non-productive time of machine setup or product change over. This resource specialisation principle is also extended to the workers to increase productivity with job divisions (Womack et. al., 1991; Burgess, 1994; Forza, 1996; Duguay et. al., 1997) that result in different groups of workers specialising only on their own unique set of simple tasks. To further improve the productivity, mechanisation of the conveyor belt system that moves the product through the production floor is employed to minimise the movement of workers, leading to the association of continuous flow production as another key practice in this paradigm. This can be related to Ford's model 'T' production (Womack et al., 1991), which involved the high volume production of a single item to ensure the maximum utilisation of the common resources to lower the overhead cost per car.

The MP is most suited to a mass market environment with stable demand for high volume and low variety products (Lee, 1989; Burgess, 1994; Duguay et. al., 1997). Such a market environment is typically associated with much matured products which are normally commodities in nature. Taking Henry Ford's model 'T' as an example, the MP flourished in the period where cars became commodities rather than luxury goods (Womack et al., 1991). Other modern day commodities identified as being suitable for this paradigm are solid-state memory cards (like Secure-Digital Cards, Compact Flash Cards, etc), Dynamic Random-Access-Memory (DRAM) chips, hard-drives for desktops and laptops, blank compact and digital video disks (CDs and DVDs), batteries, papers, pens, etc. Although these products are often marketed under different brand names, they are essentially the same products with relatively long shelf lives. Thus, the cost of obsolescence is relatively low and the competitive base here is typically cost. Therefore, accurately predicting the demand or built-to-order is unnecessary as price and availability of products are the most important criteria to meet the most suitable competitive strategy (which is cost leadership) for this environment. These criteria can be satisfied by the practices promoted in the MP described previously, for example product standardisation, specialised machines, mechanisation of production flow, make-to-stock etc. Typical organisations adapting this approach are the semiconductor companies producing solid-state memory chips like ST Microelectronics, hard-drive manufacturers like Seagate, battery manufacturers like Energizer and Duracell, and other producers of commodity products.

5.4.2 Lean Paradigm

With the Lean paradigm (LP), there is a shift in focus from a cost-driven to a quality-driven production. This is evident in the many continual quality improvement programmes that are associated with this paradigm (Sohal and Egglestone, 1994; Forza, 1996; Karlsson and Ahlstrom. 1996; Katayama and Bennett, 1996; James-Moore and Gibbons, 1997; Cua et. al., 2001; Shah and Ward, 2003; Hines et. al. 2004), for example, Total Quality Management (TQM), Total Productive Maintenance (TPM), Kaizen, Quality Circle (QC) etc. The reason for this shift in focus is the recognition of quality as the main source of problems for productivity. This is because poor quality products or parts will result in reworks/scraps that propagate down the production process, and so incur unnecessary production resources. These non-value-added activities are referred to as waste and are addressed by the quality improvement programmes seen in the LP paradigm. Thus, waste reduction programmes of any form (eg. Single Minute Exchange of Die (SMED), lot size reduction, value stream mapping etc) is a key principle identifiable with this paradigm. This principle is manifested in two key practices that are evident in the LP paradigm, namely the demand-driven production and Just-in-Time (JIT) concept (Schronberger, 1982; Neil and O'Hara, 1987; Harber et. al. 1990; Singh and Brar, 1992; Sohal et. al. 1993; Clarke and Mia, 1993; Lawrence and Hottenstein, 1995; Ramarapu et. al., 1995; Wilson, 1995; Spencer and Guide, 1995; Cua et. al., 2001; Dong et. al., 2001; Shah and Ward, 2003). In demand-driven production, no unnecessary inventories are produced; while applying JIT, no unnecessary activities and resources are deployed. Thus, reducing waste in the overall production system. Empowerment of workforce (Sohal and Egglestone, 1994; Forza, 1996; Karlsson and Ahlstrom. 1996; Katayama and Bennett, 1996; Cooney, 2002; Shah and Ward, 2003; Hines et. al. 2004) is another principle to this paradigm through practices like self-directed and multi-skilled workforces. This is necessary to support the continual quality improvement programmes and also to remove the unnecessary hierarchy of shop floor supervisors by empowering the workforce directly.

For the LP, the environment is similar to the MP paradigm apart from this being a less stable demand due to a higher product variety offering (Wilson, 1995; Engstrom et. al., 1996; Cooney, 2002). Such a market environment is typically associated with fairly mature products which have more variety and are much less of a commodity. The shelf live of such products is also relatively shorter compared to those manufactured using the MP paradigm, which also means a higher obsolescence cost. Examples of such products are computer processor chips (like the various generations of Pentium chips), cars, mobile phones, and other electronic consumer products. As the obsolescence cost of these products is substantial, it is only wise to minimise it through practices like JIT, make-to-order, Kanban systems etc., which reduce waste from excess production. Quality-driven practices evident in the LP actually yield a positive impact to the overall productivity of the manufacturing plants if implemented correctly. This is also the key reason why the LP is popular even for products that are suitable for the MP, for example computer hard-drive, as evident in the recent efforts in Six-Sigma and Lean initiatives at Seagate. Typically, cost leadership is still a highly probable strategy for such environments with quality and waste reduction programmes employed as the main means in achieving this strategy. A quality-driven organisation adopting the LP will also promote the high quality of their products as a competitive base against their competitors. However, the wide adoption of quality programmes across many organisations is beginning to make quality an ‘order-qualifying’ instead of an ‘order-winning’ criterion. A focus strategy is also suggested to rationalise the product portfolio and manage the cost of product varieties offered within this paradigm. This would ensure that variety is not offered at the expense of stable demand, high volume and repetitive production (Harber et. al., 1990; Clarke and Mia, 1993; Katayama and Bennett, 1996; Lewis, 2000; Shah and Ward, 2003). Typically organisations adopting this approach are car manufacturers such as Toyota, top-end disk-drive manufacturers such as Seagate and other reputable consumable electronics manufacturers such as Toshiba, Samsung etc.

5.4.3 Time-based Paradigm

The Time-Based paradigm (TBP) shares many similarities with the LP especially in its deployment of cross-functional teams (Q-ROC), demand-driven production (POLCA system) (Suri, 1998) and its quality programmes (to improve lead time). However, a key difference here is the emphasis of time as waste (Gehani, 1995; Kumar and Motwani, 1995; Bozarth and Chapman, 1996; Koufteros et. al. 1998; Jayaram et. al., 1999; Nahm et. al., 2003). In the LP, all waste is treated equally whether it is in the form of materials (scraps and inventories) or non-materials (time and non-value-added activities) but in the TBP, non-material wastes are treated with higher importance than material wastes. This differentiation thus separates the two paradigms with the TBP being delivery-driven (Stalk, 1988; Lindsey et. al., 1991;Gehani, 1995; Bozarth and Chapman, 1996; Koufteros et. al. 1998; Margretta, 1998; Jayaram et. al., 1999; Ko et. al., 2000) as opposed to quality-driven.

This is evident in the differences between the POLCA and Kanban systems, where the former is a combination of a pull and push system and the latter is a pure pull system (Suri, 1998). This implementation will encourage the holding of some inventories in the TBP as a result of the push mechanism in order to reduce lead time at the expense of some material wastes. Therefore, instead of the key principle of general waste reduction in the LP, a more specific waste in the form of leadtime reduction is adopted as the key principle for the TBP. The key practices here will be similar to some of those found in the LP like quality programmes, self-directed and flexible workforce, and value-stream mapping etc. (Kumar and Motwani, 1995; Bozarth and Chapman, 1996; Hum and Sim, 1996; Koufteros et. al. 1998; Ko et. al., 2000; Tu et. al., 2001; Nahm et. al., 2003) except that the focus is very much on the shortening of time to delivery, even at the expense of non-time-based attributes (excess inventory and production capacity etc.) if necessary. It is also noted that the manufacturers adopting the TBP are mainly producing high variety and highly engineered products (Gehani, 1995; Hum and Sim, 1996; Tersine and Hummingbird, 1995; Jayaram et. al., 1999). This shows that product customisation is also a key principle to this paradigm. Key practicess to enable the fast delivery of highly customised products include concurrent engineering, cross-function work teams, customer involvement, and rapid prototyping. Variable demand with high product variety and highly-engineered products are the key characteristics of companies adopting the TBM paradigm. Such an environment represents a niche market for highly customised products. As such, volume production is not possible making both the MP and the LP paradigms unsuitable. Products suitable for the TBM paradigm are typically one-of-a-kind such as custom- built sports cars or bikes, engineered-to-order specialty equipment like computer servers and telecommunications equipment. A differentiation strategy to ensure a highly perceived customer uniqueness of the product is the key, and thus is the probable competitive strategy for the TBP. Customisation alone is usually inadequate and the speed and dependability of delivery is usually the competitive edge that differentiates the competition as cost is of a lower priority for these products. Therefore, leadtime reduction practices like operating at below the full capacity, POLCA systems and other time-based management practices are commonly adopted in support of the delivery-driven objective. A focus strategy is also suggested because of the need to select a niche market for the products offered. Organisations adopting this paradigm are 3M Corporation, Xerox, Honeywell Federal Express, Domino Pizza, AT&T, Intel, Pearle Vision and LenseCrafters (Gehani, 1995; Hum and Sim, 1996; Tersine and Hummingbird, 1995; Jayaram et. al., 1999). Other organisations suitable for this paradigm are the design and manufacture companies like Datum Dynamics, which produce customised assembly tooling, and Trek Bicycle Corporation, makers of high performance bicycles.

5.4.4 Mass-Customise Paradigm

Postponement strategy is a key feature and principle to the Mass Customise paradigm (MCP) (Feizinger and Lee, 1997; Duray et. al. 2000; Duray, 2002; Su et. al., 2005), which proposed that the customisation of the final product be postponed to as late a stage as possible in the assembly process so as to consolidate the inventories of the sub-components as well as leveraging on the economies of scale from the common sub-components shared by the final products. This strategy is only possible with a highly modularised product, such as the computer, where many varieties of end products share a high percentage of common sub-components. Therefore product and process modularisation (Pine et. al., 1993; Feizinger and Lee, 1997; Gilmore and Pine, 1997; Duray, 2002) is also a key principle of this paradigm. This paradigm is also flexibility-driven (Pine et. al., 1993, Feizinger and Lee, 1997; Gilmore and Pine, 1997; Magretta, 1998), as evident from its flexible process and product configuration, thus offering fairly varied products at a reasonably low cost. The MCP typically operates in an environment of a high level of unique customer needs (Pine et. al., 1993; Feizinger and Lee, 1997; Gilmore and Pine, 1997) such as the computer market. As such, a high level of market segmentation is the norm to cluster groups of customers sharing similarities in order to exploit the economies of scale. The environment also exhibits a medium level of variety or moderate degree of customisation (Pine et. al., 1993, Feizinger and Lee, 1997; Gilmore and Pine, 1997; Magretta, 1998) as compared to the highly customised products seen in the TBM paradigm. Typical products suitable for the MCP are personal computers and other consumer electronics like digital cameras, MP3 players and mobile phones as these products consist of common electronic components like microprocessor chips, memory chips, imaging and audio processor chips, etc. These standardised modular components provide different functionalities, which can be ‘mixed-and-matched’ during the manufacturing process to provide the high product varieties required while keeping the production cost low. A focus strategy is thus suggested because of the need for careful market segmentation and clustering to manage the complexity involved in incorporating the required flexibility in the system for this flexibility-driven paradigm. Examples include Dell, Hewlett-Packard (Pine et. al., 1993, Feizinger and Lee, 1997; Magretta, 1998) and other similar computer assembly companies.

Various approaches to mass customisation can also be found in companies like Paris Miki, Lutron, Planters, ChemStation (Gilmore and Pine, 1997).

5.4.5 Agile Paradigm

Finally, the Agile Paradigm (AP) has the key objective of coping with unexpected and rapid changes (Duguay et. al., 1997; Quintana, 1998; Zhang and Sharifi, 2000; van Hoek et. al., 2001; Brown and Bessant, 2003; Bruce et. al., 2004; Coronado et. al., 2004). Thus, effective change management and strategic alliances are the two key principles of this paradigm (Vastag et. al., 1994; Zhang and Sharifi, 2000; van Hoek et. al., 2001; Guisinger and Ghorashi, 2004). This is evident in the infrastructural choices made by an organisation adopting the AP; for example, integration of product/production/business information, virtual enterprise, decentralized organisation, rapid partnership formation, outsourcing etc, all of which are practices to cope with the continuous changing market (Duguay et. al., 1997; Quintana, 1998; Zhang and Sharifi, 2000; Coronado et. al., 2004; Guisinger and Ghorashi, 2004). Strategic alliances also leverage on sharing resources to reduce risk from the dynamic environment. It is also observed that organisations adopting the AP are typically global companies with world wide operations (Vastag et. al., 1994; Prater et. al., 2001; Bruce et. al., 2004; Coronado et. al., 2004; Guisinger and Ghorashi, 2004). This is in line with the effect of globalisation which has resulted in increased competition and volatile market demand, a condition that is addressed by the AP. The scope of operations for organisations adopting the AP is also large through alliances; this is in order to provide the customer with total solution products. Thus, the AM paradigm can be identified as service-driven. Finally, the AP appears to be most suited to a highly volatile and dynamic market environment, typical of a globalised economy (Burgess, 1994; Vastag et. al., 1994; Quintana, 1998; Prater et. al., 2001; Brown and Bessant, 2003; Bruce et. al., 2004; Coronado et. al., 2004; Guisinger and Ghorashi, 2004). Organisations adopting this paradigm typically have widely dispersed operations and are generally organised in a decentralised manner to serve the diverse needs of their large customer base (Prater et. al., 2001; Coronado et. al., 2004; Guisinger and Ghorashi, 2004). Typical products suitable for this paradigm are 'all-in-one' solution products like warehouse management solutions offered by third party logistics companies, enterprise management software applications like Enterprise Resource Planning (ERP) systems, complex large scale simulation packages, etc. These products will capitalise on the wide core competencies of the organisation as well as localised knowledge for their competitive base. The competitive practices here are typically strategic partnerships, outsourcing, virtual integration and self-managed knowledge workers who adapt to the rapid changes and uncertainty of the environment (Duguay et. al., 1997; Quintana, 1998; Zhang and Sharifi, 2000; Coronado et. al., 2004; Guisinger and Ghorashi, 2004). This service-driven paradigm supports the differentiation strategy in the form of unique full-service solutions offered to differentiate from global competition and reduce competitive forces. A focus strategy is also suggested to select the appropriate market segments to compete in, in relation to the company's competencies and so create a sustainable competitive advantage. Organisations adopting this paradigm include Vanguard Medica, Britvic Soft Drinks and Remmele Engineering (van Hoek et. al., 2001). Other organisations suitable for this paradigm are third party logistics companies like DHL, ERP solution providers like SAP and automation solution providers like Brooks Automation.

5.5 Requirements of the decision model

Previous sections have construct, populate and verify the contents of the decision framework for the five manufacturing paradigms identified. It is therefore the intent of this section to summarise the findings and establish a requirement set for the decision model, against which the performance of decision modelling techniques can be plotted in the next stage.

From Section 5.3, it is apparent that each paradigm arises from a unique set of market conditions and manufacturing requirement, which defines the assumptions about the competitive landscape that enable the company to comprehend and react to. Verification of this decision framework (Section 5.4) has also revealed that the characteristics of the market conditions and requirement are in fact the results of the product maturity and the industry type that the company is in. Thus, the first set of requirements is the product life cycle stages and the industry types.

Next category will be the types of competitive strategy adopted by the companies. Although Porter's (1980) 3 generic competitive strategies are adopted for the construct of the decision framework, actual competitive strategy adopted by the companies as discussed in the literature is more varied than these generic strategies (Section 5.4). In fact, most companies adopt a hybrid focus in one or a few of the five competitive dimensions portrayed by Frohlich and Dixon (2001). These five dimensions are price, flexibility, quality, delivery and service. Obviously, competing in price is equivalent to the cost leadership strategy discussed in Porter's (1980) work. However, contemporary literatures have provided evidences that companies are competing in more than one dimensions to achieve superior market position and competitiveness. For example, top disk drive manufacturer like Seagate not only strive to produce at the lowest cost. The company has also implemented quality programme like six sigma initiatives to strive for 'zero' defects and compete in the quality dimension. Thus, competitive strategies categories must be evaluated against the compound competitive dimensions adopted by the companies. Each of these dimensions also gives rise to one or more competitive objectives, which are mainly supported by the manufacturing function. These objectives are detailed in Table 5.2.

The next category is the paradigm layer. In this case, the five unique manufacturing paradigms identified are used. Tables 5.6 to 5.10 have also provided a list of underlying principles, key mechanisms and practices associated with each paradigm. As discussed previously, the comprehensive list of practices is too large and not manageable. On the contrary, the list of underlying principles is too generic and lacks the usability. Thus, through the analytical examination of the combine list of key mechanisms discussed, a list of 29 common generic key practices are identified. This list together with the previous categories discussed are summarised in Table 5.11.

Table 5.11 Requirement set for the Decision Model

Category of requirements	**Requirements for evaluation**
Assumptions hold about the competitive landscape	To represent a unique landscape derived from the amalgamation of these two conditions, 1) Product Life Cycle Stages 2) Industry Types
Competitive Strategies	To represent a unique strategy from a combination of one or more of the following dimensions, 1) Price 2) Flexibility 3) Quality 4) Delivery 5) Service
Competitive Objectives	To prioritise the objectives to achieve from the list below, 1) Cost 2) Volume 3) Design 4) Variety 5) Conformance 6) Performance 7) Speed 8) Dependability 9) After-sale 10) Distribution
Manufacturing Paradigms	To select the best fit paradigm to adopt from the list below, 1) Mass Paradigm (MP) 2) Lean Paradigm (LP) 3) Time-based Paradigm (TBP) 4) Mass Customise Paradigm (MCP) 5) Agile Paradigm (AP)

Table 5.11 Requirement set for the decision model (cont.)

Key Practices	To highlight the key practices associated with the selected paradigm from the list below, 1) Economies of scale 2) Resource Specialisation 3) Product Standardisation 4) Continuous Flow 5) Centralised Planning and Production 6) Cost Driven 7) Waste Reduction 8) Continuous Improvement 9) Lot size Reduction 10) Self-driven Workforce 11) Cellular Manufacturing 12) Cross-functional Workforce 13) Supplier Integration 14) Integrated Information System 15) Quality Driven 16) Leadtime Reduction 17) Product Customisation 18) Cellular Organisation 19) Customer Involvement 20) Delivery Driven 21) Postponement Strategy 22) Product Modularisation 23) Flexibility Driven 24) Change Management 25) Fluid Cluster of network associates 26) Decentralised Organisation 27) Focused Competency Centers 28) Global Network 29) Service Driven

5.6 Chapter Summary

The research described in this chapter has established a requirement set for the decision model. This requirement set presented in Table 5.9 can now act as a measuring system against which the capability of existing decision modeling techniques can be assessed in the next chapter.

Chapter 6: Constructing the Decision Model

In Chapter 5, the requirement set for the decision model has been set out. Existing decision modeling methods will be reviewed against these model requirements to select the most appropriate technique to model this decision process. This chapter therefore deals with the construct of the decision model and is also the second stage of the research programme. The chapter first presents the purpose and method of this stage of research (Section 6.1), followed by a review of the decision modelling techniques for consideration (Section 6.2). Subsequently, 3 modelling techniques are identified for evaluation against the requirement set to select the best technique for the modelling of the decision process (Section 6.3). Finally, a preliminary decision model is constructed and presented in Section 6.4.

6.1 Stage 2: Purpose and Method

The purpose for this stage of the research is to model the decision process for best practice adoption. The first step in realising this objective is to select a decision modelling technique to model this process. In Chapter 5, a decision framework is formed (Section 5.2), populated (Section 5.3) and verified (Section 5.4). This allows the establishment of a detailed requirement set (Section 5.5), which forms the specifications for the decision model to be constructed. In practice, it is possible to describe many different systems with one form of model, and one system with many different forms of models (Novosad, 1982). Hence, there exist more than one suitable modelling technique to model this decision process. In view of this, to review an exhaustive list of modelling techniques would require too much resource and effort to test their relevancy and thus ineffective in modelling the problem. Therefore, a rationalise approach to shortlist the number of decision modelling techniques brought forth for investigation is adopted.

Chapter 5 has generated a set of criteria, termed the requirement set, that a decision modelling technique will need to represent (Table 5.9). These requirements can be summarised as follow:

1) Representation of the assumptions hold about the competitive landscape in which the company operates.
2) Representation of the competitive strategy adopted by the company.
3) Prioritisation of objectives to achieve by the company.
4) Selection of the best-fit paradigm for the company.
5) Association to the key practices.

The characteristics of these five criteria will define the nature of the problem in study. They are then used to rationalise the number of suitable decision modelling techniques for detailed testing. The best technique to model the decision process is selected via plotting the performance of the identified techniques against the requirement set. Finally, the selected technique is used to construct of the decision model. The following sections of this chapter are the product of applying this research programme and the outcome of the process.

6.2 Review of Decision Modelling Techniques

The first research activity in this stage is the selection of a small subset of decision modelling techniques that are suitable to construct the decision model. As discussed in Section 6.1, testing the requirement set against an exhaustive list of existing modelling techniques is too time consuming and ineffective for the attainment of the research objective in pursuit. Instead, a rationalised approach of selection is conducted. Although this runs the risk of omitting some suitable techniques, we will not be severely penalised for there exist more than one competent technique for modelling the same problem (Novosad, 1982). Therefore, this section will examine the characteristics of the decision model to identified three suitable decision modelling techniques for detailed testing in the next section.

6.2.1 Characteristics of the decision model

From 5 criteria of requirement presented in Section 5.5 and summarised in Section 6.1, the characteristics of the decision model can be derived. The first characteristic is the apparent qualitative nature of the measurements required. This is evident in the qualitative variables specified in the requirement set, like the competitive dimensions and objectives etc. As evident in Chapter 5, the competitive strategy adopted by a company is often a hybrid of one or many of the competitive dimensions described, which also led to a prioritisation list of the objectives to achieve. Therefore, selected modelling techniques selected must be also able to represent and process multi-criteria objectives.

There exist more than one suitable strategy for companies to gain competitiveness within a similar landscape depending on the resource availability of the company. One example is the portable music player market where big companies will typically compete on cost and quality by targeting at the mass market with low variety to gain the economies of scales in operation. Smaller companies who do not have the resource and distribution network will typically focus on niche market by providing variety and customisation in their products (Porter, 1980). Similarly, cultural differences, inherent legacies and resource disparities can also result in companies adopting different set of best practices from the same paradigms. This is because of the absence in a common deterministic ranking of importance for these practices. Therefore, modelling techniques selected must be able to portray the priorities of choices inherent in such decision problem.

According to Raiffa (1968), models used to represent real world decision problems falls into three major categories, namely the descriptive, normative and prescriptive models. Although the eventual outcome from this research is to prescribe the best-fit manufacturing paradigm for the company to guide the best practice adoption process, actual paradigm adopted by the company may differ. This is because the choices in strategy formulation and adoption are often the results of intuitions rather than rational judgements (Section 2.4). Thus, a prescriptive model would be inappropriate for such work, as it will be difficult to gain industrial traction due to the inherent subjectivity for this area of work. Performance of such strategic choices are also difficult to measure and benchmark because of the absence of a reference or control base. This also restricts the use of a normative approach to the decision modelling for such problem. In the end, descriptive model is the apparent choice for the representation of such decision problem. This also set the final characteristic for the form of the decision model. It is also worth noting that most existing work in best practice adoption are also descriptive in nature (Section 3.4), which reinforces this argument.

In summary, 4 characteristics of the decision problem are highlighted. They are qualitative, multi-criteria objectives, prioritisation of choices and descriptive modelling representation. The following section will identify a small subset of techniques suitable for modelling these characteristics.

6.2.2 Identification of suitable modelling techniques

Novosad (1982) has detailed 6 classifications of models in terms of their form, functions and characteristics. These classifications are summarised in Table 6.1. The characteristics of the decision problem detailed previously are then evaluated against this model taxonomy and eventually the suitable modelling techniques identified and carried forward for testing in the next section.

The first characteristic is the need for qualitative representation of the decision variables. Verbal (VbM) and Symbolic (ScM) models are the most apparent form that matches this characteristic as natural language and graphical representations used in these models are both qualitative in nature. VbM typically takes the form of a descriptive write-up or verbal description of a system while Symbolic model comes in graphical representations of an abstraction of the problem. Some of the popular techniques in these categories are Rich Picture (RP)(Davies and Ledington, 1991), Integrated Definition (IDEF) Methods (Brovoco and Yadav, 1985), Influence Diagram (ID) and Decision Tree (DT) (Yuan and Shaw, 1995). In fact, techniques for Mathematical (MtM) and Simulation (Mtm) model like Regression Analysis (RA) (Lindley, 1987) and Discrete Event Simulation (DES) (Roth, 1987) are also considered as a form of symbolic models except that their representations typically adopt a more quantitative approach in their representation of variables in the model. Nevertheless, qualitative variables can be quantified through the use of assumptions. Thus, MtM and SmM are also considered.

Table 6.1 Model Taxonomy for Form, Function and Charateristics (Adapted from Novosad, 1982)

Classification	Forms	Function	Characteristics
Verbal Model (VbM)	Written and verbal description of a system.	To provide a rich description of the system through the use of natural language.	•High level of abstraction. •Qualitative description. •Ambiguity of natural language.
Iconic Model (IcM)	Pictorial and physical representation of a system.	To retain the system characteristic for the determination of causal relationships or to serve as an explanatory function.	•Linear transformation from system. •Describe a static condition. •Describe a dynamic condition at a particular time instant.
Analog Model (AgM)	Analogy of a system to another well-defined system or model.	To explain a phenomenon by reference to some other occurence which is well-defined for explanation.	•Require sufficient one-to-one correspondence between system and model. •Varying degree of relevancy to the purpose of inquiry. •Good for prediction and inference.
Symbolic Model (ScM)	Graphical representation of a system.	To represent the law and theory of the system under study.	•No physical or functional resemblance to system. •Abstraction of a system. •Good for explanation of system behaviour.
Mathematical Model (MtM)	Mathematical representation of a system.	To present a high level abstraction in depicting real properties for explanation and solution.	•Compact and efficient language •No ambiguity. •Quantitative description.
Simulation Model (SmM)	Replica of a system in form, fit and function.	To duplicate the dynamic performance of a system for analysis and prediction.	•Brute force type of approach •High fidelity model •Glass box approach to problem solving.

Second characteristic is the multi-criteria consideration, which is very well represented by techniques like DT and DES identified earlier. Another popular technique that is widely adopted for multi-criteria decision-making is the Analytical Hierarchical Process (AHP) (Saaty, 1980), which will also be considered. This technique can handle both qualitative and quantitative criteria and variables in the same model.

Next is the prioritisation of choices in the model representation. Apparent from the list, techniques like AHP, DES and RA do model the priority or weightage for each decision variables. While DT only model how probable a choice is selected, probability and priority of choice are related. Thus, DT techniques are also considered

Finally is the need for a descriptive model to capture the causal linkages between the decision variables and alternatives. It is important that the selected modelling techniques must be able of provide such description because these links between best practices and competitive strategy are inherent to the aim of this research. All suggested methods above fulfil the characteristic of causal links representation.

Table 6.2 Comparisons of Modelling Techniques against Characteristics of Model Representation

Modelling Techniques	Representation			
	Qualitative	Multi-Criteria	Priority of choices	Causal Links
RP	✔	✘	✘	✔
IDEF	✔	✘	✘	✔
ID	✔	✘	✘	✔
DT	✔	✔	✔	✔
RA	✔	✘	✔	✔
DES	✔	✔	✔	✔
AHP	✔	✔	✔	✔

In summary, seven decision modelling techniques are highlighted and their suitability plotted against the four characteristics of model representation discussed (see Table 6.2). From the table, three techniques are identified as suitable to represent these characteristics. They are Decision Tree (DT), Discrete Event Simulation (DES) and Analytical Hierarchical Process (AHP). A detail description for these three techniques can be found in Appendix A. In the next sections, these three techniques will be contrasted against the requirement set derived in Section 5.4 to select the best technique for the construct of the decision model.

6.3 Testing of Decision Modelling Techniques

Previous section had shortlisted three suitable decision modelling techniques to model the decision problem in study. These techniques are Decision Tree (DT), Discrete Event Simulation (DES) and Analytical Hierarchical Process (AHP). Thus, the research activity in this section is to test these techniques against the requirement set defined in Section 5.5 to select the best technique for the construct of the decision model subsequently.

Chapter 5 generated these list of requirements set (see Section 5.4),

1. Representation of the assumptions hold about the competitive landscape in which the company operates.
2. Representation of the competitive strategy adopted by the company.
3. Prioritisation of objectives to achieve by the company.
4. Selection of the best-fit paradigm for the company.
5. Association to the key mechanisms for best practice selection

In the following subsections, the modelling performance of the 3 techniques will be analytically tested against each of these five requirements.

6.3.1 Representation of Competitive Landscape

As discussed in the previous chapter, competitive landscape of a company can be represented by two conditions, namely the product life cycle stages and the industry types. According to Levitt (1965), there are typically 4 stages in the life cycles, namely Introduction, Growth, Maturity and Decline. Associated with these product stages is a set of market conditions and requirements, which have to be met in order for this product to be competitive in the market place. One example is the product introductory stage where this product is new and sales volume is low. There is also relatively no competition in the market place if this product is unique. So the price of this product can be high if the customer can be convinced about the new value proposition of this product. However, a new product can also be priced low at a market penetration price if it fails to establish a differentiation with similar products in the market place. Therefore, an additional condition is required to define a unique landscape.

Porter (1980) proposed 5 industry environment types that differ most strongly in their fundamental strategic implications along the key dimensions of industry concentration, state of industry maturity and the exposure to international competition. These industry types are Fragmented, Emerging, Transition to Maturity, Declining and Global industries. The associated industry environment together with the stages of the product life cycle will determine the unique competitive position that a company needs to adopt to stay competitive on the market place.

4 product life cycle stages and 5 industry types will give rise to 20 unique sets of combinations. However, all these 20 pairs may or may not exist because of possibility of some inherent mismatch between some product life stages and the industry type. One example is the emerging industry, which are typically associated with products in the introductory and growth stage. As these products aged through the maturity stage, industry type may be transformed accordingly.

In view of these, DT and AHP are most ideal to explicitly portray the combination of the pairs of product life stages and industry. However, AHP preferred over DT for the inherent eigenvector method, which is ideal to rationalise the choices of unique competitive landscape. DES approach requires more explicit investigation into the relationship between product life cycle and industry types model prior to modelling. Thus, making this technique less than ideal for such representation.

6.3.2 Representation of Competitive Strategy

Porter (1980) proposed 3 unique generic competitive strategies that a company may adopt. However, the actual strategy pursuit by a company is much more differentiated than these generic forms. Thus, a combination of the 5 competitive dimensions (Price, Flexibility, Quality, Delivery and Service) is proposed as the means to identify the set of unique competitive strategies to be adopted (Chapter 5).

Given a choice, most company would opt to compete in all frontiers of these dimensions and this is also where the high performing companies differentiate themselves from the rest. Competing in all frontiers is not a viable strategy as discussed by Porter (1996). There are trade-offs associated with each dimensions and companies need to manage them and define their unique mix of focus. If a company manages a portfolio of products, the strategy adopted for each product might differs and company may also need to manage and check for coherence between these different strategies.

In view of these, modelling techniques chosen must be able to quantify a scale of preferences in each of these 5 dimensions. AHP is the most ideal for such quantification of qualitative variables because this technique incorporates the means to systematically quantify the weightages required. DT and DES technique both required the use of additional techniques like statistical method to quantify the values required. DT is preferred over DES because of its more explicit representation of variables.

6.3.3 Prioritisation of Objectives

The 5 competitive dimensions are associated with 10 objectives defined in Frohlich and Dixon's (2001) work, which was summarised in Table 5.2. Similarly to the competitive dimensions, objectives pursuit by the companies can be determined via some form of quantifiable scale.

For this case, DT is regarded as the more ideal than AHP because of the way the quantifiable scale is derived. Pairwise comparison approach adopted by AHP is typically manageable if the number of alternatives to evaluate is small. For example with 5 choices, the number of pairwise comparisons required is 10. This number increases to 45 for a 10 choices problem in this case. DES can adopt the same method as DT for the quantifiable scale, although the model expression is less explicit.

6.3.4 Selection of Best-fit Paradigm

Although the emergence of manufacturing paradigms and their association with radically different best practices is apparent in the industry (Section 3.2), the best-fit paradigm for a company is not. This is also the limitation of existing best practice research whereby most companies will attempt to replicate the success of their counterparts through benchmarking of best practices adoption in the industry (Section 2.4). Determining the best-fit paradigm for a company is possible through the help of experts. However, some company may also exhibit some artefacts associated to a particular paradigm. Therefore, an analytical approach to compare the expert opinions and physical evidences observable is essential to obtain the adequate contextual information required for an accurate prescription on this subject matter.

In view of this, AHP is ideal in quantifying the opinion from experts while Decision Tree is more applicable for quantifying the physical artefacts from objective data collection on the company. Physical artefacts are preferred over expert opinion because the latter is more indirect and may lack of the contextual information required. More explicit definition of this variable is required in order for the construct by DES. Thus, this technique is the least preferred.

6.3.5 Association to Key Practices

Table 5.4 to 5.8 have already provided a comprehensive list of the practices associated with each of the five manufacturing paradigms identified. Table 5.9 has also identified a list of 29 common key practices for adoption, which can be associated to one of more paradigms. As such, the links between paradigm and its associated key practices are verified. However, the priority and the precedence of choices between these practices are also important if this eventual tool is to aid the best practice adoption process. Therefore, quantifiable priority or preference choices on these key practices are important.

Similar to the argument in Section 6.3.3, DT is more appropriate than AHP when the number of choices is large. In this case with 29 alternative practices, quantifying them through pairwise comparison is ineffective and may result in large inconsistency in the choices made. Statistical means of data collection employ by DT is a better alternative. Again, DES required the explicit modelling of each practices, which is the least preferred approach.

In summary, Table 6.3 summarised and compares the 3 shortlisted decision modelling techniques discussed above. On the scale of 1 to 3, each technique is ranked and scored against the requirement set. The technique with the highest score will be selected for the construct of the decision model. In this case, the Decision Tree technique having the highest total ranking score of 13 is selected for the construct of the decision model.

Table 6.3 Comparisons of shortlisted Decision Modelling Techniques

Modelling Techniques	Requirement Set (Ranking Score)					Total Ranking Score
	Competitive Landscape	Competitive Strategy	Priority of Objectives	Best-fit Paradigms	Key Mechanisms	
DT	2	2	3	3	3	13
DES	1	1	2	1	1	6
AHP	3	3	1	2	2	11

6.4 Constructing the decision model

From Section 6.3, DT is selected as the best technique for the construct of the decision model. In this section, a preliminary decision model will be constructed to represent the decision process described in Chapter 5. The requirement set of the decision model can be converted directly into a decision tree and is shown in Figure 6.1.

This decision tree detailed the graphical model of a theoretical best practice adoption decision process defined in Chapter 5. Branches of the tree denote the decision alternatives and chance event outcomes. For example, company in the emerging market would probably have products in the introductory or growth stage. For product in the introductory stage, it is identified that Focus and Differentiation are the most appropriate strategy. Adopting the Differentiation strategy will yield 3 alternatives (Delivery, Flexibility and Service) competitive dimensions that a company can choose to compete on. Competing on the speed of delivery will result in the company adopting either the Lean or Time-based paradigms where a list of associated key practices can be selected. Table 6.4 gives the description to these practices to guide the adoption process.

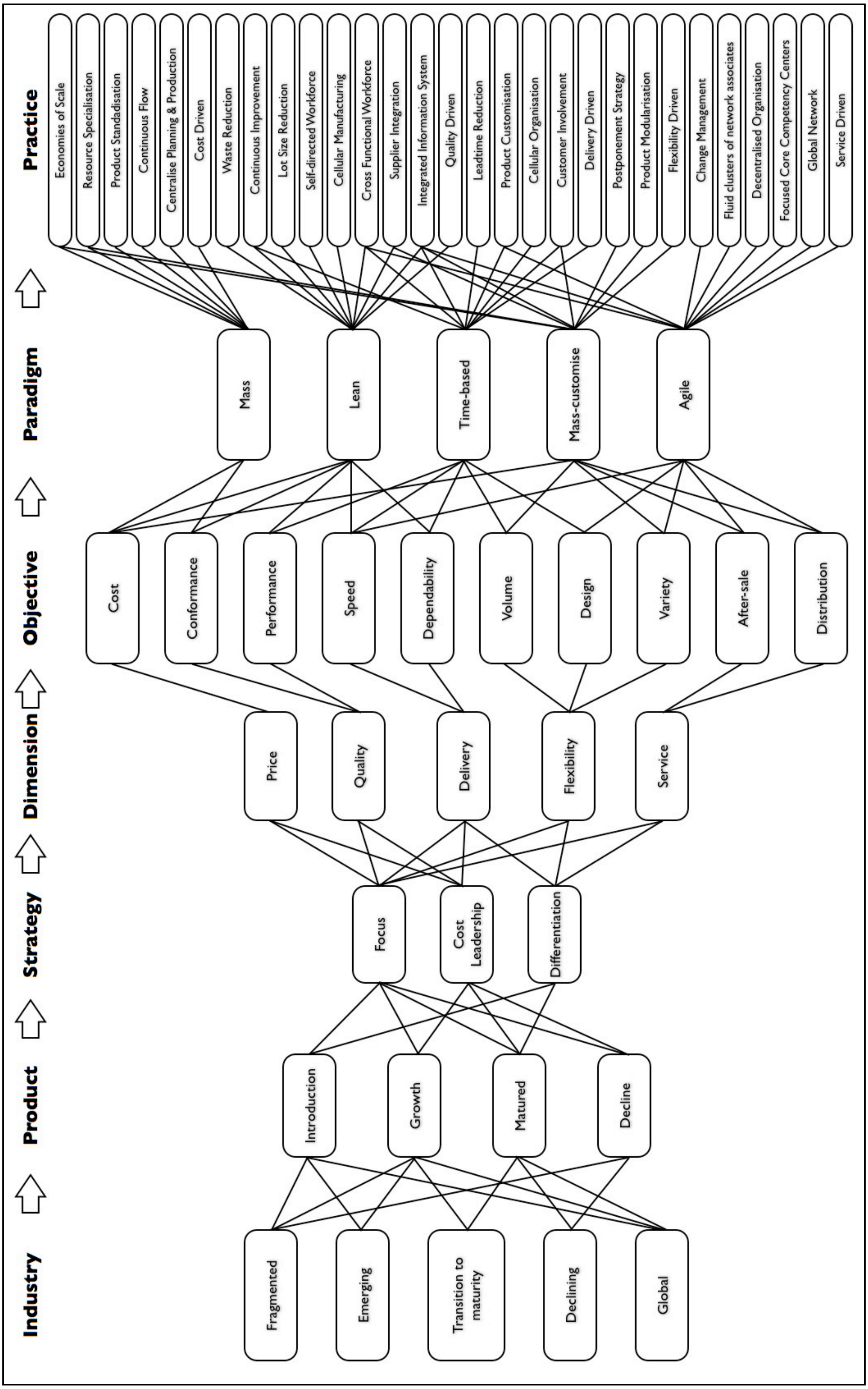

Figure 6.1 Preliminary Decision Model

Table 6.4 Description of key practices

Manufacturing Paradigm	Key Practices	Descriptions
Mass	Economies of Scale	Reducing cost through economies of scale or produce as much as possible by increasing production quantity over a fixed cost base of production resources.
	Resource Specialisation	Use specialise tools or machines. This is accompanied by producing at large quantity to gain the economies of scale.
	Product Standardisation	Standardisation of product offering to mimise the variety of specialise tools or machines required. This will pool the production volume of products on the specialise machine and increase the machines or tools' utilisation level.
	Continuous Flow	Producing to forecast and minimise disruption in the shop floor. This is to keep the machines or tools' utilisation level high and minimise the idle time.
	Centralise Planning and Production	Centralise planning is use to collate the orders to gain the economies of scales for the products to be produced. Centralise production will maximise the resource utilisation .
	Cost Driven	Lowering the cost of production is the main objectives. This will results in the setting of cost targets and implementation of tools or methods to drive the production cost down.
Lean	Waste Reduction	Waste reduction through process standardisation and simplification. Reduction and removal of non-value added processes in the manufacturing system will improve efficiency of the overall system.
	Continuous Improvement	Constant drive to improve the process to drive out waste in the manufacturing system.
	Lot Size Reduction	Drive for single piece flow to support quick change over. This is in support of the waste reduction principle to reduce non-value added activities in the sense of unnecessary work-in-progress in the manufacturing system.
	Self-directed workforce	Self-directed workforce is necessary to support the continuous improvement program. To achieve this, the skill sets of the workforce should be broad to enable the formation of self-contained work teams.
	Cellular Manufacturing	To facilitate the self-directed workforce, flexibility in the manufacturing system is required. Cellular layout of the manufacturing facility is adopted so that the ownership of tasks is promoted to encourage the work team to function autonomously.
	Cross-functional workforce	Cross-functional workforce is necessary to support the continuous improvement program. The breadth of skill sets in workforce permits greater understanding across functions to exploit opportunities for collaboration and information.
	Supplier Integration	Integration with suppliers to share information in eliminate unnecessary specification mismatch and thus reduction of waste efforts.
	Integrated Information system	Integration of information across the manufacturing organisation is require to manage the tightly coupled manufacturing network.
	Quality Driven	Quality programme is the heart of this paradigm. Poor quality results in rework or scrap which account for both the time and material waste in the system. Driving these quality programmes will support the waste reduction effort.
Time-based	Leadtime Reduction	Reduction of lead time in all aspects of the manufacturing operations. Using time performance measure across the whole system will drive the time reduction and thus improving the overall leadtime.
	Continuous Improvement	Constant drive to improve the process to drive out time waste to drive the continuous leadtime reduction.
	Product Customisation	Rapidly design and manufacture products customized to those needs is possible with the the total time reduction in the manufacturing system.
	Cross-functional workforce	Cross-functional workforce is necessary to support the continuous improvement program. The breadth of skill sets in workforce permits greater understanding across functions to exploit opportunities for collaboration and information sharing.
	Cellular Organisation	Celluar organisation creates small units of competencies centers that promotes cross-functional interaction that exploit opportunities for leadtime reduction.
	Customer Involvement	In support of the product customisation. Customer involvement in the early stage of design process is key to establish the right design specifications of the product.
	Integrated Information system	Integration of information across the manufacturing organisation to facilitate information sharing.
	Delivery Driven	Focuses on reducing the lead times for all tasks in the organisation to drive the key objectives which are delivery speed and dependability of delivery.
Mas-customise	Postponement strategy	Postponing the assembly of final product to as late a stage as possible using flexible processes and organizational structures. Ability to produce varied and individually customized products and services at the cost advantage of a standardized, mass-production product.
	Product Modularisation	Product modularity and component standardization. This is required to support the postponement strategy by modularisation of products into standadised sub-component that can be mass produced to achieve the cost advantage.
	Integrated Information system	Integration of information across the manufacturing organisation is require to manage the broad product line and supply network. Information is key to manage the tightly coupled manufacturing network.
	Flexibility Driven	Design flexibility for this paradigm is limited. The objectives to offer a considerable variety while allowing for volume flexibility because of the absence of mass market volume.
Agile	Change Management	Change management through integration of strategies, technology, people & systems.
	Fluid Clusters of network associates	This is enabled by strategic alliance and rapid partnership formation to create virtual enterprises to serve a newly emerging market.
	Decentralise Organisation	Organisation structure is flat and functional units are loosely coupled. Characterise by profit centers which are self-contain and responsible for themselves. This type or organisation will support the rapid creation and destruction of virtual network clusters.
	Focused Competency Centers	In support of the decentralise organistion while keeping the integrity of the whole organisation by reducing overlapping activities. Focused competency centers can be viewed as the building blocks for the construct of virtual enterprise.
	Global network	Leveraging the impact of people, information and technology. This is to leverage on the diversity of resources globally and at the same time diversify the impact of market risk.
	Integrated Information system	Integration of information across the manufacturing organisation is require to manage the distributed and loosely coupled manufacturing network. Information sharing across the network is essential to leverage on the diversified pool of resources.
	Service Driven	Exploration of competitive bases (speed, flexibility, innovation proactivity, quality, and profitability) through the integration of reconfigurable resources and best practices to enrich the customer by providing a total solution products

Further detailed about the tree nodes and branches can be found in Appendix B. Subsequent chapters of this paper will detail the verification and validation process for this decision model.

6.5 Chapter Summary

The research described in this chapter has constructed a preliminary decision model for the analytical selection of manufacturing best practice. The decision model provided in Figure 6.1 will be verified against experts' opinions in the next chapter.

Chapter 7: Verifying the Decision Model

In Chapter 6, a preliminary decision model has been constructed. Since the construct of this decision model is based upon the analytical synthesis of theoretical findings from the literature, there is a need to verify the model against experts' opinions to ascertain the accuracy of the model representation. This chapter therefore deals with the verification of this preliminary decision model. The chapter first presents the purpose and method of this stage of research (Section 7.1). This is followed by the selection of experts for the conduct of the verification process (Section 7.2). Subsequently, a description of the verification methodology is presented (Section 7.3). The results and findings from this research process are then discussed (Section 7.4) and the refinement to the preliminary decision model made (Section 7.5). Finally, conclusions are drawn.

7.1 Stage 3: Purpose and Method

The purpose of this stage of the research is to verify the model accuracy against existing knowledge and concepts. This is important because the construct of the decision model is based upon the analytical synthesis of theoretical findings from the literature. As such, model verification is necessary to substantiate that the model is transformed from one form into another, as intended, with sufficient accuracy (Balci et al., 1997). To achieve this objective, it is important to ensure a consistent and impartial data collection method to objectively solicit and investigate the experts' opinions on the preliminary decision model developed in Chapter 6. Once the verification is carried out and the preliminary decision model refined, the next stage of the research can then validate this model against actual industrial settings.

Three research methods are considered for this stage of the research programme. They are survey questionnaire, Delphi technique and interview. Survey questionnaire approach is a way of contacting a large number of people to obtain their views. This method does not allow interviewer intervention to correct misunderstanding (Oppenheim, 1996) or to offer explanation if a respondent is not clears about a question (Zikmund, 1991). Advantages of survey questionnaires are the reliability in assuring respondent anonymity, low level of administration, high level of standardisation, reduction of bias introduced by interviewers, the enabling of respondents to complete the survey questionnaire on their own time, and the reduction of required resources (Adesola, 2002).

The Delphi technique is a way of obtaining group input for ideas and problem solving from experts in the field. The technique requires no face-to-face participation and essentially consists of three or more rounds to elicit information and feedback from the participants involved in the process. Whilst this approach predicts a reliable judgement and maintains anonymity of participants, it requires adequate time and participants' commitment, and produces biased judgements of the selected group (Adesola, 2002).

The interview method allows the interviewer to maintain spontaneity and to clarify responses when necessary. Respondents can express themselves in their own language and the duration of the interview can be clearly determined. However, disadvantages include the expense of the interviews, the constraint upon the sample size due to the time require to undertake each individual interview, the large amount of administration involved, problem associated with respondent anonymity, the possibilities of causing inconvenience to respondents, and the effects of interviewer bias on respondents (Ellson, 2002).

The main concern about the research method of choice is the consistency and objectivity of the data collection approach. In comparison to the Delphi and Interview methods, the Survey approach is the only method that implements a consistent data structure for the data collection process through the use of a standard questionnaire set for all respondents. However, the issue here is the difficulty in obtaining a large pool of experts required to conduct this survey. On top of this, the proposed decision model is also atypical to the conventional approach of manufacturing strategy formulation and best practice adoption. Thus, the lack of direct correspondence between the researcher and the respondents for the survey method may introduce too much noise into the results due to the subjective interpretation from the experts. Although Delphi method can remove such subjectivity in the responses through iterative rounds of questionnaires, the time and participants' commitment required is an issue.

In view of these reasons for and against each of the three research methods, a hybrid approach in the form of a semi-structured interview through the use of a structured questionnaires set is adopted. This method will provide a structure to the information collected via the use of questionnaires to minimise interviewer's bias. With interviewer's involvement in the conduct of the survey, it can also ensure that all expert respondents will obtain the same interpretation from a single source (the researcher). This will eliminate any subjective interpretation, which the experts may hold. Thus, improving the overall quality of the results obtain and reduces the need for a large pool of expert respondents.

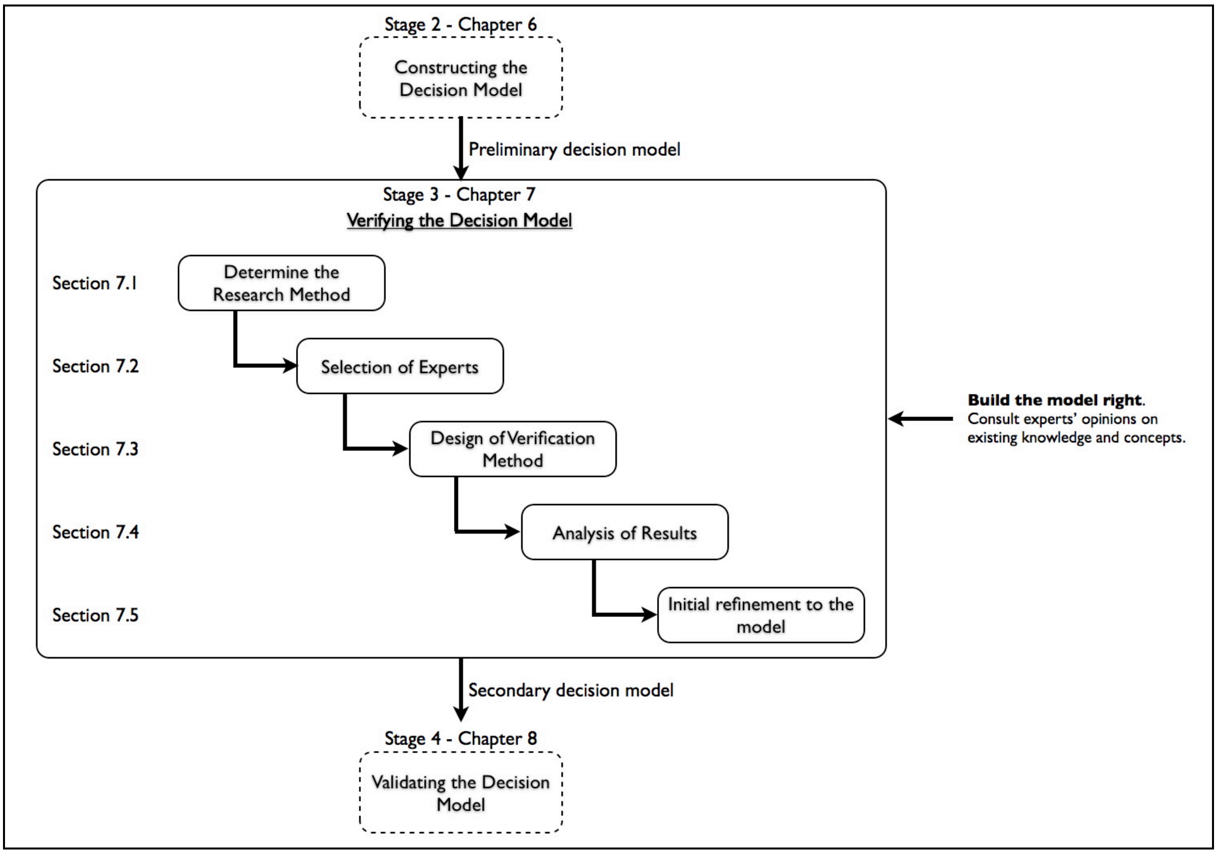

Figure 7.1 Overview of Stage 3's research activities

In summary, a semi-structured interview method is adopted for this stage of the research programme. Subsequent sections will deal with the selection of experts, the design of the verification method, the results and analysis, and eventually the refinement to the preliminary decision model. Figure 7.1 provides an overview of the research activities for this stage.

7.2 Selection of Experts

Once the research method was determined, the next step was to decide on the experts to contact. The main factor that influences the best practice adoption process is the diversity of backgrounds of the experts making the decision. A technology experts will address it from the technical standpoint looking at the operational level of things while a business expert will tends to address it at the strategic level. Academic experts possess the technical competencies in the subject matter, but they typically lack the domain knowledge on the actual industrial needs. Thus, to even the mix of experts without any biases, 2 groups of 6 experts are selected. They are 6 academics and 6 industrial practitioners in the related field. Experience of these experts is of critical importance to ensure the quality of results obtained. Thus, all experts selected have at least 5 years of working experience in their area of work.

In order that the assessment for the decision model is made on both strategic and operational level, a substantial diversity in the range of expertise provided is imperative. Hence, the 6 academic experts comprise of researchers in the area of operations and supply chain management, benchmarking, strategic manufacturing, and operations and technology planning. The 6 industry experts include managers and consultants working in the manufacturing sectors on industry and business development, benchmarking, supply chain management and operations planning. Table 7.1 provides an overview of the experts participating in this verification process.

Table 7.1 Overview of experts participating in the verification process

		Expertise/Area of Work	Designation
ACADEMIC EXPERTS	Expert A	Operations and Supply Chain Management	Research Scientist
	Expert B	Operations and Supply Chain Management	Senior Research Engineer
	Expert C	Benchmarking	Senior Research Engineer
	Expert D	Manufacturing Strategy and Strategic Positioning	Professor
	Expert E	Operations and Technology Roadmapping	Senior Research Scientist
	Expert F	Operations and Technology Roadmapping	Research Scientist
INDUSTRIAL PRACTITIONERS	Expert G	Industry Development	Senior Manager
	Expert H	Industry Development	Senior Manager
	Expert I	Supply Chain Reconfiguration and SCOR Implementation	Senior Supply Chain Consultant
	Expert J	Business Development	Senior Consultant
	Expert K	Business Development	Senior Manager
	Expert L	Operations Resource Planning	Manager

7.3 Design of the Verification Method

Section 7.1 has selected semi-structured interview as the model verification process in this stage. Thus, this section describes the design of the questionnaires and the approach of the semi-structured interview used in the verification process.

7.3.1 Design of the Questionnaires

The questionnaires were developed to meet the needs of this stage of research (Section 7.1), which is to verify the model constructed against experts' opinions to ascertain the accuracy of the model representation. A development process is required in order to ensure that the precise nature and format of the final questionnaire was suitable for its purpose (Oppenheim, 1996).

Figure 7.2 shows a nine steps model, proposed by Churchill (1998), to help researchers to develop a sound questionnaire device. Application of these steps encourages discipline and thoroughness in the formulation of the questionnaire. This model was thus used as the basis for the questionnaire development in this stage of the research.

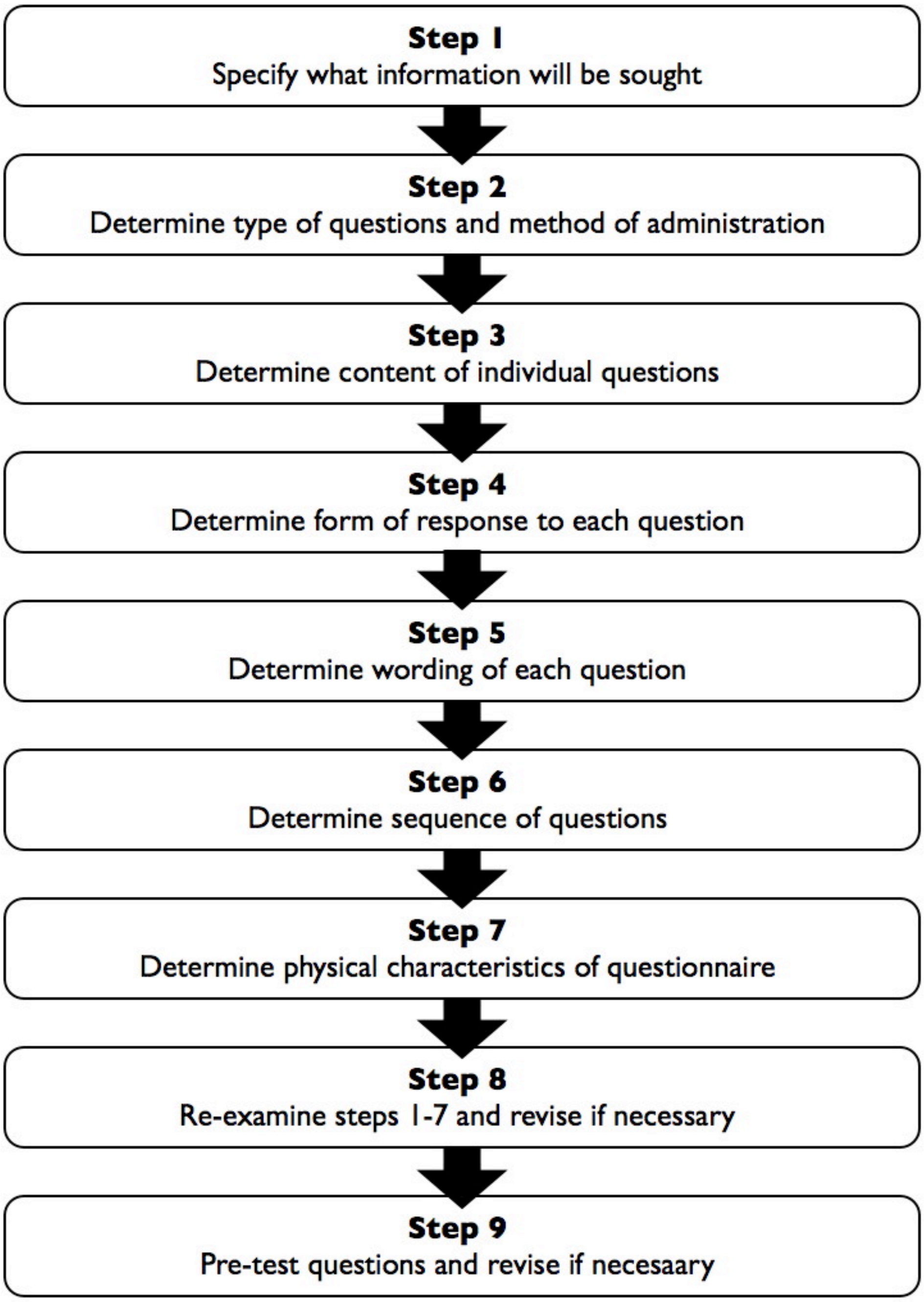

Figure 7.2 Questionnaire Design Process (Source Churchill, 1998)

Eventually, three sets of questionnaires were prepared with reference to a typical best practice adoption process derived from Chapter 3. Details of these questionnaires can be found in Appendix C. The first set of 30 questionnaires is designed to assess the competitive orientation of a company's current approach to business with their main products and customers. The second set of 40 questionnaires is designed to assess a company's current achievement and requirement with their main products and customers. The third set of 120 questionnaires is designed to assess a company's current practices in the manufacturing operations. Together, these three sets of questionnaires provide the practical scenario statements that a company can identified with and answer to. These questionnaires represent a typical subset of the collective knowledge of existing best practices and their linkages with competitive strategies. Thus, they will also be used to assist the researcher in the collection of artefacts observation to validate the causal linkages in the decision model for the next stage.

7.3.2 Conduct of the Verification process

The verification process is conducted to check the accuracy of the model representation against experts' opinion on existing knowledge and concepts. Thus, the decision framework (Figure 5.2) and the preliminary decision model (Figure 6.1) are first presented to the experts to explain the background and purpose of this research. This is necessary for the experts to understand the decision process adopted and the decision variables considered so that accurate comparison can be made against the existing knowledge and concepts.

Subsequently, the three sets of questionnaires were handed to them to answer with reference to a manufacturing company that they are familiar with. This is necessary to assess the objectivity of the questionnaires designed to solicit the competitive orientation, manufacturing requirement and the physical artefacts of existing practices found in a company.

The experts' feedback and responses to the decision process and questionnaires used will be presented in the next section for analysis and discussion.

7.4 Analysis of Results

This section describes the feedback and response to the decision process and questionnaires used. Key comments from the experts are summarised below,

1. Some of the academic experts were not convinced about the manufacturing paradigm concept described. The confusion is about the difference between manufacturing strategy and paradigm. The remaining experts followed the rationale of the decision process and had comment about the concept adopted.
2. Alternative competitive strategies model (Treacy and Wiersema, 1993) to the Porter's model (Porter, 1980) adopted, was suggested by one of the academic experts. Industrial experts concurred with the 3 competitive strategies suggested in the model. However, they felt that they are too general to be useful in characterising the different business approaches of a company.
3. One of the academic experts suggests that a direct link from strategies to objectives to practices would be more straightforward and simpler to understand as compared to the more complex structure as suggested in the model with an intermediate layer of manufacturing paradigm.
4. Industry experts concurred with the list of key practices suggested. However, they had also raised two concerns. The first is the omission of some obvious practices from the proposed list like Just-in-time (JIT), Kanban system, Six-Sigma, Total Quality Management (TQM), Total Productive Maintenance (TPM), and Concurrent Engineering etc. The second is the lack of specific actionable practices identifiable for a selected industry vertical.
5. There is a general concern raised on whom should these questionnaires be directed to because the scope of questions is quite broad, ranging from

strategic to operational issues. Thus, it is difficult to obtain an accurate assessment of a company from a single respondent.

6. Despite the difference in the sentence statements for questionnaires set 1 and 2, the experts felt that these questionnaires seems to be asking about the same things in a different manner. Thus, these questionnaires appear to be repetitive.
7. Most of the questionnaires in set 2 appeared in opposite pairs, which they feel is redundant and repetitive.
8. Many of the experts would like to know the intent or objective of each statement rather than guessing them. The rationale is so that they could make better judgement about the validity and usefulness of the statements asked.
9. The quantity of questionnaires (a total of 190 statements in total) makes it very prone to mistakes and errors in data collection.
10. There are concerns about how these questionnaires are going to be applied. Passing it to a managing director of a company would not yield much useful results because of the inherent subjectivity the company have about their business and manufacturing operations. Some level of expert judgement is necessary to ensure the objectivity of the data collected for the accurate assessment on the validity of the model.

In summary, comments 1 to 4 are concerns about the validity of the structure and content of the decision model while comments 5 to 10 are about the applicability and accuracy of the questionnaires designed. In general, majority of the experts are agreeable with the proposed decision model for best practice adoption. Concern about the manufacturing paradigm concept was addressed through the dissemination of the authors' previous work. The experts had expressed that the analytical generalisation made on each paradigm to be reasonable. However, the accuracy of the relationships portray would need to be validated through a more extensive empirical testing in the industry.

Suggestion about the (Treacy and Wiersema, 1993) competitive strategy model was considered. Instead of the market scope and the basis of competitive advantage suggested by Porter (1980), Treacy and Wiersema (1993) suggested the 3 value disciplines for competitive strategies, which are Operational Excellence, Product Leadership and Customer Intimacy. Closer examinations of these value disciplines reveal that they resemble a compound dimension of the five (Price, Quality, Delivery, Flexibility and Service) competitive dimensions portrayed in the model. For example, Operational Excellence is a compounded competitive dimension of Price, Quality and Delivery. Although actual composition of each value disciplines with respect to the 5 competitive dimensions could not be validated at this stage, this suggestion will be considered and evaluated in the next stage as a probable substitution to two decision layers of Strategy and Dimension, which would make the final decision model simpler.

The suggestion in comment 3 is very valid because the translation of relationship between the objectives and practices is more direct and intuitive. For example, Economies of scale should contribute directly to the Cost objective. However, there are also other practices where the links with the objective are more complex, like Waste Reduction will contribute to the objectives of Cost, Conformance, Speed and Dependability of Delivery. These complex relationships are very difficult to validate empirically if we were to map the objectives with the practices directly. Assuming that we are adopting this suggested model, direct mapping between the proposed objectives and practices would yield a maximum combinatory relationship of 290 (10 objectives multiply by 29 distinct practices). However, with the introduction of the Paradigm layer, it actually simplifies the relationship as we are only considering the mapping between the paradigms to the objectives they support. In this case, it reduces the maximum combinatory relationships to 50 (10 objectives multiply by 5 paradigms). The relationships between the paradigm and practices have also been previously verified in the authors' previous work and thus are much easier to be validated subsequently.

Comment 4 has raised the concern about the omission of some obvious practices from the proposed list as well as the lack of specific actionable practices for a selected industry vertical. Both of these concerns deal with the specificity of the key practices list and it is also intentional that these key practices listed are more generic in term of terminology used. The reason is to make the intended tool more applicable for cross industry adoption. Practices like JIT, Kanban, Six-Sigma and TQM discussed are in fact achieving the similar objective like the "Waste Reduction" practice discussed in Section 5.3. Thus, they can be regarded as a subset to the "Waste reduction" practice proposed. The main intent of adopting more generic practices in the proposed list is to ensure an adequate comprehensive coverage of existing practices while retaining the manageability of the total decision nodes in the model.

Finally, feedbacks from comments 5 to 10 are considered and the questionnaires refined subsequently. Appendix C provides the detail of these final questionnaires adopted. Concerns about the applicability of the questionnaires as highlighted in comments 5, 9 and 10 will be addressed in the case study design of the model validation in the next stage.

7.5 Initial refinement to the Decision Model

Through the verification process, comments and opinions from the experts are used to refine the preliminary decision model constructed in Chapter 6. The only change required on the model is the removal of the competitive strategy layer, which was agreed to be redundant. In place of it is just the competitive dimension layer, which was adequate to describe any compound competitive strategy as demonstrated in the previous section. Other changes proposed by the experts involving the refinement of the questionnaires will be addressed in the next chapter. Figure 7.3 presents the secondary decision model for the validation in the next stage.

With the removal of the generic competitive strategy layer, the branches between the product maturity layer and the competitive dimension layers approach the maximum combinatory possible (twenty). The reason is because such causal linkages between product maturity and competitive dimension are not apparent. Thus, it is assumed at this stage that product at any maturity stage are capable to compete in any of the five competitive dimension. This assumption may or may not hold true especially when the competitive landscape of a company is defined by the combinatory permutation of industry type and product maturity stage as discussed in Section 5.4. However, the validation of the accuracy of such causal linkages portrayed in the model is the objective for the next stage of research and thus will be addressed in the next chapter.

In summary, the verification process conducted in this stage has verified the structure and contents of the decision tree presented in Figure 7.3. Validity of the causal linkages demonstrated in this decision tree will be measured against real-life industry case studies and discussed in the next chapter.

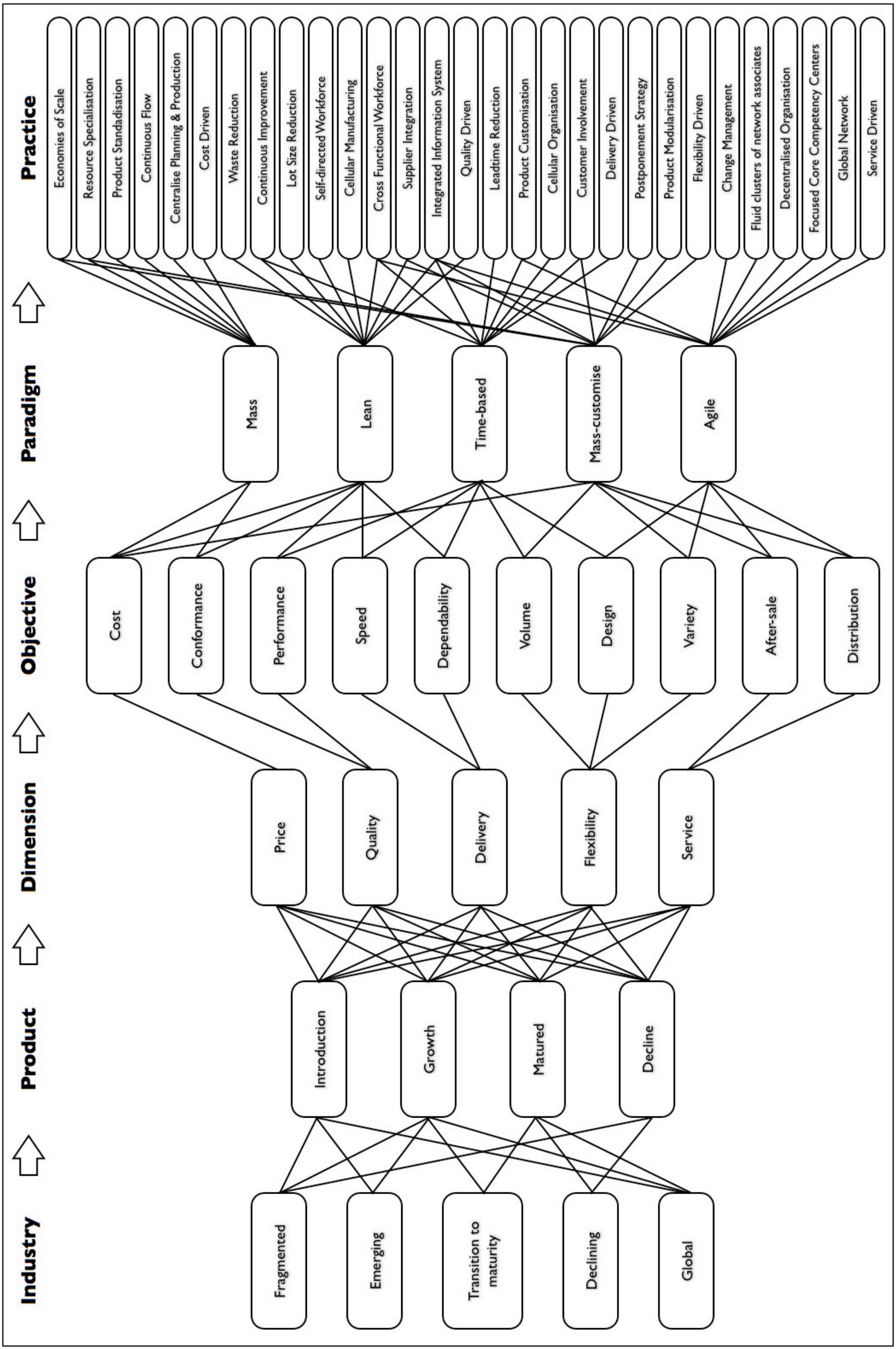

Figure 7.3 Secondary Decision Model

7.6 Chapter Summary

The chapter concludes the achievement of the first research objective of the research programme, which is the development of the decision model for the adoption process of manufacturing best practices. This decision will be validated against actual industrial scenario to ascertain the validity of the causal linkages portrayed by the decision model in the next chapter.

Chapter 8: Validating the Decision Model

The preceding chapter has verified the decision model against the experts' opinions to ascertain the accuracy of the model representation. It also concluded the achievement of the first objective of the research programme and provides a secondary decision model presented in Figure 7.2. This chapter will proceed with the fourth stage of the research programme to validate this decision model against real-life industrial case study. Causal linkages depicted in the decision model will be measured against the artefacts observed in actual industrial scenarios. The chapter will first presents the purpose and method of this stage of research (Section 8.1). This is followed by the design of validation method (Section 8.2) and a presentation of the 8 case studies conducted (Section 8.3). Subsequently, these cases are analysed and discussed (Section 8.4). Final refinement of the decision model is then made (Section 8.5) and the conclusions drawn.

8.1 Stage 4: Purpose and Method

The purpose of this stage of the research is to validate the secondary decision model constructed (Figure 7.2) for model accuracy against actual industrial scenarios. Causal linkages depicted in the decision model will be validated against the actual industrial artefacts observed.

Five major types of research strategies as documented by Yin (2003) are considered for this stage of research. They are Experiment, Survey, Archival Analysis, History and Case Study. According to Yin (2003), the choice of research strategy to use would depends on the three conditions, namely:

1) The types of research question posed.
2) The extent of control an investigator has over actual behavioural events.
3) The degree of focus on contemporary as opposed to historical events.

Table 8.1 has contrasted these conditions against the research strategies for the selection.

Table 8.1 Relevant Situations for Different Research Strategies (Source: COSMOS Corporation, quoted in Yin, 2003)

Strategy	Form of Research Question	Requires Control of Behavioural Events?	Focuses on Contemporary Events?
Experiment	how, why?	Yes	Yes
Survey	who, what, where, how many, how much?	No	Yes
Archival Analysis	who, what, where, how many, how much?	No	Yes/No
History	how, why?	No	No
Case Study	how, why?	No	Yes

Explicit in the research aim is an intention to develop a decision model for best practice adoption. Thus, the research questions to be answered by this decision model are “How does a manufacturing firm decides on the manufacturing practices to adopt?” and “Why a manufacturing firm chooses a certain set of manufacturing practices to adopt?” From Table 8.1, the suitable research strategy for these form of research questions are Experiment, History and Case Study. Since the purpose of this stage is to validate the decision model against actual industrial scenarios, controlling the companies’ best practice adoption behaviours is not required. Instead, the physical artefacts from the companies will be observed as evidences to proof the validity of the proposed decision model. Contemporaneous evidences are also sought for this study, as historical data are difficult to verify. Therefore, Case Study was selected as the most appropriate research strategy for the validation of the decision model.

Subsequent sections of this chapter will deal with the design of the validation method and the presentation of the results and analysis. Eventually, refinement to the model is made and the final decision model presented.

8.2 Design of the Validation Method

Previous section has selected Case Study as the most appropriate research methodology for this validation stage. This section therefore presents the case study design, the choice of industrial test-sites and the data collection method.

8.2.1 Case Study Design

There are five important components to a case study design (Yin, 2003). They are,

1) A study's questions;
2) Its proposition, if any;
3) Its unit(s) of analysis;
4) The logic linking the data to the propositions; and
5) The criteria for interpreting the findings.

The first component of the design is the study's questions. These are defined in Section 8.1, which has also led to the selection of this research method. Therefore, the key research questions to be answered by the decision model are "How does a manufacturing firm decides on the manufacturing practices to adopt?" and "Why a manufacturing firm chooses a certain set of manufacturing practices to adopt?"

Second component to the design is the proposition or statement of opinion for this study. The execution of Stage 1 to 3 of the research programme has resulted in a secondary decision model for best practice adoption. This model has detailed a series of logical steps on how the decisions to select the most appropriate manufacturing best practices are made. The decision variables and causal linkages portrayed in the model also offered a rationale on why these decisions are made. In order to validate the decision model against actual industrial scenarios, statements of opinions are required to direct the direction of this study. These statements not only reflect the important theoretical issues involved, it also highlights where to look for the evidence in the validation process (Yin, 2003). From the decision model proposed (Figure 7.2), the four key statements to be validated are proposed,

1) The industry type that a company is in and the product stage of their main product are adequate to define the competitive landscape of the company.
2) There exist an appropriate set of probable competitive strategies with respect to one or more of the competitive dimensions in Price, Quality, Delivery, Flexibility and Service, which a company can choose to compete in the market.
3) Each manufacturing paradigm supports a unique set of objectives that can be related to the competitive dimensions.
4) There is a unique set of best practices that can be identified with each manufacturing paradigm in support of the competitive environment of the company.

Through the validation of these 4 statements of opinion, it can then be proven that companies sharing the similar competitive environment would have a similar set of the most appropriate competitive strategies to compete in. Based upon the chosen competitive strategy, there exist a most suitable manufacturing paradigm for the company. The generic list of practices defined for this paradigm can then be used to guide the successful adoption of the best practices most suited for the company.

The third component of the design is related to the fundamental problem of defining what the “case” is. Proposition directs what to study while the unit of analysis defines the subject in study and it is related to the research questions defined earlier. In this case, both questions have highlight how and why a manufacturing firm decides and chooses the set of manufacturing best practices to adopt. Therefore, an appropriate unit of analysis will be a manufacturing firm.

The fourth component is to define the logic that will link the data collected to the statements of opinions. This is important for the interpretation of the findings. However, this component has been the least well developed in case studies as reported by Yin (2003). A promising approach adopted is the idea of “pattern matching” as described in the work of Campbell (1975) and Trochim (1989), whereby several pieces of information from the same case can be related to the theoretical propositions. This will be substantiated by cross-case synthesis to improve the robustness of the findings.

Finally, the last component is the criteria for interpreting the study's findings. The question of concern for pattern matching is "How close does a match have to be in order to be considered a match?" A fatal flaw in doing case studies is to conceive statistical generalisation as the method for generalising the results from case study. This is because of the lack of sampling units in the case study method, which only allows analytic generalisation using multiple cases (Yin, 2003). In this case, the previously developed theory (decision model for best practice adoption) is used as a template with which to compare the empirical results of the case study. If two or more cases are shown to support the same theory, replication may be claimed. The empirical results may considered to be even stronger if two or more cases support the same theory but do not support an equally plausible, rival theory. Figure 8.1 portrayed such generalisation as Level Two Inference. Yin (2003) has proposed that this should be the aim for conducting any case study research and thus forms the criteria for interpreting the study's findings.

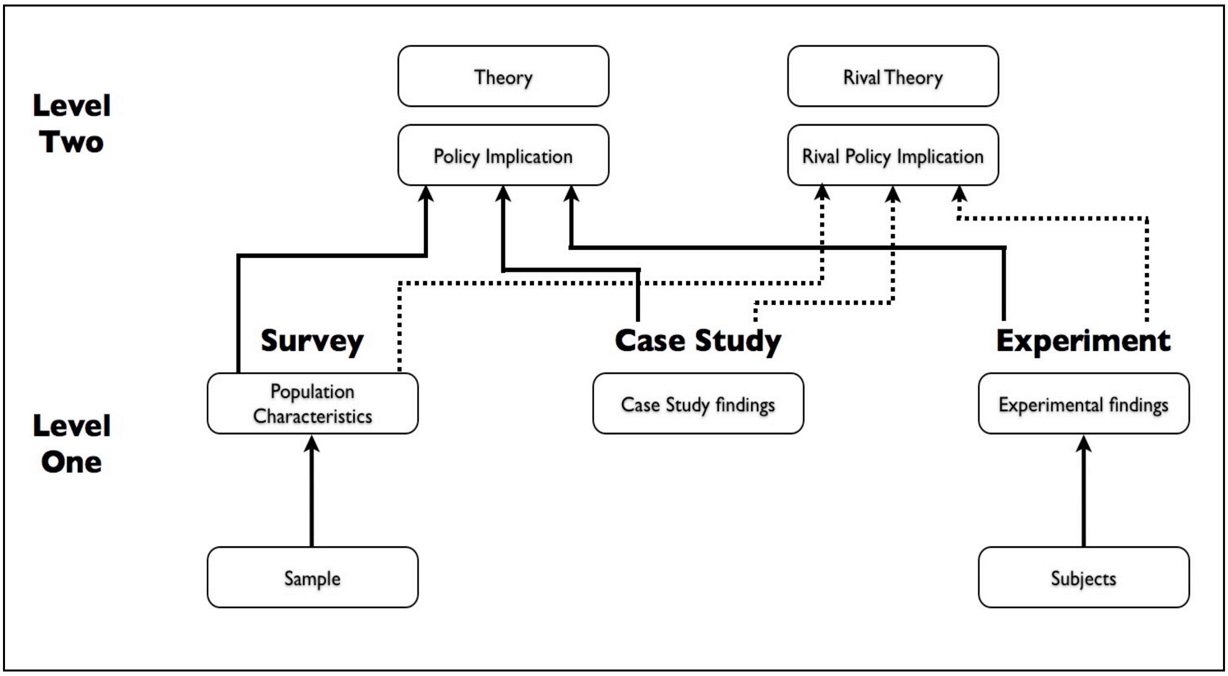

Figure 8.1 Making Inferences: Two Level (Source: COSMOS Corporation, quoted in Yin, 2003)

In summary, a complete case study design is discussed, which covers the five key components of the design. This design has also benefited from the development of a theoretical framework for the case study, which in this case is the construct of the decision model from the earlier research stages. Subsequent subsections will present the choice of cases and the data collection method employed.

8.2.2 Choice of Industrial Test-sites

The unit of analysis is identified as a manufacturing firm previously. However, there is still a need to decide the type of design to adopt for the case study. Yin (2003) has described 4 types of design based on a 2x2 matrix shown in Figure 8.2.

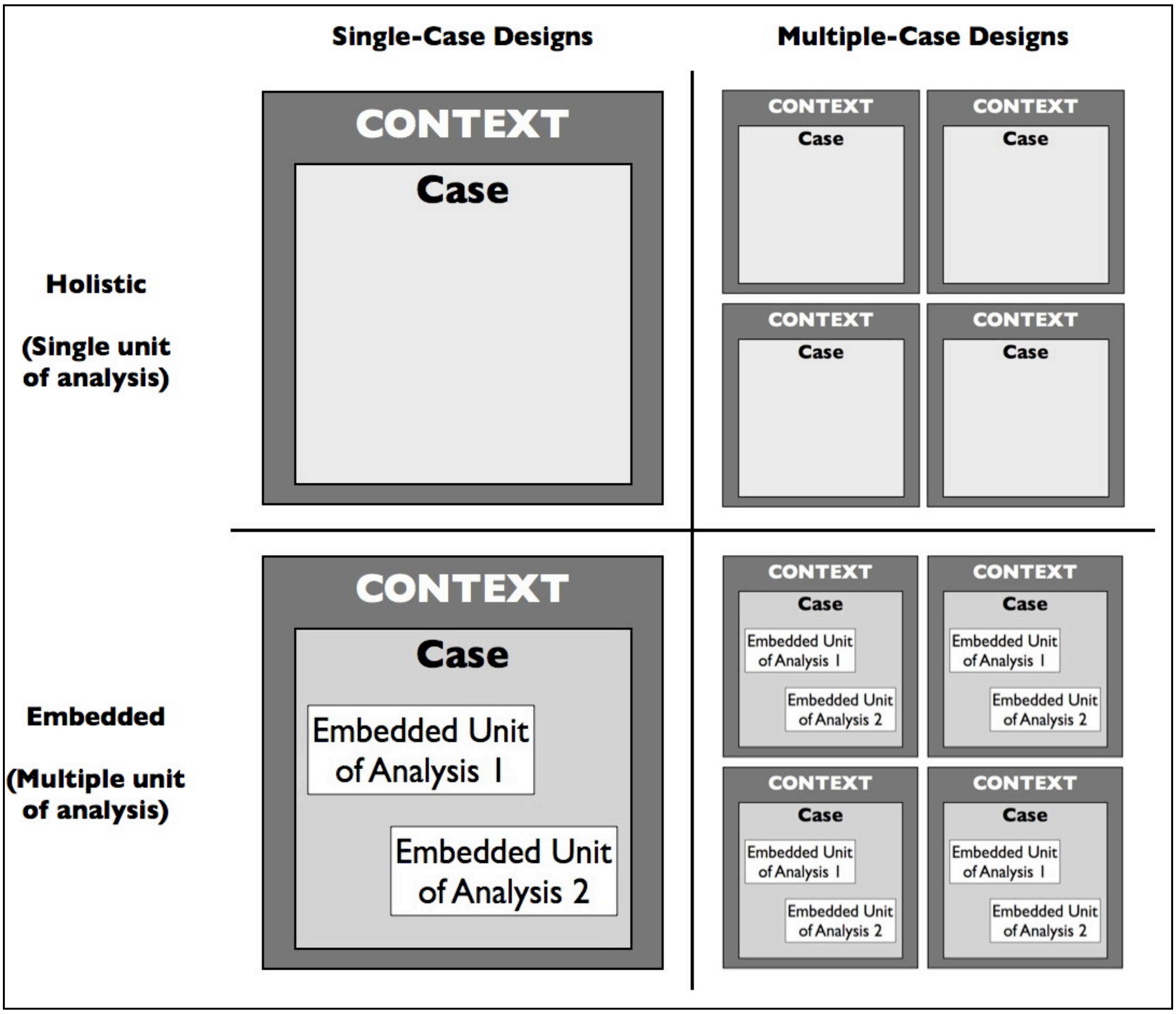

Figure 8.2 Basic Types of Designs for Case Studies (Source: COSMOS Corporation, quoted in Yin, 2003)

According to Yin (2003), single case design works well if it represents a critical case in testing a well-formulated theory or when it represents an extreme or unique case. Other rationales for single case design are when it is a representative case or a longitudinal case where studying a single case is done at two or more different point in time. Since the subject in study does not fall in any of the above rationales for single case study design, multiple-case design was chosen.

Unit of analysis was previous identified as a manufacturing firm. However, on closer examination of the 4 statements identified, a holistic design of examining the global nature of a manufacturing firm is found to be inadequate to address all of these statements. A shortfall of holistic design is that it is often conducted at an abstract level and lacks the examination of specific phenomenon in operational detail (Yin, 2003). The latter information is critical to ensure the sensitivity of the analysis. Thus, an embedded design is chosen and the larger unit of analysis for a manufacturing firm is broken down into 4 subunits of analysis in association with the statements proposed and the decision model. They are, the Competitive Landscape the firm is in, the set of Competitive Dimensions on which the firm choose to compete, the set of Objectives the firm choose to achieve, and the set of practices the firms adopted. Data focused at these sub-units can then be analysed in context under the bigger unit of the manufacturing firm.

In view of the design analysis discussed, a multiple-case embedded design is selected. The next task is then to decide on the number of cases to study. Replication logic is considered for this decision (see Hersen and Barlow, 1976). Evidence of replications in case studies will reinforce the significances of the findings. Yin (2003) has proposed that 3 or 4 cases to be conducted for two different applications are considered to be adequate. Thus, for the case of proofing the validity of the decision model, 2 different groups of 4 manufacturing firms are selected. In this case, the first group consist of 4 exemplar high-performance firms where the relationship between the practices adopted and its competitive strategy are assumed to be strong. On contrary, the second group will consist of 4 typical average-performing firms where these relationships are assumed to be poor. In order to examine the selected firms over the spread of competitive environment depicted by product stages and industry types, the 8 manufacturing firms are selected for each grid of the competitive spaces generated (see Figure 8.3). It is also worth noting that Company A to D are the exemplar firms, which typically operate in the global market. Some of these firms produce more than one type of products and only the products that fit the required spaces depicted in Figure 8.3 are selected.

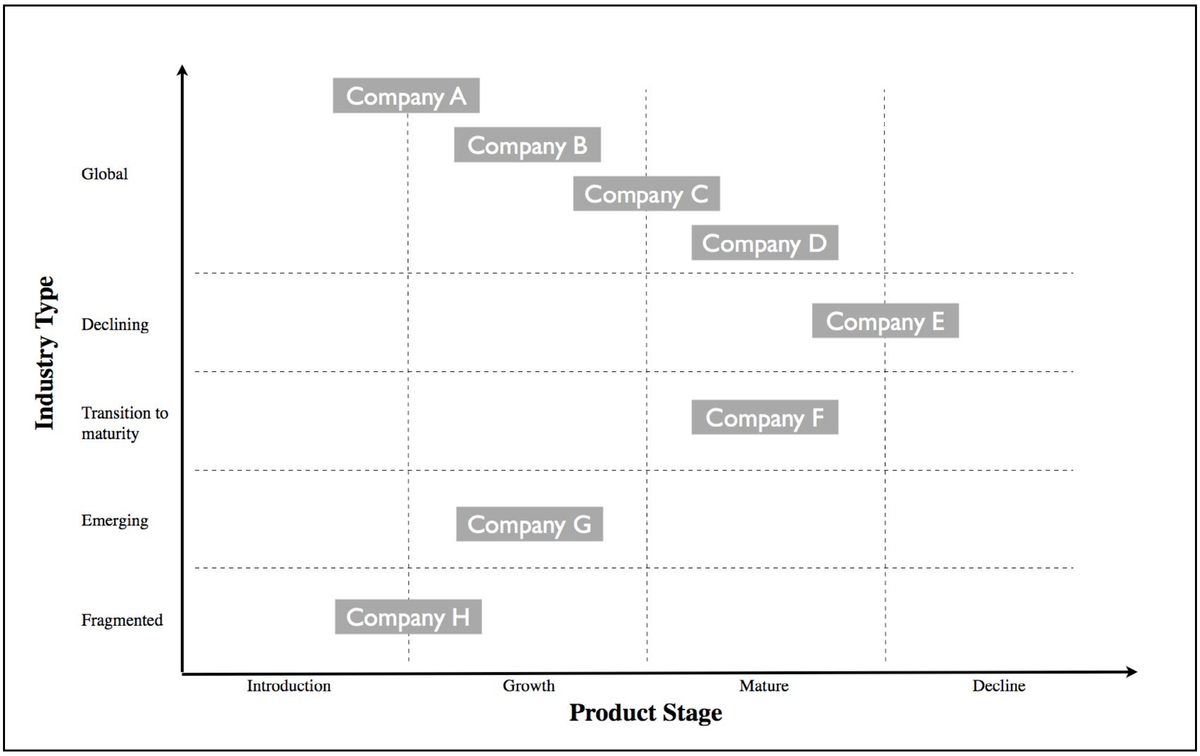

Figure 8.3 Competitive spaces occupied by the selected manufacturing firms

In summary, a multiple-case embedded design is chosen and 8 manufacturing firms selected for the case studies. Details of these firms will be discussed in the next section.

8.2.3 Data Collection Method

8 manufacturing firms with respect to their main product range are selected for the case studies. Replication logic is typically applied to case studies and this approach to multiple-case studies is illustrated in Figure 8.4. Previous stages and sections have developed the theory, designed the case study and selected the cases. Thus, this subsection deals with the design of the data collection method for the conduct of the case studies.

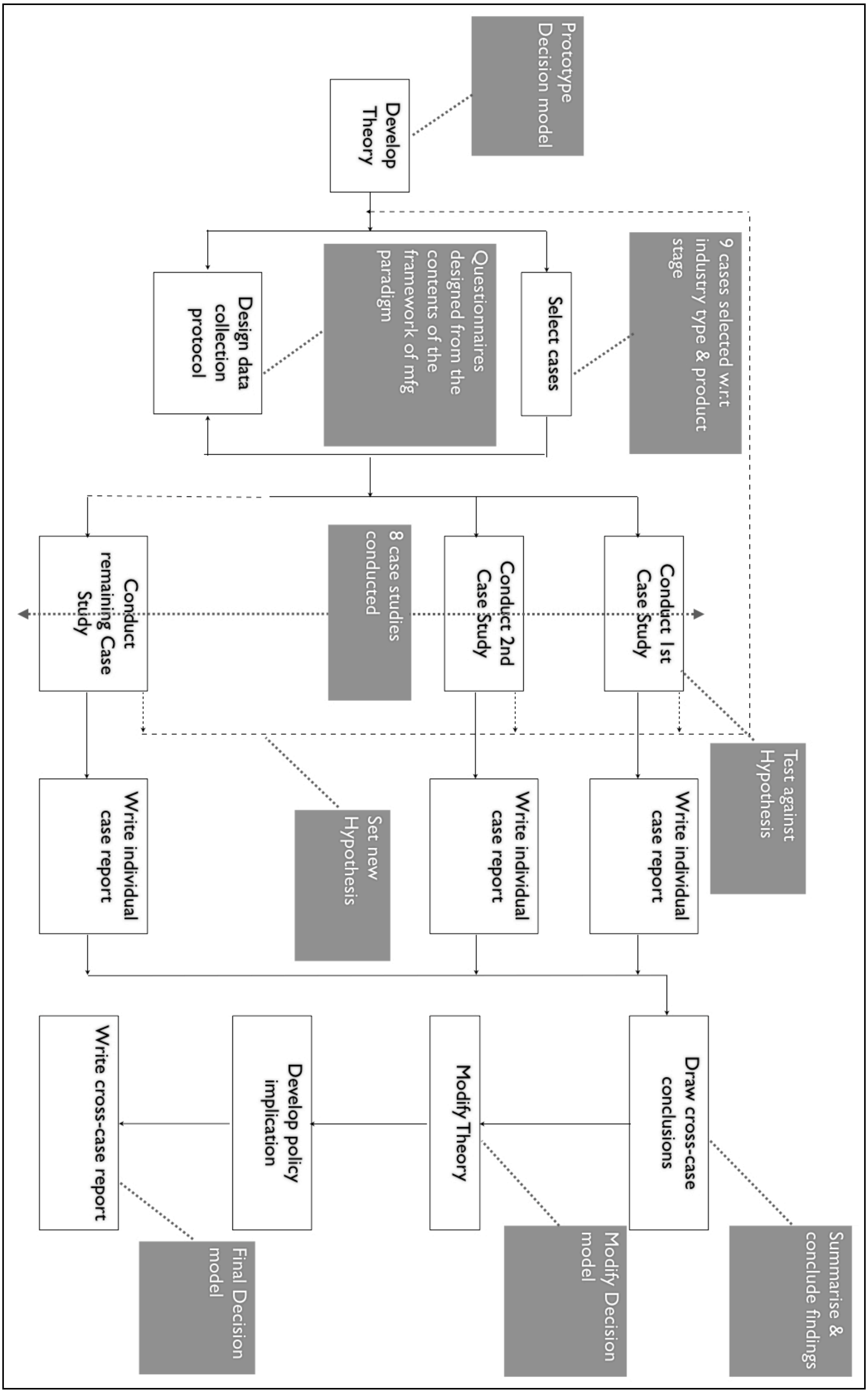

Figure 8.4 Overview of case study research design (Adapted from Yin, 2003)

There are several desired skills required on the case study investigator. Two of the important considerations for the investigators are their grasp of the issues being studied and their inclination to introduce bias into the research. Each case study investigator must understand the theoretical or policy issues because analytic judgements have to be made throughout the data collection phase. As such, the researcher conducting the study (in this case, the author) is the best candidate for the job because of the extensive knowledge gathered throughout the conduct of the research. However, the same researcher will tends to seek the use of a case study to substantiate a preconceived position. In this case, the researcher is especially prone to the problem of introducing bias into the findings in the process. In order to reduce the degree of such bias, contrary findings reflected in the case study will reduce such likelihood.

Data collection protocol is a major way of increasing the reliability of case study research and is intended to guide the investigator in carrying out the data collection process. In general, a case study protocol should have the following (Yin, 2003),

1) An overview of the case study project (project objectives and auspices, case study issues, and relevant readings about the topic being investigated).
2) Field procedures (presentation of credentials, access to case study "sites", general sources of information, and procedural reminders).
3) Case study questions (the specific questions that the case study investigator must keep in mind in collecting data and the potential sources of information for answering each question).
4) A guide for the case study report (outline, format for the data, use and presentation of other documentation, and bibliographical information).

Based upon these guidelines, the data collection method is designed.

Firstly, access to the 8 selected manufacturing firms and interviewees were obtained through personal contacts and referral. Due the large quantity of decision variables to be investigated, especially with regard to the practices adopted in the company, a considerable amount of time is required to be spent in the selected company for the conduct of semi-structured interviews with both the senior management as well as the operations personnel. On-site observations are also conducted to validate the information collected so as to remove any subjective opinions from the interviewees.

Each case study is conducted over a period of about 2 weeks with an average number of 3 to 4 site visits per company. First visit to the company are typically to meet up with the senior management of the company to explain the background and purpose of the research. This stage is critical to win the trust and confidence of management in order to gain access to the operations of the companies for the subsequent visits. Business and strategic level discussion are also conducted with the senior management in a less structured and exploratory interview manner. This is done so in order for the interviewees to share their opinions and insights about their business in an open and free manner. The necessary is because the true competitive environment is much complex then is generalised in the decision model in terms of industry types and product stages. Open discussions will draw out unique considerations of a company not captured or unknown to the researcher conducting the interviews. Subsequent site visits and interviews are more structured and standardised in order to objectively collect the artefacts of interest for the validation of the model.

The data to be collected include the strategic and operational artefacts associated with the chosen product group from the manufacturing firm. This is conducted by deploying the 3 sets of questionnaires developed in Chapter 7, which is detailed in Appendix C. As discussed, the researcher is the best candidate to answers all the questionnaires pertaining to each company. This will ensure that the same interpretation of the questionnaires is applied across all the companies. The structured questionnaires also allow the systematic collection of evidences against which the model can be validated. Results collected from the semi-structured interviews and on-site observation will then be illustrated in a case write-up for each company against the four statements proposed in Section 8.2.1. Cross-case analysis will then be conducted to validate the findings and draw some conclusions to the research.

In summary, this section described the rationale for the case study design, the choice of industrial test-sites and the data collection method. Subsequent sections will present the case study findings and analysis against the propositions.

8.3 Case Study Findings

This section discusses the case study findings. A background and overview of each selected companies is presented. These are the results from the semi-structured interviews conducted. The three sets of questionnaires (Appendix C) are also used to assist the data collection process. This is to ensure the systematic collection of the physical artefacts sought.

8.3.1 Background and Overview of Case Studies

8 companies are selected for the case studies conducted between July and October 2006. These companies are mapped into the competitive environment profile graph illustrated in Figure 8.3 with respect to the industry type the company is in and the product stage of the select product range for investigation. Companies A, B, C and D are the global companies selected while the remaining 4 companies (E, F, G and H) consist of 2 big manufacturing firms with a sizeable operations and 2 small and medium size enterprises (SMEs).

Anonymity is requested by most of the companies selected. The reason is because of the sensitivity associated with some of the information sought like company's strategy and their competitive practices adopted and planned. As such, the backgrounds of these companies are discussed in context with its businesses without disclosing the name of the company. Summary of these companies are presented subsequently.

Company A

Company A manufactures metal-cutting machine tools. The company operates six manufacturing facilities in England, Japan, Singapore, and the US, producing lathes, machining centers, milling centers, and dedicated manufacturing systems. The company also provides training services and sells parts and used machines. The study was conducted at the manufacturing facility in Singapore and was approached at the director level. Subsequent detailed conversations were held with the operations managers.

The interview with the director reveals that the company are involved in the development of software applications for machine tools. They also design and customise machine parts and assembly, tailoring to customers' requirements and specification. The company has 7 manufacturing facilities in Japan, U.S, England, Singapore and China to produce machines close to their intended market in order to provide the best after-sales services and support to their customers around the world. The company is also the leading machine tool builder in the world with key focus on technology, quality, customer service and support. The company is capable of producing more than 200 kinds of machines to meet its diverse customers' needs.

The investigation into the company's operations reveals a state-of-the-art factory integration system in the facility. The site visited was designed to be an advanced manufacturing facility termed as "Cyber Factory". An obvious sight was the minimal movement of the operators and the cleanliness of the facility. There is a high level visibility of shop floor activities through the overall system monitoring provided the Point of Production (POP) system installed. This system also includes information like material delivery, machining and material requirement planning. A common database standard was adopted across the facility to enable the efficient and error-free exchange of information. Thus, eliminating the need for delayed and unreliable paper reports. Multi-tasking machine tools are used to reduce the in-process machining time of components produced by eliminating the transfer time of components across different machines to complete a set of tasks. This has also reduces the in-process inventory of semi-finished components as they are produced from start to finish in one pass on the same machine.

Company B

Company B is a semiconductor foundry that provides wafer fabrication services and technologies to semiconductor suppliers and systems companies. The Company focuses on providing foundry services to customers that serve the high-growth technologically advanced applications in the communication, computer and consumer sectors. It has a total of five fabrication facilities in Singapore and has service operations in nine locations across eight countries in North America, Europe and Asia. The study was conducted at the manufacturing facilities in Singapore and was approached at the deputy director level. Subsequent detailed conversations were held with the operations planning and industrial engineering department.

The interview with the deputy director reveals that the company is one of the world's top dedicated semiconductor foundries. The company operates 5 manufacturing facilities with each focusing on different level of process technologies nodes ranging from 0.6 micron to 65 nanometer. Together, they produce integrated circuit (IC) chips for a wide range of electronic products. The company also provide customer-centric services like consultation and design support through its alliance with leading Electronic Design Automation (EDA) and design services companies. It also provides turnkey manufacturing solutions that leverage on the company's strong collaboration with its suppliers and backend services (Assembly and Test operations). The company also participated in joint R&D collaboration with industry partners to drive standards in the form of a common platform for technology, manufacturing and design enablement support. Thus, providing the customers with more choice and flexibility as well as reducing the risks and costs in the investment of future technologies. This common platform also simplifies the design process through the use of pre-qualified design libraries, design kits and design flows, thus greatly improves the speed to delivery.

The investigation into the company's operations reveals that a high level of automation existed in the manufacturing facilities. This is especially so in its newer fabrication facilities where its latest 300-millimeter facility is fully automated. The drive towards automation is a result of the needs for a tighter and more stringent manufacturing cleanroom environment to enable the high-end technology node processes of 90 nanometer and beyond. The equipment cost is also very high in comparison to other industries. Thus, the utilisation of these machines becomes very critical in the control of production cost. Yield rate is also key determinant of the production cost especially for the high-end IC chips, which call for the need of very stringent in-process quality control system. The importance of manufacturing efficiency in this company is evident from the big team of industrial engineers whom is supporting the planning and scheduling operations of the plants. Continuous improvement in terms of leadtime reduction and process control are also observed.

Company C

Company C designs, manufacturers and markets rigid disc drives (hard drives), which are used as the primary medium for storing electronic information in systems ranging from desktops, notebook computers, consumer electronics devices to data centers. The company sells its disc drives primarily to major original equipment manufacturers (OEMs), and also markets to distributors under its brand name. It has R&D and product sites across U.S. and Singapore. Manufacturing and customer service sites are located in U.S., Northern Ireland, China, Malaysia, Singapore and Thailand. The study was conducted at the manufacturing facility in Singapore and was approached at the director level. Subsequent detailed conversations were held with the operations planning department.

The interview with the director reveals that the company is the world's largest disc drive manufacturer. The company has a very comprehensive product line ranging from the price-sensitive desktop market, consumer electronics devices, pocket and portable storage, notebook computers and enterprise-class network servers. It's success was attributed to the strategy of ownership and vertical integration of key underlying technologies in designing, developing and producing the component that underpin its storage products. Its strength in technical competencies provides the flexibility to address the world's evolving storage needs. While the market continues to grow, there is also a trend of industry consolidation from 12 disc drive manufacturers in 1998 to the current 7. Cost pressure on the disc drives market is also high with the competing technology advancement from the semiconductor industry in the form of the rapid price reduction and increasing storage capacity of solid state memories. Commitment in R&D to push the technology frontier is key to the company in moving up the storage capacity curve to meet the increasing market demand for higher electronic storage capacities in this information age.

The investigation into the company's operations reveals a very high level of operations efficiency derived from the ongoing continuous improvement programmes. The company has also successfully implemented Six Sigma and had achieved many accolades of manufacturing excellence and industry's best-in-class awards for its products. Each of its manufacturing facilities was focused on producing a small range of its entire product line. Thus, the production mix per facility is not very high in order to achieve the maximum production efficiency. The Singapore site also functions like a regional headquarter for the company's Southeast Asia operations. Orders for the region are consolidated here for centralised planning for the regional sites in Malaysia, China and Thailand. The manufacturing processes are fairly mature and efficiency gains are typically achieved through a more effective planning and scheduling.

Company D

Company D designs, manufactures and markets personal computers and related software, services, peripherals and networking solutions. The company also designs, develops and markets a line of portable digital music players along with the related accessories and services, including the online distribution of third-party music, audio books, music videos, short films and television shows. The company has manufacturing facilities in Ireland, U.S., Taiwan, Korea, China and Czech Republic, most of which are operated by external vendors. Most of the components required in production are sourced through third party vendors in Taiwan, China, Japan, Korea and Singapore. Logistics required in the distribution of their products are also outsourced to third party logistics providers. The company has ceased their manufacturing operations in Singapore several years ago. Thus, this case is based upon the previous working engagement with the company, their current annual report and current interviews with its operations managers.

As evident in the company's profile, this company has moved away from the operations activities of the production and distribution of its products to focus on the design and management of these activities as well as its higher value-added activities like software development and online businesses. The strength of the company has always been innovation in design to provide new products and solutions to their customers with superior ease-of-use and seamless integration. The company has been expanding its distribution network through the close collaboration with its third party logistics and service providers to effectively reach out to its targeted customers and provide them with quality sales and after-sales support experience.

Despite the wide range of products and services offered by the company, the product variety per product type is fairly limited in comparison to the offering by its close competitors. This is done so to effectively reduce the inventory holding cost incurred. Smaller product variety and standardisation generate the economies of scale required for the cost-effective sourcing of components. Thus, reduces the product cost as evident in the increasing price competitiveness of the company's products seen in recent years. The company's effective distribution network has also achieved a very short leadtime for order fulfilment. Although the company is able to achieve a competitive price point and quick delivery for its products, there are some signs of slight degeneration in the quality its products in form of components failures experienced. This is a result of the lack of ownership in the manufacturing processes, which they company had been addressing through the deployment of the company's operations personnel to manage these third party manufacturing facilities.

<u>Company E</u>

Company E is manufacturer of metal cans and closures. It is one of the major suppliers of packaging materials in Singapore, supplying mainly to customers in the food and beverage, dairy product, pharmaceutical and petroleum industries. The company has joint venture in 2 product facilities in Malaysia and China. Together, they are serving 47 customers in 16 countries. The study was conducted at the manufacturing facility in Singapore and approached at the director level. Subsequent detailed conversations were held with the operations manager.

The interview with the director reveals that the company is facing a strong cost pressure in the industry. Although the company has a good reputation in the metal containers business, they are constantly under threat by alternative forms of packaging materials like polyethylene and paper carton, which can be cheaper than tin containers. Rising prices in its main raw material (tin sheets) has also resulted in the lowering of their profits as well as the slow growth in sales experienced. Thus, it is obvious to describe the competitive environment of this company as a declining industry where it experiences declining sales and the threat from technological substitution in the form of alternative packaging materials from competitors. Its products are also in the matured or even the decline stage with a fairly high risk of substitution from new packaging materials. From the interview, cost reduction in all forms has been the primary concern of the company, which implies cost leadership as the key strategy for the company's competitiveness.

The investigation into the company's operations reveals that the company is quite inadequate in its planning activities and the manufacturing facility has a poor visibility of its production schedules and capacity. The production lines are organised in functional sections to maximise the machine utilisation of its specialise equipment. Basic quality processes are in place to ensure the parts and products produced will meet the required specifications and quality standards. Semi-finished and finished goods inventory are high because of the poor planning, which often resulted in material shortages and delays in delivery. Although the product range offered by the company is large, the variety in production is fairly low for any given week, with dedicated lines producing single product at high volume before switching over to another product due to the long set-up time required for each change.

<u>Company F</u>

Company F is an engineering company specialises in material handling equipment and retail storage systems. The company's key capability is in project engineering and fabrication where it has a niche in the design, fabrication, supply, installation, and maintenance of aircraft ground support and maintenance equipment. The company do not have a full production facility as most of their parts are imported. They only have a small workshop to perform minor design modification to the imported parts and most installations are done on the customer sites. The company was approached at the executive officer level, and subsequent conversations were held with the engineers and technical staffs.

The interview with the chief executive officer reveals that the company has been in this business for over 40 years and has a very good track record in this industry. The company do not have their own products and merely act as a distributor whom also performed value-added services to their customer in the form of engineering design and installation. As a result, it also faces a risk that the products they distribute are getting more modular and simpler to be customised and installed by end-user customers they had been serving. This also means that the value-adds the company can provide for their customer is reducing. Thus, it has been the company's strength to provide a strong after-sales support and maintenance services to their customers as most of the products they distribute are from Europe without any local service offices. This industry is also reaching maturity as evident in the emergence of standards in the products and its designs. The company has also reported a drop in their dealer's margin with increasing competition. The key strategy adopted by the company has been to provide an excellent after-sale support and distribution network where their advantage of proximity to customers can be leveraged on.

The investigation into the company's operations reveals that the company has a very competent technical team and had invested a lot in the training of their engineers and technician through overseas attachment with their suppliers. The company also has a very good network with their suppliers and had worked closely with them through the reflecting of customers' feedbacks for product improvement. Collaborations with their suppliers also ensure that the company is able to provide timely delivery for their project. The company has also set up subsidiary companies for specific niche market like the Retail and Library Display System market, where the company is leveraging on its designing capability to market the fabricated custom design products made from 3rd party manufacturers' parts under their own brand name.

Company G

Company G is a manufacturer and exporter of operable walls, restroom cubicles, retractable seats, fastfood furniture and lockers. The company's key capability is in the design and fabrication of custom fit installations for restaurants, auditoriums, offices and restroom spaces. Similar to company F, this company also do not have their own production facility. It has a small workshop to perform the fabrication of sub-components, which are then brought to the customers' sites for the final installation. The company was approach at the executive officer level, and subsequent conversations were held with the chief operation officer.

The interview with the chief executive officer reveals that the branding of the company has been very strong in the Singapore especially in restroom design and installation. The chief executive officer is also the founder and current president of the Restroom Association of Singapore (RAS) and founder of the World Toilet Organisation (WTO). As an advocate to better toilet standards, he has stimulated the growth of this industry especially in this region. Thus, it is evident that the company is in an emerging industry with the emergence of new customer needs associated to the changing expectation of restroom standards. The company has been able to experience growth despite the perceived view that it's products and services are a declining trade. The key reason for its success is the company's constant drive to promote new standards and quality as well as its ability to work with government and standards agencies to establish these new requirements. Thus, the key strategy of the company has been to become the industry's de facto standard and establish a strong brand name in this business.

The investigation into the company's operations reveals that the scale of operation of the company is not very large. The company has a competent team of graphic designers and a handful of craftsmen. Operations are very similar to a craft trade whereby the equipment used are mainly general-purpose machines and hand-held tools that perform saw, lathe, drill and mill operations under the skilful hands of the craftsman. The main raw material used is a type of composite wood, which was imported. The same material is used for the other products of the company like the operable walls, fastfood furniture and lockers. The company is also actively sourcing for new alternative materials that are lighter and easier to process, while retaining the similar properties as the current composite wood used. The company also has plans to vertically integrate and invest in the production of building material for their products in order to reduce their dependency on their current suppliers and reduce their cost as well as improving on their delivery time.

Company H

Company H is a Singapore-based global distributor and retailer of tyres, wheels and car accessories, and has sales and operations in more than 30 countries around the world. The company has a manufacturing facility in Thailand producing custom designed aluminium alloy wheels primarily for the aftermarket sectors. The study was conducted at the manufacturing facility in Thailand and was approached at the executive officer level. Subsequent detailed conversations were held with the factory and production managers.

The interview with the chief executive officer reveals that the company is very new to manufacturing (less than 2 years) and its key business was in distribution and retailing. The company is experiencing high growth and had already plan to set up a second manufacturing facility adjacent to its current plant to cope with the rising demand. It has its own in-house wheel designers to provide custom wheel designs for its customers, which are then manufactured in the plant. The industry for this aftermarket business is very fragmented, serving a very diverse market needs with very high product differentiation. In fact, the company now have over 100 different wheel designs in production and the number is growing. The life-spans of the products are also very short as there is constantly newer designs to replace the old. Products typically move from the introduction stage to the decline stage within 6 to 9 months and company's product lines are constantly refreshed. Flexibility in terms of design and volume is the key strategy adopted by this company.

The investigation into the company's operations reveals that its production planning and control is very poor. This is quite typical, judging that that the company is fairly new in the manufacturing business. Production schedules of the facility are decentralised and handled individually by the sections managers. As a result, visibility of the production resource utilisation and capacity is poor. The inefficiency of the facility is also very high, partly due to the high set-up times as a result of high-mix low-volume production conditions. Leadtime for the products is also fairly long (about 2 months) and there are opportunities to improve on it through good planning practices. Quality processes are also poorly implemented, thus contributed to the inefficiency in both resource utilisation and material usage. The workforce are lowly skilled and mainly involved in the manual transportation of parts between sections and machines. During the study, the company had also expressed interest to implement Lean practices to improve their efficiency and capacity.

8.3.2 Summary of results from the questionnaires

Three sets of questionnaires (Appendix C) are used to assist the systematic data collection of the physical artefacts sought. As the information sought is not found from a single source, several sources of evidence are used to furnish the 3 questionnaires sets for each company. The author is responsible completing the questionnaires in each case, with the findings validated by the primary contacts from each company.

A multiple-case embedded design is chosen for the case study. Thus, the larger unit of analysis for a manufacturing firm is broken down into 4 subunits of analysis of the Competitive Landscape the firm is in, the set of Competitive Dimensions the firm choose to compete, the set of Objectives the firm choose to achieve, and the set of practices the firms adopted. Questionnaire set 1 sought the information about the competitive orientation of the company in terms of their value discipline (Treacy and Wiersema, 1993). In this case, these value disciplines are referred as the general competitive strategies of the company. A numerical score in each of the 3 value discipline are obtained via the questionnaire set but only the discipline with the highest score are identified as the primary competitive strategy for the company. A tabular summary of the questionnaire set 1 is shown in Table 8.2.

Questionnaire set 2 sought the information about the competitive objectives of the company. These objectives are also related to the competitive dimension as described in Section 5.2. A tabular summary of this questionnaire set is shown in Table 8.3.

Finally, questionnaire set 3 sought the information about the practices adopted by the company. These practices are associated with the manufacturing paradigm as defined in Section 6.4. A tabular summary of this questionnaire set is shown in Table 8.4.

In the next section, these findings will be analysed against the 4 statements proposed in Section 8.2.1.

Table 8.2 A tabular summary from questionnaire set 1

Company									
H	G	F	E	D	C	B	A		
X								Fragmented	Industry
	X							Emerging	
		X						Transition to maturity	
			X					Declining	
				X	X	X	X	Global	
X							X	Introduction	Product
X	X				X	X	X	Growth	
		X	X	X				Matured	
			X					Decline	
			X		X			Operational Excellence	Strategy
X	X					X	X	Product Leadership	
		X		X				Customer Intimacy	

Table 8.3 A tabular summary from questionnaire set 2

Dimension		Company: H	G	F	E	D	C	B	A	Objective
	Price				X	X	X	X		Cost
	Quality		X		X	X	X	X		Conformance
			X			X	X	X	X	Performance
	Delivery		X			X		X		Speed
					X		X			Dependability
	Flexibility	X								Volume
		X	X	X					X	Design
		X	X	X			X	X	X	Variety
	Service	X		X	X	X			X	After-sale
		X		X		X			X	Distribution

Table 8.4 A tabular summary from questionnaire set 3

Paradigm					Company								Practices
Agile	Mass-customise	Time-based	Lean	Mass	H	G	F	E	D	C	B	A	
	X			X				X	X	X	X		Economies of Scale
	X			X				X		X	X		Resource Specialisation
				X				X	X	X			Product Standardisation
				X				X		X	X		Continuous Flow
				X				X		X	X		Centralised Planning & Production
				X				X	X	X	X		Cost Driven
			X							X	X	X	Waste Reduction
		X	X							X	X	X	Continuous Improvement
			X									X	Lot Size Reduction
			X			X	X						Self-directed Workforce
			X									X	Cellular Manufacturing
X		X	X			X	X					X	Cross-functional Workforce
	X		X				X		X	X	X		Supplier Integration
X	X	X	X						X	X	X	X	Integrated Information System
			X							X	X	X	Quality Driven
		X							X		X	X	Leadtime Reduction
X		X			X	X	X					X	Product Customisation
		X							X				Cellular Organisation
	X	X			X	X	X		X		X	X	Customer Involvement
		X							X		X		Delivery Driven
	X								X				Postponement Strategy
	X								X	X	X		Product Modularisation
	X				X	X			X			X	Flexibility Driven
X									X				Change Management
X							X		X				Fluid clusters of associates
X					X				X				Decentralise Organisation
X							X		X	X			Focused Competency Centers
X					X				X			X	Global Network
X					X		X		X			X	Service Driven

8.4 Case Study Analysis

This section analyses the case study findings against the statements proposed in Section 8.2.1. In this case, the previously developed theory (decision model for best practice adoption) is used as a template with which to compare the empirical results of the case studies presented in the previous section. Analytic generalisation is employed to attain Level Two Inference as shown in Figure 8.1. Analysis will be carried out and presented with respect to the 4 statements below,

Statement 1: On the Competitive Landscape
The industry type that a company is in and the product stage of their main product are adequate to define the competitive landscape for the company.

Statement 2: On the Competitive Strategy
There exist an appropriate set of probable competitive strategies with respect to one or more of the competitive dimensions in Price, Quality, Delivery, Flexibility and Service, which a company can choose to compete in the market.

Statement 3: On the Manufacturing Paradigm
Each manufacturing paradigm supports a unique set of objectives that can be related to the competitive dimensions.

Statement 4: On the Manufacturing Best Practices
There is a unique set of best practices that can be identified with each manufacturing paradigm in support of the competitive landscape of the company.

8.4.1 Statement 1: On the Competitive Landscape

The first statement generalises the claim that the industry type of a company and the product stage of its main product are adequate to define a unique competitive landscape for the company. In this case, the case studies were intentionally selected to cover the full spectrum of these competitive spaces to contrast the different environment faced by companies (Section 8.2.2). Thus, the claim is that there exist clusters of competitive spaces, defined by industry types and product stages, where a common competitive strategy can be identified.

To validate this claim, Table 8.2 is examined. Evidence sought is a pattern of strategy zoning in the competitive spaces defined by industry types and product stages. Figure 8.5 presents the preliminary strategy zoning derived from Table 8.2.

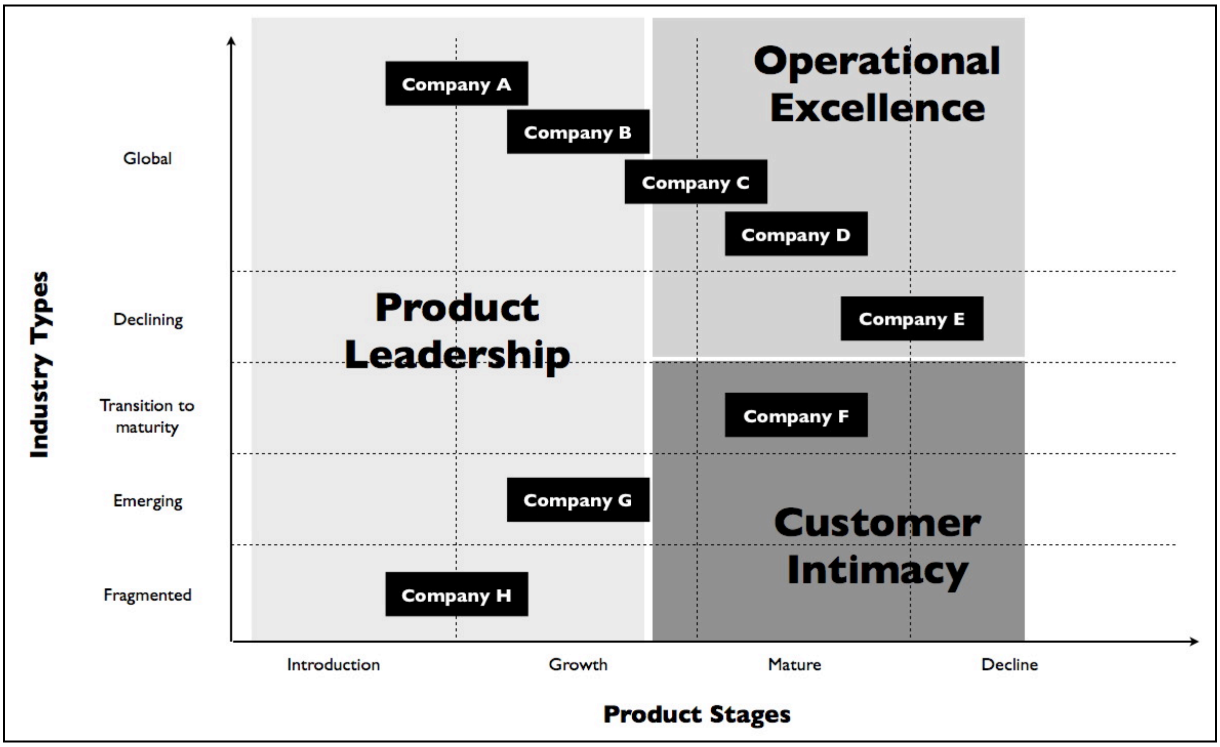

Figure 8.5 Strategy zoning in the competitive spaces

From Figure 8.5, it is evident that there exists a zone for the common application of product leadership strategy. This zone spans from the product introductory to the growth stage, in particularly for the fragmented, emerging and global industry. This supported by the results obtained for Company A, B, G and H.

Some evidence of zoning for operational excellence strategy is observed for the mature and decline product stage along the global and declining industry band. Company C and E support this evidence. Although Company D is reported to be more inclined toward the customer intimacy strategy (see Table 8.2), the company does exhibit some inclination towards operational excellence strategy. This is evident in the numerical scoring of Company D for the questionnaire set 1. The probable reason for Company D's shift of focus from operational excellence is the high level of manufacturing and logistic outsourcing practiced by the company (Section 8.3.1).

Company F exhibits inclination towards customer intimacy. However, a single case evidence is not sufficient to conclude this zoning. Company F is also an engineering company whose business is to provide engineering services in terms of equipment customisation and maintenance. Thus, the company do not own or produce any products. As such, customer intimacy becomes the only obvious strategy that the company can create differentiation in the market. Similar evidence is also reported from Company D. It seems apparent that the absence of manufacturing activities in-house via outsourcing would suggest the shift towards a more service-oriented customer intimacy strategy for product stage in the mature band. However, it is inconclusive on whether all products in the matured stage will be outsourced eventually.

It is also worth noting that there exist some ‘blank’ zones in the Figure 8.5. These blank zones are along the product introductory and growth stage for transition in maturity and declining industry as well as the mature and decline product stage for the fragmented and emerging industry. Obvious reason is the inherent bias of self-evidence on the proposed relationships between the Industry and Product layer. Few companies are actually found in these spaces especially for the latter ‘blank’ zone. However, it is not the intent of this research to answer this question.

In summary, evidence for strategy zoning is apparent in the competitive landscape defined by industry type and product stage. Thus, the statement is validated. It is therefore reasonable to support the claim that the industry type of a company and the product stage of its main product are adequate to define a unique competitive landscape for the company.

8.4.2 Statement 2: On the Competitive Strategy

Given that statement 1 is accepted, there exist a common competitive strategy for a competitive landscape. Treacy and Wiersema's (1993) model of value discipline are adopted in support of this claim. However, it is also evident that 3 generic competitive strategies are too generalise an approach to adequately differentiate the varied competitive strategies adopted by companies (Section 7.4). Similar to Porter's (1980) model of Focus, Cost Leadership and Differentiation strategy, all competitive strategies are found to be a compound strategy from the 5 competitive dimensions of Price, Quality, Delivery, Flexibility and Service (Section 7.5). Company can choose to compete in one or more of these dimensions in the market. Therefore, the second statement claims that each company chooses a unique set of competitive dimensions, which is defined as its competitive strategy.

From Table 8.3, it is apparent that all companies exhibited a varied combination of objectives that are associated with the competitive dimensions. Even for companies that share the same strategy zone in Figure 8.5 (Company A, B, G and H), the variation is large. Thus, there is strong evidence that generic strategies are inadequate to define the actual competitive strategy adopted by the company.

Closer examination of Table 8.3 reveals two distinct clusters of competitive dimensions (see Table 8.5). It shows that Company B, C and D have dominantly focus on the 3 competitive dimensions of Price, Quality and Delivery. On contrary, Company F, G, H exhibit dominant focus on the other 2 competitive dimensions of Flexibility and Service. This is an interesting observation because coincidentally, the former group of companies belong to the exemplar companies while the latter belong to the average-performing companies. Also, all the exemplar companies selected operate globally. Therefore, there is strong evidence that the three competitive dimensions of Price, Quality and Delivery predominantly drive global competitions. Being high-performing companies, Company B, C and D are driven to excel in these dimensions in order to stay competitive.

Table 8.5 Clusters of Competitive Dimensions

Dimension		Company H	Company G	Company F	Company E	Company D	Company C	Company B	Company A	Objective
Price					X	X	X	X		Cost
Quality			X		X	X	X	X		Conformance
			X			X	X	X	X	Performance
Delivery			X			X		X		Speed
					X		X			Dependability
Flexibility		X								Volume
		X	X	X					X	Design
		X	X	X			X	X	X	Variety
Service		X		X	X	X			X	After-sale
		X		X		X			X	Distribution

It is also noted that companies with smaller scales of operations will tends to focus on the competitive dimensions of Flexibility and Service. This is evident in Company F, G and H. The rationale of focusing on these dimensions is to address the niche market associated with them. This can also be related to the differentiation strategy proposed by Porter (1980). Products in this sector are typically high mix with low volume.

In summary, strong evidence suggested that each company chooses a unique set of competitive dimensions, which is defined as its competitive strategy. However, some of these competitive dimensions are dominant for certain clusters of competitive landscape. In the case studies, it is apparent that global companies are predominantly competing in the dimension of Price, Quality and Delivery while local start-ups with smaller scales of operations achieved competitiveness in the dimensions of Flexibility and Service.

8.4.3 Statement 3: On the Manufacturing Paradigm

The third statement claims that each manufacturing paradigm supports a unique set of objectives that can be related to the competitive dimensions. In order to validate this statement, evidence is sought to match a paradigm to a cluster of objectives. The obvious way to achieve this is to determine the dominant paradigm of a company and list out the associated objectives from Section 8.4.2. However, there is no obvious pattern matching between the practices adopted by the companies and the theoretical pattern suggested in the decision model as shown in Table 8.4. There is also no apparent suggestion of a dominant paradigm for each of the selected case study companies. Therefore, the alternative pattern matching between the practices adopted and the associated objectives is used instead. From the theoretical linkages between the paradigms and objectives presented in Section 7.5, these practices can then be link back to the paradigms for the validation of this statement.

For this analysis, exemplar companies are initially assessed. This is because it is assumed that these companies achieve superior performance by exhibiting a strong alignment between their practices and objectives. Thus, the correlation between the practices adopted by these companies and their associated objectives is assumed to be strong. Table 8.6 highlighted 3 clusters (I, II and III) of practices predominantly adopted by these companies. Examining the associated objectives of these companies in Table 8.3 reveals that the dominant objectives are cost, conformance, performance.

Table 8.6 Clusters of practices adopted by exemplar companies

Paradigm					Company								Practices	
Agile	Mass-customise	Time-based	Lean	Mass	H	G	F	E	D	C	B	A		
	X			X				X	X	X	X		Economies of Scale	I
	X			X				X		X	X		Resource Specialisation	I
				X				X	X	X			Product Standardisation	I
				X				X		X	X		Continuous Flow	I
				X				X		X	X		Centralised Planning & Production	I
				X				X	X	X	X		Cost Driven	I
			X							X	X	X	Waste Reduction	I
		X	X							X	X	X	Continuous Improvement	I
			X									X	Lot Size Reduction	
			X			X	X						Self-directed Workforce	
			X									X	Cellular Manufacturing	
X		X	X			X	X					X	Cross-functional Workforce	
	X		X				X		X	X	X		Supplier Integration	II
X	X	X	X						X	X	X	X	Integrated Information System	II
			X							X	X	X	Quality Driven	II
		X							X		X	X	Leadtime Reduction	II
X		X			X	X	X					X	Product Customisation	
		X							X				Cellular Organisation	III
	X	X			X	X	X		X		X	X	Customer Involvement	III
		X							X		X		Delivery Driven	III
	X								X				Postponement Strategy	III
	X								X	X	X		Product Modularisation	III
	X				X	X			X			X	Flexibility Driven	III
X									X				Change Management	III
X							X		X				Fluid clusters of associates	III
X					X				X				Decentralise Organisation	III
X							X		X	X			Focused Competency Centers	III
X					X				X			X	Global Network	III
X					X		X		X			X	Service Driven	III

Conclusive pattern matching between practices to objectives is not possible from these data. However, the clusters of group I and II practices shared by company B and C exhibit a strong evident of the significance of these practices. Company B and C are both electronic component manufacturers, sharing many common objectives like cost, conformance and performance. Thus, it is reasonable to claim that practice from group I and II supported these objectives. These practices also matches most of the practices associated with Mass and Lean paradigm, which implies that Mass and Lean paradigm support these objectives too.

Cluster of group III practices exhibited by company D comprises of practices shared by the Time-based, Mass-Customise and Agile paradigm. Evidently, this company also shared the common group of cost, conformance and performance objectives (Table 8.5). However, the missing practices that is evident in company B and C is not surprising considering that this company outsourced all their manufacturing and distribution functions. Thus, it can be suggested that these group III practices supported some of the remaining objectives.

Closer examination of the practices associated with Mass-customise paradigm also shows that 7 of the 8 practices coincide with the practices adopted by company D. This implies that mass customisation is dominant in this company. Together with the set of practices from change management to service driven, part of Agile practices are also evident in company D. In view of these evident, it can be postulated that mass-customise and agile paradigms may in fact belong to a similar paradigm, which is evident in the collection of practices found in Company D.

Extending from this idea of the possibility of merging two paradigms into one, Lean and Time-based paradigm can be merged to include a cluster of practices from waste reduction to delivery driven. With this new set of practices, the match against company A's practices become apparent. Thus, it can be postulate that Lean and Time-based paradigms may in fact be one group too. However, comparing the evidence reported in company B and C, it is concluded that Lean practices are in support of the Price and Quality oriented objectives while Time-based practices support the Delivery and Flexibility oriented objectives.

In summary, there is substantial evidence to show that a unique set of objectives is supported by each paradigm. However, some evidences have postulated the merging of paradigms especially the Mass-customise and Agile paradigm. Together, they support the Flexibility and Service oriented objectives. Evidence also suggest that Mass paradigm is predominantly in support of cost objective while Lean paradigm can supplant it to extend the support to Price and Quality oriented objectives. Finally, Time-based paradigm supports the Delivery and Flexibility oriented objectives.

8.4.4 Statement 4: On the Manufacturing Best Practices

The final statement generalise the claim that a unique set of best practices can be identified with each manufacturing paradigm in support of the competitive landscape of the company. However, previous analysis has discussed the absence of an obvious match between the practices adopted by the company and the practices theoretically associated with the paradigms defined. Thus, it is suggested that the current list of paradigms suggested is inaccurate to validate this statement and a revised list is necessary.

Evidence has suggested the merging of Mass-customise and Agile paradigm (Section 8.4.3). Since Company D is an exemplar for this merged paradigm, the characteristic of Company D's operations will be used to name this new paradigm. In this case, it is apparent that outsourcing is a dominant characteristic observed in company D. Thus, a new paradigm is suggested and is named as the Outsourcing paradigm in place of the Mass-customise and Agile paradigms. This paradigm will be associated with all the practices from the two paradigms it is replacing. Table 8.7 highlights the new sets of unique practices in association with the revised list of paradigms suggested. This table will be used as a basis for the validation of this statement.

Section 8.4.3 has provided the evidence that Mass practices are linked to Price oriented objectives while Lean practices are linked to Quality oriented objectives. Time-based practices are linked to Delivery and Flexibility oriented objectives.

Finally, Outsourcing practices are linked to Price, Flexibility and Service oriented objectives.

Table 8.7 Unique set of best practices against manufacturing paradigm

Paradigm: Outsourcing	Paradigm: Time-based	Paradigm: Lean	Paradigm: Mass	Practices
X			X	Economies of Scale
X			X	Resource Specialisation
			X	Product Standardisation
			X	Continuous Flow
			X	Centralised Planning & Production
			X	Cost Driven
		X		Waste Reduction
	X	X		Continuous Improvement
		X		Lot Size Reduction
		X		Self-directed Workforce
		X		Cellular Manufacturing
X	X	X		Cross-functional Workforce
X		X		Supplier Integration
X	X	X		Integrated Information System
		X		Quality Driven
	X			Leadtime Reduction
X	X			Product Customisation
	X			Cellular Organisation
X	X			Customer Involvement
	X			Delivery Driven
X				Postponement Strategy
X				Product Modularisation
X				Flexibility Driven
X				Change Management
X				Fluid clusters of associates
X				Decentralise Organisation
X				Focused Competency Centers
X				Global Network
X				Service Driven

Section 8.4.2 reported the existence of 2 unique clusters of competitive dimensions (see Table 8.5). In association with the competitive dimension associated with each paradigm, it is apparent that Mass and Lean paradigms can be linked to the clusters for Price, Quality and Delivery while the Outsourcing paradigm belong to the clusters of Flexibility and Service. Time-based paradigm will transition between these two clusters.

Finally, relating back to the competitive landscape (Section 8.4.1), it is apparent that Company A is an exemplar for the Time-based paradigm, Company B and C are the exemplars for Lean paradigm and Company D is an exemplar for Outsourcing paradigm. Mass paradigm is omitted because this paradigm is mostly supplanted by the Lean paradigm as evident in Chapter 3. Table 8.4 has provided evidence that Mass paradigm is still at work in Company E, which also re-enforced the argument that Mass paradigm is dated. Thus, it can be suggested that Time-based paradigm is dominant for products in the introductory and growth stage, Lean paradigm is dominant for the growth to matured stages and Outsourcing paradigm is dominant for products in the matured to declining stages. On top of that, start-up companies with smaller scale operations evident in Company F, G and H can leverage on competing in the Flexibility and Service dimension to gain competitiveness. Therefore, Outsourcing paradigm is also dominant in such companies.

In summary, substantial evidences supports the statement that a unique set of best practices can be identified with each manufacturing paradigm in support of the competitive landscape of the company. Table 8.7 defines these unique sets with respect to the paradigm identified. The manufacturing paradigms in support of the competitive landscape are illustrated in Figure 8.6. Best-fit paradigms with respect to Company E, F, G and H are also suggested.

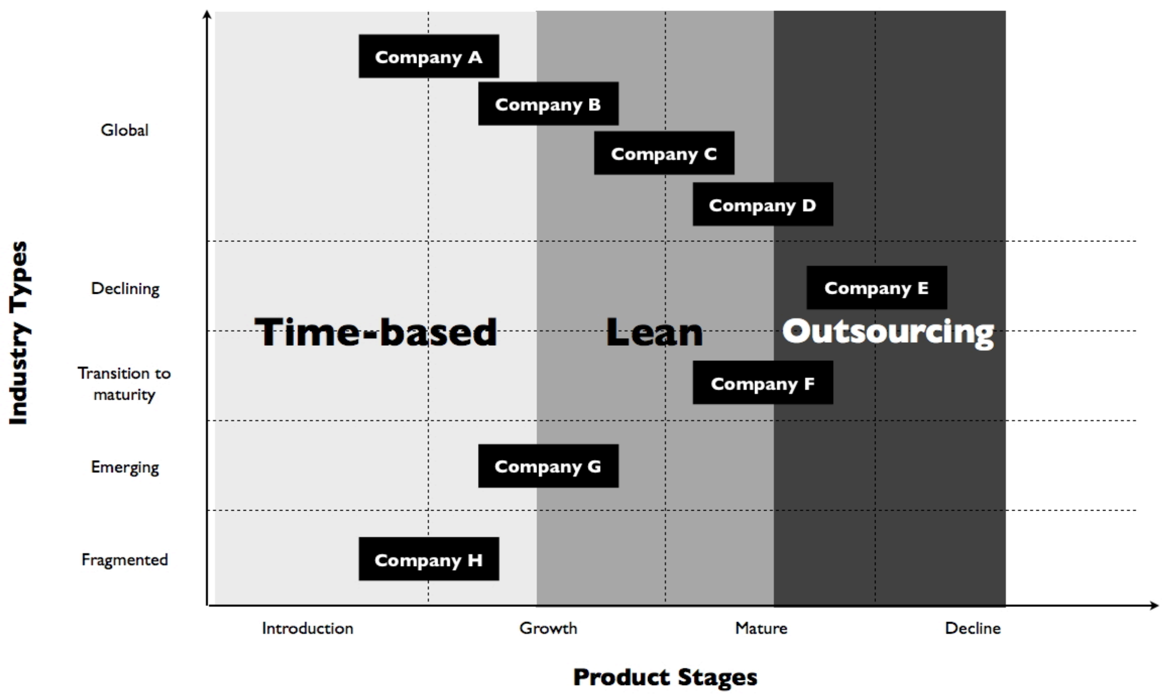

Figure 8.6 Manufacturing paradigms in support of the Competitive Landscape

8.5 Final refinement to the Decision Model

Through the validation process, strategic and operational artefacts collected from the case studies are used to refine the secondary model obtained from Chapter 7. Analysis conducted in Section 8.4 suggested several refinements to the decision model, which are discussed in this section.

The first is the reordering of the first 2 layers (Industry and Product layers) of the secondary decision model depicted in Figure 7.2. Validation of statement 1 (Section 8.4.1) supports the claim that industry type of a company and the product stage of its main product are adequate to define the unique competitive landscape of the company. Section 8.4.2 further supports this claim by providing evidence of distinct strategic zoning between exemplar (global) companies and local start-ups. Thus, it is suggested that linkages between the Industry and Dimension layers is more apparent than the initially suggestion of Industry to Product to Dimension layers. Table 8.8 presents a tabular summary of the linkages between Product stages, Industry types and Competitive dimensions.

Table 8.8 Linkages between Product Stages, Industry Types and Competitive Dimensions

		Industry				
		Fragmented	Emerging	Transition to maturity	Declining	Global
Product	Introduction	X	X			X
	Growth	X	X			X
	Matured			X	X	X
	Decline			X	X	X
Dimension	Price			X	X	X
	Quality			X	X	X
	Delivery	X	X	X	X	X
	Flexibility	X	X			X
	Service	X	X			X

The second is the merging of the Mass-customise and Agile paradigms suggested in Section 8.4.3 and validated in Section 8.4.4. The new paradigm in place is named as the Outsourcing paradigm, which supports the Price, Flexibility and Service oriented objectives. Unique sets of practices associated with each paradigm are also suggested (Table 8.7). Section 8.4.3 has also provides evidences of linkages between Mass paradigm to Price oriented objective, Lean paradigm to Price and Quality oriented objectives and Time-based paradigm to Delivery and Flexibility oriented objectives. Thus, the objective layer depicted in Figure 7.2 can be dropped because of the implied association between the competitive dimensions and its associated objectives.

In summary, the validation process has validated the causal linkages suggested in the decision model. The structure of the decision trees are also simplified with the reordering of the Industry and Product layers as well as the removal of the Objective layer. The final decision tree is presented in Figure 8.7. The lines depicted in this decision tree represent the probable outcomes or choices for each decision nodes. For example, the Price node in the Dimension layer has three lines connected to the Mass, Lean and Outsourcing Paradigm. This means that either one of these three paradigms are able to support the Price competitive dimension. Detailed explanation of all linkages in this final decision tree will be presented in the next Chapter as a guide for industry application.

8.6 Chapter Summary

The research described in this chapter has validated and refined the decision model against the real-life industry scenario. The final decision model will be operationalised in the form of a guide for industry application in the next chapter.

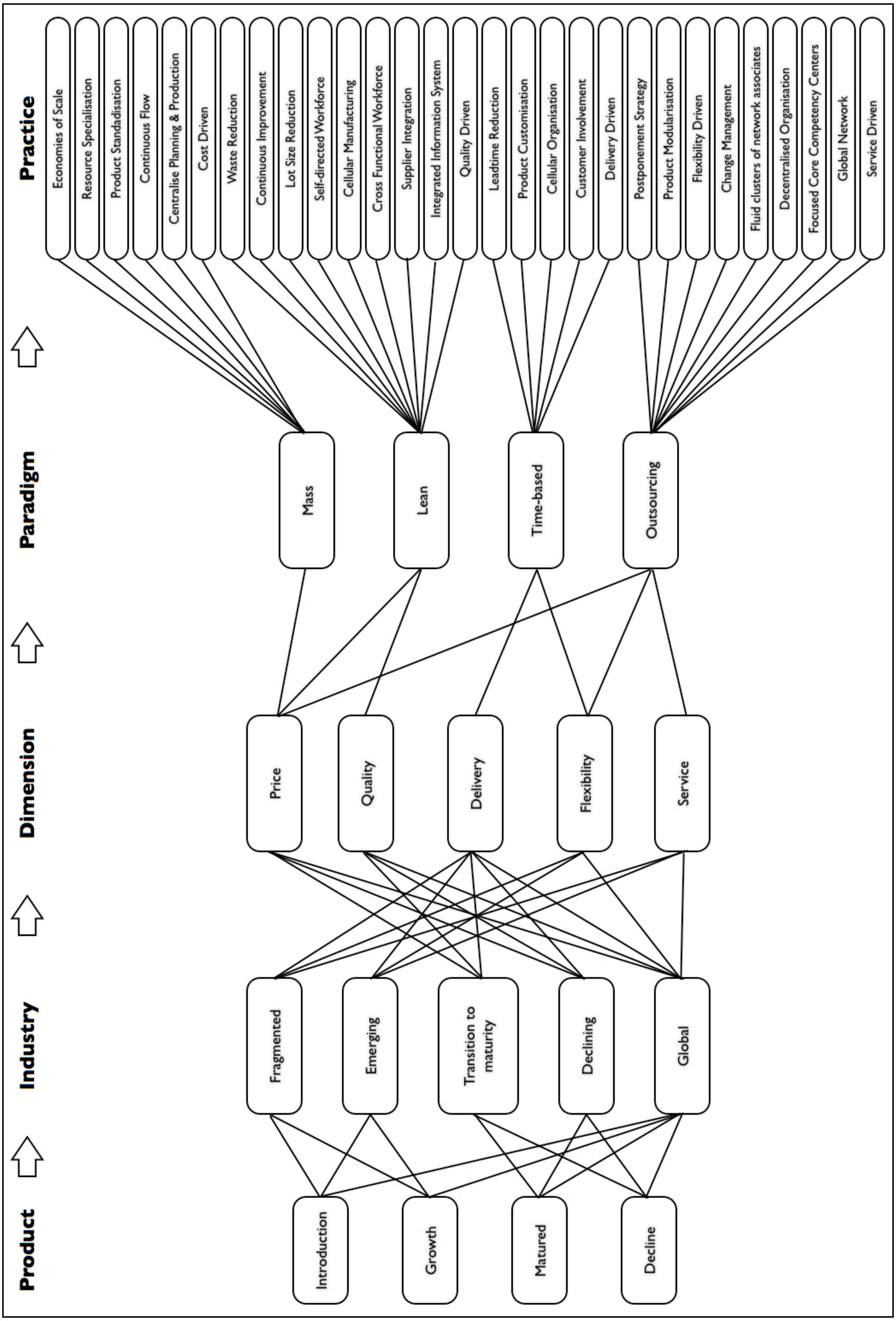

Figure 8.7 Final Decision Model

Chapter 9: Applying the Decision Model

In Chapter 8, the final decision model is established and presented in Section 8.5. This chapter deals with the operationalisation of this decision model in the form of a decision support guide to aid the analytical selection of manufacturing best practices. The chapter first presents the purpose and method for this stage of research (Section 9.1). Subsequently, an overview and description of each stage of the decision process is presented.

9.1 Stage 5: Purpose and Method

The purpose of this final stage of the research programme is to present the final decision model in the form of a decision support guide. As illustrated in Figure 9.1, the final decision model has been constructed, verified and validated by combining the following logical sources:

- Requirements for the decision model (Chapter 5)
- Characteristics of the decision modelling techniques (Chapter 6)
- Experts' opinion on existing knowledge and concepts (Chapter 7)
- Strategic and Operation artefacts from case studies (Chapter 8)

These sources provide the required information to finalise the contents and structure of the final decision model as shown in Figure 9.1. The assumption held by a company on its environment is defined as its Competitive Landscape (Chapter 5). In this case, evidence has validated that the Product stages and the Industry types of a company are adequate in defining this Competitive Landscape (Section 8.4.1). Generic competitive strategies suggested by Porter (1980) and Treacy and Wiersema (1993) are dropped. In place of it are the Competitive Dimensions of Price, Quality, Delivery, Flexibility and Service, where a company's Competitive Strategy is its choice to compete on one or more of these dimensions (Chapter 7). Competitive Objectives layer is also dropped because the objectives are implicit to these Competitive Dimensions used (Section 8.5). Finally, Mass-customise paradigm and Agile paradigm previously defined are combined to form a new Outsourcing paradigm (Section 8.4.3). Shared practices associated with each of these manufacturing paradigms are sorted to provide a unique set of manufacturing practices against each paradigm (Table 8.7). Finally the competitive dimensions supported by each paradigm are also sorted (Section 8.4.4).

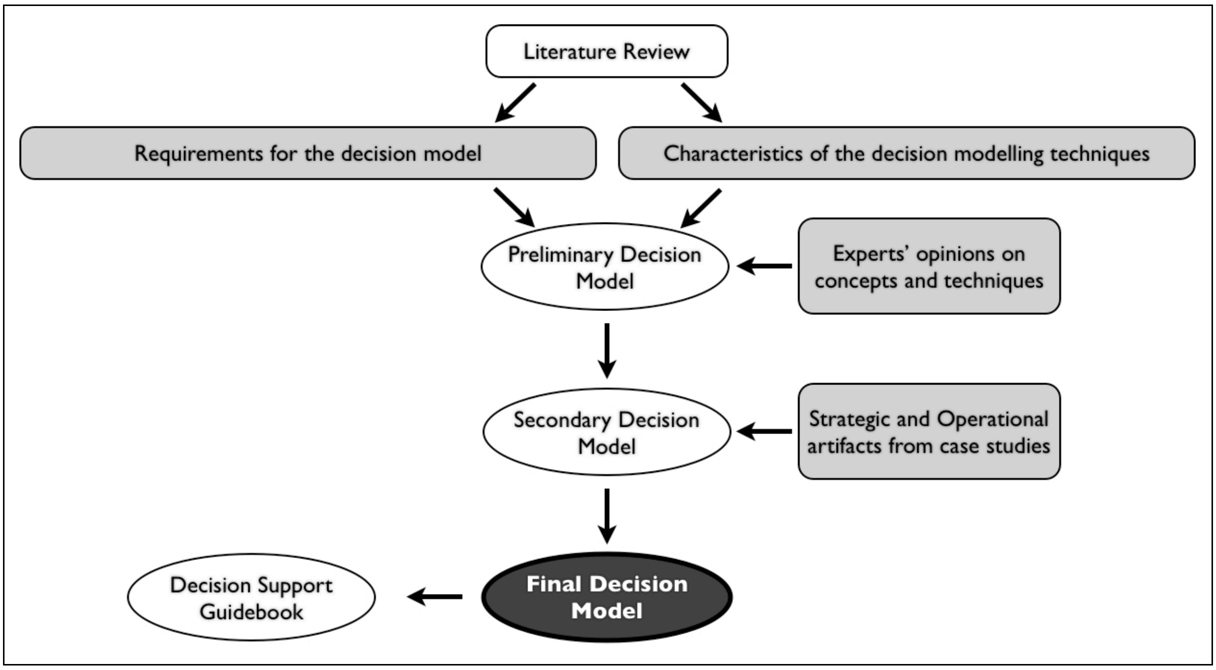

Figure 9.1 Phases leading to the Decision Model for Manufacturing Best Practice Adoption

9.2 Decision Process for Best Practice Adoption

This section provides a detailed description of the decision model to illustrate the structure and contents of this decision model and its use in a decision support guide. Firstly, an overview of the decision process is provided. Subsequently, a detail description of each of the decision stages in the guidebook is presented.

9.2.1 Overview of the Decision Process

The final decision model is presented in Figure 8.8 and it depicts a 4-stage decision process that links the Competitive Landscape to the probable Competitive Strategy to the Best-fit Paradigm and its associated manufacturing best practices for adoption. Figure 9.2 presents an overview of this 4-stage decision process.

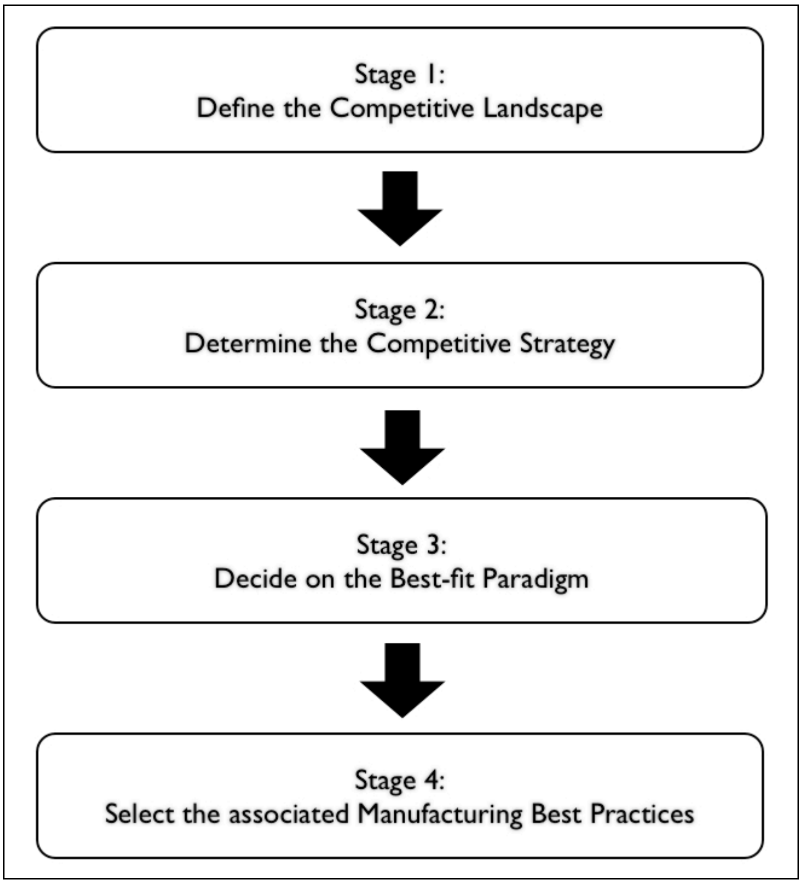

Figure 9.2 Overview of the 4-stage decision process

This decision model provides a structured guide that will help practitioners in the analytical selection of manufacturing best practices. In achieving this, it helps the practitioner to:

- Maintain high level of coherence between the competitive strategy and manufacturing practices adopted.
- Formalise the adoption decision process through the provision of a holistic decision model.
- Understand the empirical links between practices and strategic goals.
- Manage trade-off between the competitive dimensions in the adoption process.

The decision support guide presented in this chapter is intended as a guide for the management of Manufacturing Best Practice Adoption. It sets out a series of key decision stages in this process. The intention is to provide an analytical approach to best practice adoption that will help to ensure that the adoption process is rigorous and successful. However, this guide does not replace procedures, experience, nor provide a foolproof method. It is an aid that could and should enhance the process of best practice adoption. The guide can be used in two ways. Firstly, to act as an analytical guide for senior management, project managers and project teams involved in the implementation of manufacturing best practices, by providing guidelines and suggestions to assist the adoption decision. Secondly, it provides a holistic view of the best practice adoption process and provides linkages between best practices and strategic goals.

9.2.2 Stage 1: Define the Competitive Landscape

Stage 1 of the best practice adoption decision process is to define the Competitive Landscape of a company. This will establish the assumptions a company hold about the business they are in. These assumptions frame the boundaries and define the view about the external needs and internal requirements of operating the business within these boundaries.

Competitive Landscape is defined by the Product stage and the Industry type the company is in. They are typically 4 stages (Introduction, Growth, Mature and Decline) of a product life cycle. The product stages are generally related in the rate of growth of industry sales of the product as shown in Figure 9.3. This rate of growth reflects the buyer behaviour, product configuration, and competition profile which will characterise the manufacturing requirement and set the priorities on the capabilities that the manufacturing function needs to fulfill in meeting the requirement. Discussion of these 4 stages of product life cycle in contrast of these requirements is presented in Appendix D. Checklist to determine the product stage is found in Appendix E. A summary of the product stages against its requirements and the probable competitive dimensions and objectives is presented in Table 9.1.

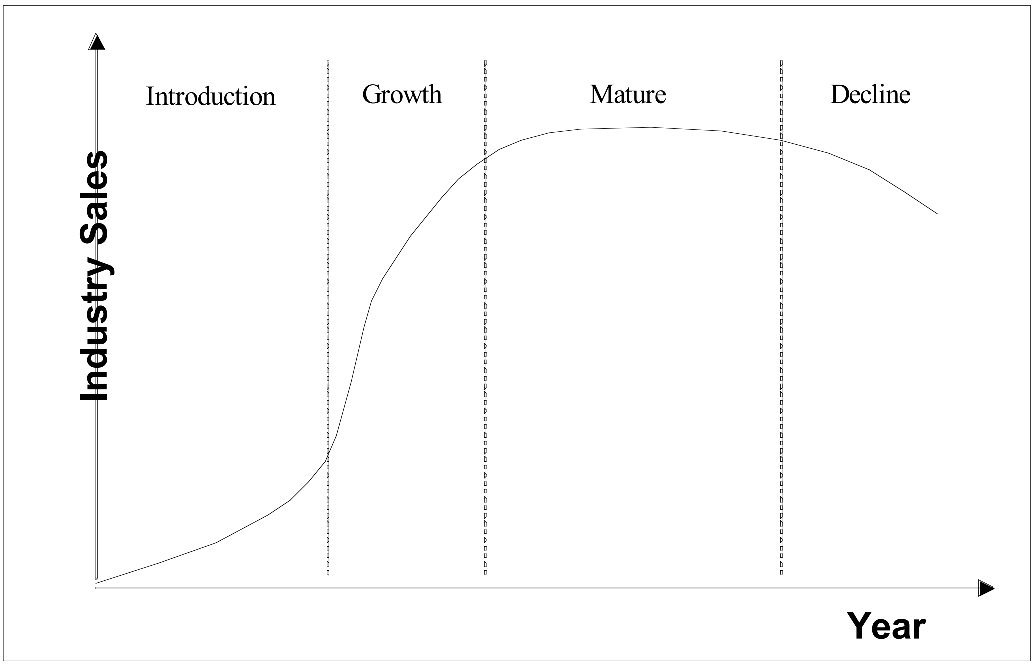

Figure 9.3 Stages of the Product Life Cycle

Industry environment differ most strongly in their fundamental strategic implications along a number of key dimensions (Porter, 1980),

- Industry concentration;
- State of industry maturity;
- Exposure to international competition.

Five generic industry types are selected on the basis of these dimensions. They are Fragmented Industries, Emerging Industries, Transition to Industry Maturity, Declining Industries and Global Industries. In each of these environments, the crucial aspects of industry structure, key strategic issues and characteristic strategic alternatives are identified. Contrast of these 5 industry types is presented in Appendix F. Checklist to determine the industry type is found in Appendix G. A summary of the industry types against its market conditions, strategies to adopt and the probable competitive dimensions is presented in Table 9.2.

Table 9.1 Summary of the product stages against the requirement and the probable competitive dimensions and objectives

Product Life Cycle Stages	Requirements	P	Q	Q	D	D	F	F	F	S	S
		Cost	Conformance	Performance	Speed	Dependability	Volume	Design	Variety	After-sale	Distribution
Introductory	• Low volume • Design under review • Require flexibility of the manufacturing system • Demand general purpose equipment and skill/multi-skilled workers • Product selling on its uniqueness • Target market is price in sensitive • Key objective is to gain market penetration with Delivery (D), Flexibility (F) and Service (S)				X		X	X	X		X
Growth	• Design established • Competition and volume increases • Increasing pressure on price competition • Standardisation of product design and manufacturing process • Highly structured tasks and automation may be introduced • Key objective is to keep up the competition with Quality (Q) and Price (P).	X		X	X					X	X
Mature	• Maturity drive price pressure • High volume • High automation • Matured product and processes required less skilled operators • Key objective is to exert the cost advantage on competitors with Price (P)	X	X	X		X				X	
Decline	• Price competition most severe • Decreasing volume • Product and market consolidation required • Product design very matured • Key objective is to sustain the cost advantage while maintaining some Flexibility (F)	X	X		X	X			X		

Table 9.2 Summary of the industry types against the market conditions, strategies to adopt and the probable competitive dimensions

Industry types	Market Conditions	Strategies/position to adopt	Price	Quality	Delivery	Flexibility	Service
Fragmented	• Variable demand • Absence of economies of scale • Diverse market needs (high varieties)	• Consolidation to create economies of scale • Standardise market • Identify mass market • Make acquisition for critical mass			X	X	X
Emerging	• Low volume • Fluctuating demand • Unstable supply • High uncertainty and unpredictable changes	• Shape industry structure • Promote new standard • Prepare for possible shift in the orientation of its supplies and distribution channels • Proactive moves to strategic positioning			X	X	X
Transition to maturity	• Slowing growth • Greater emphasis on cost and service • Overcapacity drive price down • Falling profit margin	• Rationalising the product mix • Correct pricing • Process innovation and design for manufacturing • Increasing the scope of purchases • Identifying niche market • Grow internationally	X	X	X		
Declining	• Shrinking demand • Shift in needs	• Typical strategy is disinvestment or harvest • Alternative strategy is seek leadership in terms of market share or create niche or strong position in particular segment	X	X	X		
Global	• Existence of comparative advantage in Production, Logistics and Marketing • Purchasing economies of scale • Differing product needs • Sensitivity to leadtime • Complex market segmentation	• Industrial policy and competitive behaviour • Relationships with host government and major markets • Broad line Global competition • Global/National Focus • Seek protected niche	X	X	X	X	X

Table 9.1 and 9.2 provides the probable competitive dimensions for competition in relation to the product stages and industry types respectively. However, Competitive Landscape is a product of then. Thus, it is apparent that there is a possibility of strategic mismatch between the product stage and the company's industry type. For example, a product in its introductory stage for a declining industry type. In such situation, it is an obvious case of a wrong product for a wrong market. Therefore

Company will need to review their product and business strategy. Tools provided for this stage of the decision process can also be used to assist such change.

9.2.3 Stage 2: Determining the Competitive Strategy

Stage 1 of the decision process offers suggestions on the probable competitive dimensions for competition. In Stage 2, the company needs to determine its competitive strategy with respect to the five competitive dimensions. Profile chart of competitive dimension in Figure 9.4 can be used to assist this process.

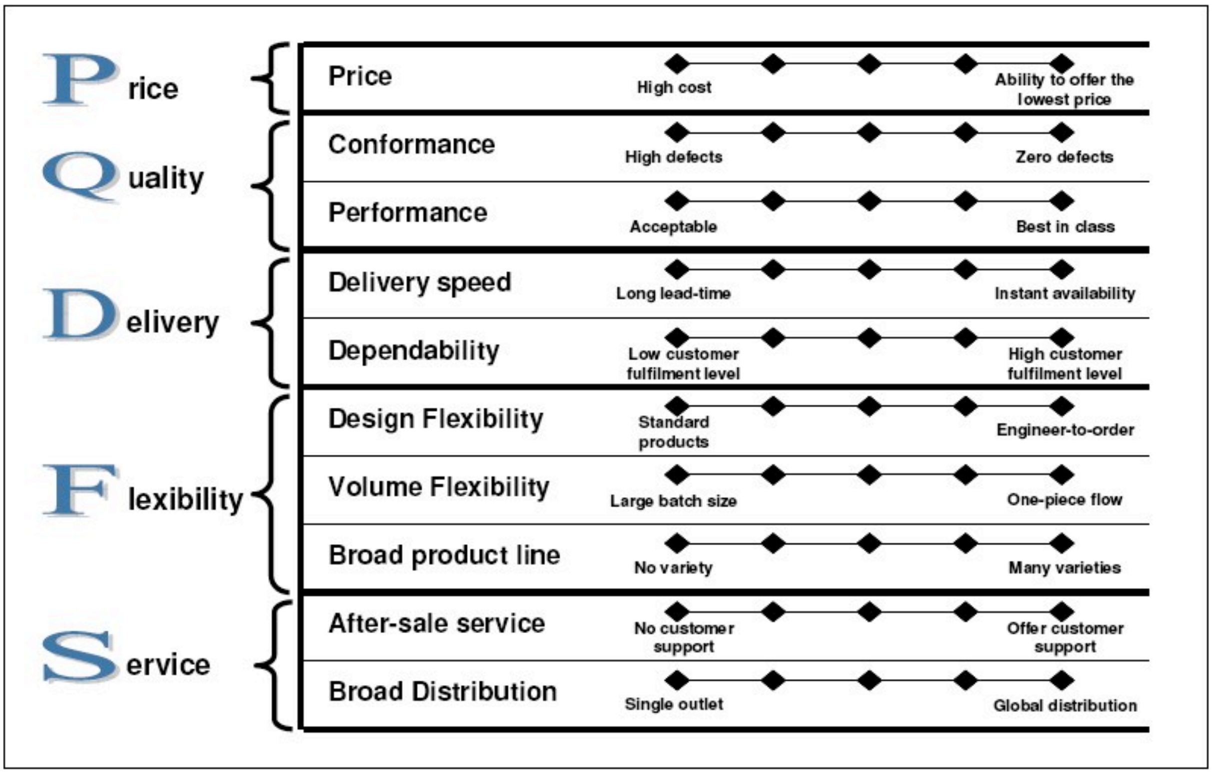

Figure 9.4 Profile chart of Competitive Dimensions

The profile scale on the right of the chart in Figure 9.4 serves 2 purposes. The first is a checklist to assess the company's current competitive position. The second is to indicate a future position where the company would like to be. Through the use of this profile chart, the competitive strategy of the company with respect to the five competitive dimensions is determined.

Similar to Stage 1, where there is a possibility of strategic mismatch between the product stage and industry type. In Stage 2, the possibility of strategic mismatch will be the suggested competitive strategy in Stage 1 and the selected competitive strategy in Stage 2. In this case, the senior management of the company involved in this exercise will need to review these competitive strategies and make a choice. Please note that it is not the purpose of this guide to prescribe a competitive strategy for a company. The guide should be used as tool to review the company's strategic choices.

9.2.4 Stage 3: Decide on the Best-fit Paradigm

At the end of Stage 2, the company's competitive strategy is determined. Based on the suggestion of the best-fit paradigm presented in Figure 8.8, the most suitable paradigm can be selected. Table 9.3 provides a summary of the match between competitive dimensions and manufacturing paradigms.

Table 9.3 Summary of the match between competitive dimensions and manufacturing paradigms

Competitive Dimensions	Manufacturing Paradigms			
	Mass	Lean	Time-based	Outsourcing
Price	**XX**	X		X
Quality		**XX**		
Delivery			**XX**	
Flexibility			X	**XX**
Service				**XX**

Depending on the strategic choice make, the company will decide on the most suitable paradigm to adopt. It must be noted that the paradigms prescribed by the decision model is not meant to be exhaustive. So there is possibility that the company may find it difficult to choose a paradigm of choice. For example, if the company's competitive strategy is to compete in the 4 dimensions of Price, Quality, Delivery and Flexibility, then there is a torn of choices between the Lean and Time-based paradigm. The obvious solution would be to adopt both paradigms. However, this is not correct. No company should compete in all dimensions. Suggestions of paradigm given in Table 9.3 should be used as a guide to rationalise the strategic choices.

Eventually, company should select a maximum of 2 key dimensions to compete, one primary and the other secondary. Choice of paradigm can then be easily selected. It should be noted that the primary dimension/s supported by each paradigm is denoted by a double crosses as presented in Table 9.3. This is also evident in the final decision model presented in Figure 8.8.

9.2.5 Stage 4: Select the associated Manufacturing Best Practices

The final stage of the decision process is to select the Manufacturing Best Practices for adoption. Table 9.4 provides the tabular list of key best practices with respect to each manufacturing paradigm. These practices suggested are not industry/company specific practices nor is it a meant to be. Instead, each of these practices listed can be associated to a cluster of practices in relation to it. Take for example the Cross Functional Workforce associated with the Lean paradigm. Under this practice, it encompasses company specific training programmes, job rotation opportunities and recruitment processes to attain it. Thus, this list is meant as a guide for the development of company specific practices in support of it.

The guide can also serve as a tool to review current practices adopted and rationalise the plan for adoption of new practices. A way to do so is to check the current practices in place in relation to the 29 key practices listed in Table 9.4. This check will reveal the dominant paradigm adopted by the company currently. When view in relation to the competitive strategy of the company, adoption gaps can be identified. Thus, implementation roadmap can then be planned.

Table 9.4 List of key manufacturing best practices associated with each manufacturing paradigms

Key Manufacturing Best Practices	Manufacturing Paradigms			
	Mass	Lean	Time-based	Outsourcing
Economies of Scale	X			
Resource Specialisation	X			
Product Standardisation	X			
Continuous Flow	X			
Centralise Planning and Production	X			
Cost Driven	X			
Waste Reduction		X		
Continuous Improvement		X		
Lot-size Reduction		X		
Self-directed Workforce		X		
Cellular Manufacturing		X		
Cross-functional Workforce		X		
Supplier Integration		X		
Integrated Information System		X		
Quality Driven		X		
Leadtime Reduction			X	
Product Customisation			X	
Cellular Organisation			X	
Customer Involvement			X	
Delivery Driven			X	
Postponement Strategy				X
Product Modularisation				X
Flexibility Driven				X
Change Management				X
Fluid Cluster of Network Associates				X
Decentralise Organisation				X
Focused Core Competency Centers				X
Global Network				X
Service Driven				X

9.3 Chapter Summary

This chapter has presented a guide based on the final decision model. It provides a holistic view to the decision process, variables and the causal linkages between manufacturing best practices and competitive strategy. This guide is structured, procedural and descriptive, focuses on how to carry out the analytical selection of manufacturing best practices from the start to the end. The next chapter will conclude the research programme, make contribution to knowledge and recommend further research in this field.

Chapter 10: Conclusions

This research set out to create a decision model that would guide practitioners in the analytical selection of manufacturing best practices. This chapter summarises the research findings against the research aim and discusses the contributions to knowledge. The limitations of the research are then discussed and directions for future work suggested. Finally, concluding remarks are made.

10.1 Overview of Research Aim and Programme

This section provides an overview of the research aim and programme. The research aim in this work was as follow:

"to develop a decision model for best practice adoption that links practices to competitive strategies and guide practitioners in the analytical selection of manufacturing best practices."

This research aim was then addressed by completing a set of objectives, namely to:

1. Develop a decision model for the adoption process of manufacturing best practices.
2. Validate the decision model with real-life industrial case studies.
3. Apply the decision model in the form of a guidebook for industrial application.

The research described in this thesis has set out to create a decision model for best practice adoption through a structured research programme. Initially, the decision framework was formed by reviewing the best practice problem and the adoption approaches from best practice and manufacturing strategy literatures. This defined the structure and content for the model and established the requirement set for the construct of the decision model. Existing decision modeling techniques was reviewed against this requirement set to select the most appropriate technique to construct the decision model. The preliminary decision model was then constructed using the selected technique. As the decision model constructed is based upon the analytical synthesis of existing knowledge in the field of manufacturing strategy and best practice research, verification of the model with expert in the field is necessary to ensure the accuracy of the model representation. Subsequently, this model is then validated against real-life industrial scenario through case study research to check for the validity of linkages portrayed in the decision model. Finally, the validated model was captured in a guidebook for industrial application.

10.2 Summary of Research Contribution

The research presented in this thesis makes two principal contributions to knowledge on the subject of manufacturing best practice adoption. Furthermore, in executing the research programme, a number of advances has been made, that are themselves important contributions to knowledge and deserve highlighting. This section summarises both the primary and secondary contribution of this research

10.2.1 Primary research contribution

The novel contribution to knowledge that this research programme has provided is twofold. Firstly, comprehensive and in-depth knowledge has been gained about existing manufacturing best practices and its adoption approaches to formulate a holistic decision model that links best practices to the context of competitive environment. Secondly, a decision model is developed and captured in the form of a guidebook to aid practitioners in the analytical selection of manufacturing best practices. Within each of these categories, a number of findings have been made that can be summarised as follows:

<u>Holistic decision model that links practices to the context of competitive environment</u>

A review of existing manufacturing best practices was conducted through an historical account of manufacturing paradigms (Section 3.2). However, some of these practices are also commonly associated with manufacturing strategies (Hayes and Wheelwright 1984; Skinner 1985; Swamidass and Newell 1987). Thus, linkages were established between manufacturing paradigm, manufacturing strategies and competitive strategies. Through these linkages, a decision framework was constructed that links manufacturing practices to manufacturing objectives to competitive strategies and environment (Section 5.2). The research findings were,

1) A taxonomy for manufacturing best practice that relates practices associated with each manufacturing paradigm, which enables the creation of new customised practices.

2) The association of manufacturing paradigm in the context of competitive environment, which defines the competitive objective to achieve and the competitive strategies supported.

Existing decision modeling techniques were reviewed against the requirement of the decision model (Section 6.2). Though limitations exist for each technique, decision tree was selected as the most appropriate techniques (Section 6.3) and the decision model constructed (Section 6.4). The research findings were,

3) A decision tree that depicts the linkages between industry type, product life cycle, competitive strategy, competitive dimension, manufacturing objectives, manufacturing paradigm and associated key practices.

4) A prescriptive decision aid that provide both the critical decision stages and their linkages to provide the alternatives of competitive choices and manufacturing actions that can be associated with the manufacturing best practices.

<u>Decision support guide to aid practitioners in the analytical selection of manufacturing best practices</u>

The decision model constructed was validated against real-life industrial case studies (Section 8.3) to test the validity of the linkages represented in the model. The research findings from the case study research conducted were,

1) The industry type that a company is in and the product stage of their main product are adequate to define the competitive landscape of the company (Section 8.4.1).

2) Strategic zoning is evident in the competitive landscape defined and there exist an appropriate set of probable competitive strategy with respect to one or more of the competitive dimensions in Price, Quality, Delivery, Flexibility and Service, which a company can choose to compete in the market (Section 8.4.2).

3) Each manufacturing paradigm supports a unique set of objectives that is related to the competitive dimensions. Thus, there exist a best-fit paradigm for a competitive strategic position that a company choose to adopt (Section 8.4.3).

4) A unique set of best practices can be identified with each paradigm in support of the competitive strategic position of the company. This list can be used as guide to assist the analytical selection of manufacturing best practices for adoption (Section 8.4.4).

Finally, a guide that captures the final decision model is presented (Section 9.2). This guide provides a structured and holistic adoption approach to manufacturing best practice adoption by establishing the rationale between internal actions in an organisation and the external performance achieved. It also provides the relative importance of each manufacturing best practices with respect to the strategic goals of the organisation.

10.2.2 Secondary research contributions

In the process of executing the research programme, a number of advances have been made that are themselves important contributions to knowledge. This section highlights these.

1) Taxonomy of manufacturing best practices in terms of manufacturing paradigm (Section 3.2). This provides the evolution and state-of-art of existing best practices as well as the basis that leads to the development of the decision model. The contemporary and comprehensive taxonomy was subsequently developed and constructed for this research programme (Section 5.3). This may now be of further assistance to other researchers who are also considering a structured classification and grouping of best practices.

2) Requirements of a decision model for best practice adoption (Section 5.4). These requirements assess the capabilities of decision modeling techniques against the performance of comparable modeling techniques. Thus, setting the criteria that are perceived to be what practicing managers desired of a decision modeling approach. This requirement set provides an important foundation for future work addressing decision modeling for best practice adoption.

3) Deployment of best practice as a strategic instrument. Explicit to the decision model developed, the linkages established between practices to competitive strategy enable such tool to devise and deploy best practices to achieve the desired strategic goals. Although the decision guide developed (Chapter 9) has not been tested (Section 10.3), important groundwork has been carried out on which future work can be built upon.

10.3 Limitations of the Research

Although this work supports the concept of deploying best practices in support of a strategic goal. This role of best practice has not been widely discussed as evident in the literature review on best practice adoption, thus the research gap that directed this research. A foundation has been provided in this research work on which future research can proceed. However, to do so, this work presented must inevitably receive objective criticism before progression in this subject can take place. Therefore, this section indicates the weakness within both the research programme and the finding presented in this thesis.

10.3.1 Limitations of Research Programme

The research activities have followed the stages of theory formulation, testing and operationalisation of theory, which directly relates to the 3 research objectives presented in Section 4.2. However, there are two issues that need to be highlighted about the manner in which this research has been conducted.

Firstly, it is important to note that the decision model formed is just one of the adoption approaches for best practices. It is not the intent of this research to propone this approach as the best solution for best practice adoption. The research process undertaken has not attempted such proof, rather, the decision model developed have been verified as contributing to the field of best practice, and are worthy of further development.

Secondly, only eight sets of industrial case studies have been executed as opposed to an industry wide survey of a bigger pool of manufacturing companies. Although the rationale of such approach is to ensure the quality of analysis as explained in Section 8.2, this inductive approach still has its limitation. Inference made with regard to the linkages portrayed in the decision model from a small sample size like this is often subjected to criticism of statistical error in the analysis results. Fortunately, these case studies have been conducted with sufficient rigour to minimize such biases. Nevertheless, this decision model formed is still a coarse prototype and will benefit from extensive validation with more companies. Hence, the final decision model and the guidebook can serve as a basis with which extensive testing can take place for future development.

10.3.2 Limitations of Research Findings

This section identifies prominent concerns that have arisen about the findings gained from executing the research programme.

First, the taxonomy of manufacturing best practice that relates practices associated with each manufacturing paradigm to a set of underlying principles and key mechanisms (Section 5.3) are just one form of classification for best practices. Like many other taxonomies, there is no one best classification for group of subjects. The value in such taxonomic approach is its useful to the user in structuring and organising a system of entities. In the case of this research, it had provided a structure in which the decision model was constructed. On this basis, this research does not claim that the taxonomic approach of manufacturing paradigm is the best way and the most fully suited to classified best practices.

Second, there is a concern that the decision stages portrayed in the decision model may not be the only way that the decision of best practice adoption is formed. True enough, some experts whom were involved in the verification process have raised such concern. However, all experts had also unanimously verified that the decision stages proposed were rationale and sound. It is understood that different individual will have their unique decision-making processes dependent on their technical and cultural background. Therefore, to prescribe a one solution for all process will often subject to criticism of exclusion in some decision variables or stages. Whilst this decision process is felt to be justified, this process should be a subject to be addressed by future research.

Third, there are always concerns for the rigour of case study research and thus also the concern for the validity of the findings concluded in Chapter 8. Indeed, some of the case studies have both validated and invalidated a similar proposition (Section 8.4). However, on close examination of the cases, the reason for the discrepancy was resolved. This is exactly the reason why case study research was adopted instead of survey. Decision modeling is a complex problem and the linkages portrayed in the model are complex. Unidirectional method like surveys are inadequate to capture the full information and knowledge required in understanding the phenomenon. Therefore, case study research is still the most appropriate method for validating the model and the findings concluded are results from a sound and rigorous research methods.

Finally, it is important to caution that this body of research has not been an attempt to replace existing adoption approaches like benchmarking. Rather, the intention is to assist practitioners in addressing the strategic aspects of best practice.

10.4 Directions for Future Research

As discussed above, this research is considered to be an essential preliminary step to apply best practice as an strategic instrument, and a significant foundation and progression has been made in the analytical selection of manufacturing best practices in relation to the competitive strategy of the company. This section identifies the direction that future work should take to support the progress of research in this area.

First, concerns have been raised both on the case study research methodology adopted and the validity of findings in Chapter 8. Despite the rigour exhibited in the conduct and analysis of the case studies, biases and errors in the analysis of such a small sample size is unavoidable. In fact, the results will be subjected to other forms of error even if another research method is adopted. Nevertheless, a final decision model was validated and applied to a decision support tool for industrial application. Thus, one direction of the future work would be the continual testing of the decision model and tool against other companies to validate the robustness of the linkages portrayed.

Second, on the subject of continual testing, the decision support was not subjected to any form of testing in industry setting against the criteria of feasibility, usability and usefulness, which are regarded as critical importance for such development of process research (Platts, 1993). However, it is not the focus of this research to fully test and operationalise the tool develop. Rather, this research is a preliminary step towards the development of such tool. Therefore, the rigorous testing of the decision support tool developed would be another direction for future work.

Finally, the decision support tool developed has prescribed generic key mechanisms to aid the selection of best practices. As with all form or generic tools, they are meant for a general pool of users as a beginner guide to the subject matter. Mis-interpretation of the mechanisms described is also highly possible especially when this tool has not been subjected to rigorous testing for application in the industrial settings. Therefore, to further benefit the practitioners, industry-specific research work to extend and tailored built a set of industry specific practices into such tools would prove to be valuable for unseasoned practitioners. This will simplify the selection process by removing the guesswork and interpretation expected. Hence, the next direction of future works.

10.5 Concluding Remarks

This concluding chapter has given accounts of the primary and secondary research findings and contributions against the research aim and objectives. The limitations of the research have been identified and led to the recommendations for future works suggested. This research has made a novel and significant contribution to the body of knowledge on best practice and its adoption. It is hoped that the outcome of this research will make the similar contribution in practice.

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Appendix A: Description of Decision Modelling Techniques

Three Decision Modelling Techniques are shortlisted for testing in Chapter 6. They are Decision Tree (DT), Analytical Hierarchical Process (AHP) and Discrete Event Simulation (DES). These techniques will be detailed in this Appendix.

A.1 Decision Tree (DT)

A decision tree is a decision support tool that uses a graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility (Yuan and Shaw, 1995). It is used to identify the strategy most likely to reach a goal as well as a descriptive means for calculating conditional probabilities. Decision trees are goal oriented forecasting methods, which provide roadmaps, or networks for reaching selected future goals (Novosad, 1982). Sometimes, they are also referred to as logical trees and are created specially for one kind or type of problem. This technique is often very useful in guiding actions under highly routine, but multi-directional conditions.

A decision tree can be used for data exploration in one or more of the following ways:

- To reduce a volume of data by transforming it into a more compact form which preserves the essential characteristics and provides an accurate summary.
- Discovering whether the data contains well-separated clusters of objects, such that the clusters can be interpreted meaningfully in the context of a substantive theory.
- Uncovering a mapping from independent to dependent variables that is useful for predicting the value of the dependent variable in the future.

Works related to the construct and use of decision trees for data description, classification and generalization have exists in a wide variety of disciplines (Yuan and Shaw, 1995). Some examples are its deployment in traditional fields of statistics, engineering (logic synthesis, pattern recognition) and decision theory (decision table programming). Renewed interest for this technique has also been reported recently, which focuses on the research in artificial intelligence (machine learning) and the neurosciences (neural networks).

Amongst all decision support tools, there are some advantages of decision tree that is worth noting. First is its ability to generate value even with little hard data. This is achieved through the insights generated based on experts describing a situation (its alternatives, probabilities, and costs), and their preferences for outcome. Second, this technique can be combined with other decision techniques, for example net present value calculations, to be used to optimise an investment portfolio. Finally, a decision tree is simple to understand and interpret after brief explanation and the results provided can also be easily replicated by simple mathematics, which would minimise the ambiguity issue suffered from the use of natural language in the representation. Despite these advantages, this technique does share a common issue facing most quantitative modelling methods; which is the accurate translation of qualitative attributes to an quantitative value required by the model. For example, the translation of “high likelihood of occurrence” can be interpreted as a probability of 0.99 for some and 0.8 for others. Thus, this subjectivity in judgements needs to be addressed to ensure the accuracy of the model representation.

A.2 Analytical Hierarchical Process (AHP)

The Analytic Hierarchy Process (AHP) method, introduced by Saaty (1980), directs how to determine the priority of a set of alternatives and the relative importance of attributes in a multiple criteria decision-making problem. This technique has also been widely adopted in various field of work. For example, Schniederjans and Wilson (1991) utilized the AHP method to determine the relative weights of attributes and applied these weights to a goal programming model for information system selection. While Lai et al. (1999) had conducted a case study to select a multimedia authoring system using this technique. Since its invention, AHP has been a widely used tool at the hands of decision makers and researchers especially in addressing multiple criteria decision-making problems (Bard, 1986; Hamalainen, 1988; Azis, 1990; Kang and Stem, 1994; Tavana and Banerjee, 1995; Tummala et al., 1997; Zhengling et al. 2003; Tolgo et l., 2005).

AHP is a multiple criteria decision-making technique that employs an eigenvalue approach to the pair-wise comparisons. It also provides a methodology to calibrate the numeric scale for the measurement of quantitative as well as qualitative performances. Through a principle of hierarchic composition, the technique can derive composite priorities of alternatives with respect to multiple criteria from their priorities with respect to each criterion. AHP can also helps to incorporate a group consensus through the provision of questionnaires for the comparison of each element and geometric mean to arrive at the final solution (see Saaty, 1980).

Key characteristic of AHP lies in its provision of consistency vector for the model derived. This is very important for the case of measuring qualitative responses, as inconsistency is inherent in peoples' judgement especially when they are faced with intangible choices. For example if a person needs to quantify his preferences for 3 different cars (Car A, B and C), he will be having a very difficult time to come up with a consistent scoring on his preferences. The reason is because his scale of liking for each car is subjected to a complex mixture of intuition, feeling, rational judgement, and other known and unknown external factors. The scoring he provides today may be different from the one yesterday or the one the week or month before. The fact is that it is natural for human to made inconsistent judgement on intangible choices. AHP resolve such inconsistency through the help of pairwise comparison and ordinal intransitive to fill out the entire judgement matrix to derive at a consistent composite scoring on the true preference of choices.

Despite its strengths in managing qualitative responses and multi-criteria decision problems, AHP do not model stochastic representation explicitly. Instead, it is assume that the preference scoring derived for each choice as an indication or representation of the probabilistic behaviour in the decision making process. For example if a person's preference scoring for car A, B and C are 0.5, 0.3 and 0.2 respectively, then it is assumed that there is 50% chance that this person will choose car A if left to chance. However, this may or may be true depending if this choice is made under bounded rationality. If the decision maker had already resolve his preference scoring before he is asked to make his choice, then it is a 100% chance that he will choose car A over the rest instead of the 50% assumed (because he would have known his choice beforehand). It is also worth noting that such technique derive causal links from the subjective judgement of the assessor rather than the objective observation on the system under investigation. As such, the quality of results obtain is highly dependent on the choice of credible candidates selected. Thus, such rationality and subjectivity in the judgements need to be taken into consideration to ensure the objectivity of the modelling outcome.

A.3 Discrete Event Simulation (DES)

A detailed description of Discrete Event Simulation (DES) is provided by Pidd (1998). Carrie (1988), Law and Kelton (1991), ElMaghraby and Ravi (1992), Roth (1987), and Thesen and Travis (1989). These authors have been generally referenced in the construction of this summary, and should be referred to for a further more detailed description. Part of the description presented here is quoted from Baines (1995).

A DES model model operates through emulating the time dependent behavious of activities within a real system, by acting through equivalent activities in the model. The number of activities in a DES model are usually less than within the real system so as to improve modelling efficiency. Likewise, these activities will be considered to behave in a discrete manner, meaning that activities will start and stop instantaneously even though in reality they may take a short period of time to do so. Model execution time is reduced relative to the real system through considering activities in terms of events that take place at the start and finish of an activity. When a DES model is first executed, events that can be scheduled are placed into an event list, in order of the time at which they will occur. Time is then advanced to the first event, the event is executed, and then removed from the event list. When an event has been executed, this may cause more events added to the list, then once again the time is advanced forward and the cycle repeated. A detailed description of this mechanism is given by Law and Kelton (1991).

Other terms associated with DES are entities, sets, attributes, and states. Entities are mobile components upon which transactions take place, for example, products flowing through a manufacturing system. Sets are mechanism used to group entities in any convenient way, for example, a queue or machine. Attributes are parcels of information attached to entities. Finally, states refer to the condition of elements, such as entities, in a model.

Key advantage of DES lies in its provision of a predictive computational model that mimic the behaviour of the system modelled for What-if analysis. This is very important for off-line experimentation without causing disruption to the real system. However, detailed causality relationships between the entities in the system need to be modelled explicitly and the final model verified and validated to yield quality results. As such, DES required considerable amount of time modelling.

Appendix B: Description of nodes and branches of the Preliminary Decision Tree Model

A preliminary decision tree model is presented in Figure 6.1 in Chapter 6. There are a total of 7 decision layers in this tree. This appendix will present the tabular links between each adjacent layers depicted.

B.1 Industry types and Product Stages

Industry Types	Product Stages			
	Introduction	Growth	Matured	Decline
Fragmented	X	X		X
Emerging	X	X		
Transition to maturity		X	X	
Declining			X	X
Global	X	X	X	

B.2 Product Stages and Competitive Strategies

Product Stages	Competitive strategies		
	Focus	Cost Leadership	Differentiation
Introduction	X		X
Growth	X	X	
Matured		X	X
Decline	X	X	

B.3 Competitive Strategies and Dimensions

Competitive Strategies	Competitive Dimensions				
	Price	Quality	Delivery	Flexibility	Service
Focus	X	X	X	X	X
Cost Leadership	X	X	X		
Differentation			X	X	X

B.4 Competitive Dimensions and Objectives

Competitive Dimensions	Objectives									
	Cost	Conformance	Performance	Speed	Dependability	Volume	Design	Variety	Afetr-sale	Distribution
Price	X									
Quality		X	X							
Delivery				X	X					
Flexibility						X	X	X		
Service									X	X

B.5 Objectives and Paradigms

Objectives	Paradigms				
	Mass	Lean	Time-based	Mass-customise	Agile
Cost	X	X		X	
Conformance	X	X			
Performance		X	X		
Speed		X	X		X
Dependability		X	X		
Volume			X	X	
Design			X		X
Variety				X	X
After-sale				X	X
Distribution				X	X

B.6 Practices and Paradigms

Practices	Paradigms				
	Mass	Lean	Time-based	Mass-customise	Agile
Economies of Scale	X			X	
Resource Specialisation	X			X	
Product Standardisation	X				
Continuous Flow	X				
Centralise Production and Planning	X				

Cost Driven	**X**				
Waste Reduction		**X**			
Continuous Improvement		**X**	**X**		
Lot size Reduction		**X**			
Self-directed Workforce		**X**			
Cellular Manufacturing		**X**			
Cross-functional Workforce		**X**	**X**		**X**
Supplier Integration		**X**		**X**	
Integrated Information System		**X**	**X**	**X**	**X**
Quality Driven		**X**			
Leadtime Reduction			**X**		
Product Customisation			**X**		**X**
Cellular Organisation			**X**		
Customer Involvement			**X**	**X**	
Delivery Driven			**X**		
Postponement Strategy				**X**	
Product Modularisation				**X**	
Flexibility Driven				**X**	
Change Management					**X**
Fluid Cluster of network associates					**X**
Decentralised Organisation					**X**
Focused Core Competency Centers					**X**
Global Network					**X**
Service Driven					**X**

Appendix C: Details of the three sets of Questionnaires used

Three sets of questionnaires are designed for use in the verification and validation process. The first set of 30 questionnaires is designed to assess the competitive orientation of a company's current approach to business with their main products and customers. The second set of 40 questionnaires is designed to assess a company's current achievement and requirement with their main products and customers. The third set of 120 questionnaires is designed to assess a company's current practices in the manufacturing operations. Details of these questionnaires are presented in this appendix.

C.1 Questionnaire Set 1

	STATEMENT	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Our core processes are invention, commercialisation and market exploitation					
2	We achieve a low cost position on product and service support					
3	Our focus is on flexibility and agile manufacturing					
4	We offer great prices and quality					
5	We frequently review our product portfolio					
6	Consumers ask for our product by name					
7	We are experts in our customer's business					
8	We are always on the lookout for new product ideas					
9	Our core processes are end-to-end product delivery and customer service cycle					
10	Important improvement levers for us are process redesign and continuous improvement					
11	Our services provide exactly what our customers need					
12	We have regular meetings to plan for future customer needs					
13	Our products are premium priced, but worth it					
14	We believe in solving the client's broader problem					
15	We build a better product, for which customers will pay more					
16	Our company is recognised as a provider of leading products					
17	We understand (can quantify) how changes to our service offer will benefit our customers					
18	We believe that variety kills efficiency					
19	Our products last and last and last					
20	Our company is recognised as a provider of best total cost					
21	Important improvement levers for us are problem expertise and service customisation					
22	We believe in cannibalising our success with breakthroughs					
23	We are a no-hassle firm					
24	Our core processes are client acquisition and development, and solution development					
25	We actively pursue lean and six sigma manufacturing capabilities					
26	Consistency is our middle name.					
27	We actively collect performance feedback from our customers					
28	Our company is recognised as a provider of best total solution					
29	It's important for us to know what's hot and what's not					
30	Important improvement levers for us are product technology, time to market and R&D cycle time					

C.2 Questionnaire Set 2

	STATEMENT	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	We only sell standard products					
2	We design and built our product to customers' specifications					
3	We operate in a niche domestic market					
4	Our customers know what they want or need					
5	Price competition is dominant in our market					
6	Our product range is small and focused					
7	Our customers want instant availability					
8	Our products are only distributed to domestic market					
9	We charge a premium for our products					
10	Our customers are willing to wait					
11	We have very little rejects or returned products from our customers					
12	We deliver instantly and fast					
13	Most of our customers are regular					
14	Our products are best in class in the industry					
15	Our customer orders are unpredictable					
16	Most of our customers are 1st time buyers					
17	Our customers are looking for state-of-the-art products					
18	Our customers expect our product to conform to the product specification closely					
19	We take in order of any size					
20	Our customers look for customised solutions and products					
21	We are seldom late on delivery					
22	Our time to deliver is longer than what we desire					
23	We find it unnecessary to provide after-sale customer support and maintenance					
24	Our customers want no-frill products					
25	Our customers accept postponement of delivery date					
26	We operate around the world					
27	We offer one of the lowest priced products in the market					
28	We offer large number of product variety					
29	We only accept orders of a certain minimum quantity					
30	We experience some difficulties in meeting our delivery dates					
31	Our rejects or returned products is higher than what we desire					
32	Our customers only buy standard products from us					
33	We offer good after-sale customer support and maintenance					
34	Our demand is stable and predictable					
35	Our products are distributed worldwide					
36	Our customers come to us for variety and choices					
37	Our customers are not very particular about the product quality					
38	We compete on other criteria other than price					
39	Our customers expect compensation for late delivery					
40	Our products is not the best but it has its market					

C.3 Questionnaire Set 3

	STATEMENT	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	A lot of our products shared common parts or components					
2	Our products design are modular which allow mix and match for variety					
3	Our workers are only trained to perform a single type of task					
4	The task to be performed by a worker is simple					
5	Our workers are trained to perform different type of tasks					
6	The task to be performed by a worker required special training					
7	Our workers do rotate between different tasks to be performed					
8	Our workers only perform one task unless instructed to change					
9	We try to maintain similar daily production outputs					
10	We try to maintain similar weekly production outputs					
11	We try to maintain similar monthly production outputs					
12	Our production output is lower than our demand					
13	We are producing at maximum capacity					
14	We understand and practice production smoothing					
15	We even out the required production quantity equally over the days and weeks					
16	Our inventory level is higher than what we desired					
17	Our inventory level is low					
18	We understand and practice Just-in-Time (JIT)					
19	We understand about just-in-time but do not practice it					
20	We understand about just-in-time but think that it is unsuitable for us					
21	We keep inventory for just-in-case situation					
22	Our production flow is continuous					
23	Our production flow is paced and controlled					
24	We map out our processes for documentation					
25	We map out our processes for changes					
26	We map out our processes to identify which steps to remove					
27	We always tries to find out the root cause for our problem					
28	We are only concern about getting the problem fixed only					
29	We actively changes the price of our products according to their demand					
30	We price our products according to the market price					
31	We price our products according to our cost price plus a profit margin					
32	Our production machines or equipment are multi-purpose					
33	Our production machines or equipment are can process different products					
34	Our production machines or equipment are can only process one type of product					
35	We have different machines or equipment for different products					
36	We constantly reduces out scrap or reject rate					
37	Our scrap or reject rate is higher than what we desire					
38	Our scrap or reject rate is low					
39	We believe that process is the problem and not people					
40	We believe that quality is the responsibility of every employee					
41	Every employee can raise suggestion to improve quality					
42	We can be better than what we are now					
43	We believe that all problems can be prevented					
44	We understand and practice flexible manufacturing system					
45	We only accept standard work					
46	We provide high-level of customisation for our customer					
47	We have a high mix in our product produced					

C.3 Questionnaire Set 3 (cont.)

48	We only focus on producing a few key standard products					
49	We constantly measure ourselves against our competitors					
50	We are better than our competitors					
51	We are not performing as well as what we desire					
52	We work very closely with our suppliers					
53	We only work with a few key suppliers					
54	We buy from any suppliers who offer us the lowest price					
55	We share production information with our suppliers					
56	We are very involved in our supplier's business					
57	Most of our quality improvement action originate from the shopfloor personnel					
58	We understand and practice group technology					
59	We group similar items to simplify design					
60	We group similar items to simplify manufacturing and business processes					
61	All production planning and scheduling are done centrally					
62	Production planning are done centrally but scheduling are left to the individual section or function manager					
63	All production planning of our production facilities are done centrally					
64	Each production facility plans for themselves					
65	We have multiple production facilities					
66	Each production facility produces vastly different products					
67	Each production facility produces similar products					
68	We understand and practice focused factory					
69	We understand and practice Kanban/pull system					
70	We produce to forecast					
71	We produce to actual order					
72	We constantly looking for ways to reduce our set-up times					
73	Our performance are measured by the quantity of products we can produce					
74	Our performance are measured by how fast we can deliver an order					
75	We do not have any performance measurement system in place					
76	We understand and practice concurrent engineering					
77	We form cross-functional teams to work together for the whole product development process					
78	All functional departments only works within themselves					
79	We understand and practice rapid prototyping					
80	We use computer aided design (CAD) tools or softwares					
81	Rapid prototyping is unnecessary for our business					
82	We practice the analysis and re-design of workflows and processes in our organisation					
83	We understand business process re-engineering (BPR) and practice it					
84	We conduct our business online via the internet					
85	We are linked to our suppliers electronically to share critical information					
86	Information Technology (IT) is key to our business					
87	We have install an Enterprise Resource Planning (ERP) system					
88	We understand and practice cellular manufacturing					
89	Our workstations, machines or equipment are arranged in a group or cell dedicated to a sub-component					
90	Our workstations, machines or equipment are arranged in a group or cell dedicated to a product					
91	Our workstations, machines or equipment are arranged in accordance to their functions similarity					

C.3 Questionnaire Set 3 (cont.)

92	Every employee have the opportunities to suggest and make changes for improvement					
93	We work in self-directed teams					
94	We form teams that consist of cross-functional people					
95	We form partnership with our suppliers readily					
96	We form partnership with our customers readily					
97	Our partnership with our suppliers are long-term					
98	Our partnership with our suppliers are short-term					
99	Our partnership with our customers are long-term					
100	Our partnership with our customers are short-term					
101	We understand and practice outsourcing					
102	We do not produce the whole product ourselves					
103	Our main activities are assembling semi-finished parts together to produce the final product					
104	We design for our customer					
105	We do not design but accept design from our customer					
106	We share production information with our customers					
107	Our customer are very involved in our business					
108	We know our suppliers' business					
109	We know our customers' business					
110	We collaborate with our competitors to share cost					
111	We design our product for final customisation at customer end					
112	We produce generic or family products that is later differentiated into a specific end-product					
113	We constantly invest and acquire our suppliers					
114	We experience constant vertical integration					
115	We constantly invest and acquire our customers' businesses					
116	We constantly invest and acquire our competitors' businesses					
117	We constantly invest and acquire our suppliers' businesses					
118	We do not produce in batches					
119	We can switch our production between different products with minimal setup time and cost					
120	We understand and practice one-piece flow					

Appendix D: Contrast of the 4 Product Stage

Probable course of industry evolution can be predicted through the concept of product life cycle. as evident in the some of the industry types described in previous section. Figure 9.3 portray the typical 4 stages (introduction, growth, mature and decline) of a product life cycle and the rate of growth of industry sales of the product. This rate of growth reflects the buyer behaviour, product configuration, and competition profile which will characterise the manufacturing requirement and set the priorities on the capabilities that the manufacturing function needs to fulfill in meeting the requirement. These priorities will form the manufacturing objectives or goals for the manufacturing function. The 4 stages of the product life cycle will be discussed to contrast these requirements in this appendix.

D.1 Introduction

Introduction stage is the start of the product life. The product is very new and the buyer inertia is very high. Therefore, the take-up rate on the product is very low which explains the slow rate of industry growth. Buyer group in this stage is also very small as they are the early adopters whom are typically the high income purchasers and thus not price-sensitive. These buyers are looking to be the first few to own this product which will set them apart from the masses.

As the product is new, product quality is not consistent. Product design and development is essential as frequent design changes is expected as the product progresses through this early stage of its life. Product typically is customised for a niche market which explains the many product variations in low volume with no standards.

There tends to be fewer competitors at this stage because of the size of the niche market which the product is targeting as well as the perceived uniqueness the product portrayed. However, fewer competitors for the same product do not mean that there is no competition. The product needs to achieve market penetration by attracting buyers whom might otherwise purchase other products that may or may not be similar to it.

D.2 Growth

As the product gain market penetration and awareness with the market, sales will increase by volume as new buyer groups begin to purchase the product. The product now is in the growth stage of the life cycle. The profile of buyer group also widens and the product now needs to target at the mass market. The steep rate of growth in figure 7 portrays the big jump in volume.

Quality of the product is more consistent as the production ramp-up. Design changes are also necessary to manage the complexity and improve the reliability and manufacturability of the product to accommodate the increase in volume. Standardisation is also necessary to achieve the volume required.

The rapid growth will attract many competitors to the market. Early producer can capitalise on experience curve gain to achieve cost advantage as well as quality superiority over it competitors. In order to achieve the economies of scale required, mergers and acquisition is predominant.

D.3 Matured

After the rapid growth, the market will eventually reached saturation which signifies the mature stage. Majority of the mass market would have already purchased the product and new purchases are generally from repeated buyer. Repeat buyers are also more knowledgeable about the product and thus more discerning and price-sensitive.

Product quality and price is of the outmost importance at this stage because of the buyer profile. Therefore standardisation is the key to trade-off variety in order to consolidate existing volume to maintain the economies of scale. After-sales service is also more important as the existing pool of user is large and new sales are slow.

Price competition is intense at this stage. Early producer who are able to acquire the cost advantage through economies of scale will use this advantage and it acquired financial strength to oust out smaller competitors in the market. New entrants to the market are low as prices tend to fall, which means lower profits and margin for new producer. Demand is relatively stable at this stage.

D.4 Decline

Product is near the end of life at this stage. It is usually unlikely to have new buyers. Repeated sales to existing buyers are also low. Buyer tends to be looking for substitution for the product. Product can remain at this stage for as long as its functionality is not substituted.

Typical products at this stage are of an older technology facing obsolescence or have become a commodity. No product differentiation exists and the product only competes on price. After-sale service at this stage is also not sustainable because of the risk of obsolescence and the decreasing market size as existing owners leaving the market.

Competition is low as many competitors divest and exit the market. Margins continue to fall and further cost reduction is required for the continual production of the product to be viable. No new competitors are likely to enter this market.

Appendix E: Checklist to determine the Product Stages

Checklist presented in this appendix can be used to determine the stage of the product in its life cycle.

I1 ☐ Product is at the start of its life
I2 ☐ Buyer is price-insensititve
I3 ☐ Sales volume is low
I4 ☐ Product is unique
I5 ☐ High level of customisation is necessary
G1 ☐ Rapid growth of sales volume
G2 ☐ Product is selling to mass market
G3 ☐ Many new competitors entering the market
G4 ☐ Increase in the channels of distribution
G5 ☐ Merger and acquisition is predominant
M1 ☐ Market saturation
M2 ☐ Increasing sales to repeated buyers
M3 ☐ Intense price competition
M4 ☐ Stable demand
M5 ☐ New entrants are low
D1 ☐ Product obsolescence is high
D2 ☐ Decreasing market size
D3 ☐ Many competitors exit market
D4 ☐ Little or no new competitors entering market
D5 ☐ New technology threatens substitution

I1 – I5 : Introduction
G1 – G5 : Growth
M1 – M5 : Mature
D1 – D5 : Decline

Appendix F: Contrast of the 5 Industry Types

Industry environments differ most strongly in their fundamental strategic implications along a number of key dimensions,

- Industry concentration;
- State of industry maturity;
- Exposure to international competition.

Five generic industry types are selected on the basis of these dimensions for in-depth consideration. In each of these environments, the crucial aspects of industry structure, key strategic issues and characteristic strategic alternatives are identified. Competitive strategies for each of the industry type are then developed.

F.1 Fragmented

Fragmented industry is an industry in which no firm has a significant market share and can strongly influence the industry outcome. Usually fragmented industries are populated by a large number of small- and medium-sized companies, many of them privately held. The essential notion that makes these industries a unique environment in which to compete is the absence of market leaders with the power to shape industry events.

Industries are fragmented for a wide variety of reasons, with greatly differing implications for competing in them. Some industries are fragmented for historical reasons because of the resources or abilities of the firms historically in them. However, in many industries there are underlying economic causes, and the principal ones are as follow,

- Absence of economies of scale or experience curve
- High transportation costs
- High inventory costs or erratic sales fluctuations
- No advantages of size in dealing with buyers or suppliers

- Diseconomies of scale in some important aspect, e.g low overhead, diverse product line, close local control, personal service etc.
- Diverse market needs
- High product differentiation
- Exit barriers
- Local regulation
- Government prohibition of concentration
- Newness

Two key strategic moves in this industry type are to overcome fragmentation through consolidation or to cope with the fragmentation by matching the firm’s strategic posture to the particular nature of competition. Overcoming fragmentation can be a very significant opportunity to achieve high pay-off by driving out the small and relatively weak competitors. Common approaches to consolidation are,

- Create economies of scale or experience curve
- Standardise diverse market needs
- Make acquisitions for a critical mass
- Recognise industry trends early

However, this consolidation strategy is not always possible especially when the reasons for fragmentation are not fundamentally an economic one; e.g., the lack of resources or skills in the firm, complacency of firm, and the lack of attention for the opportunity for consolidation.

In many situations, industry fragmentation is indeed the result of underlying industry economics that cannot be overcome. In such situation, coping with the fragmentation would be the strategy to survive and thrive in this competitive environment. Common approaches to deal with the nature of competition in this industry type are,

- Tightly managed decentralization through intense coordination, local management orientation, high personal service and close control.

- Adopting the strategy of designing an efficient and low-cost standard facility at multiple locations.
- Increasing the value-add on the products or services provided as oppose to commodities that are common in this industry type.

Specialising on particular product type or segment to achieve some bargaining power with suppliers through developing a significant volume of a product. Other specialisation by customer type, order type or geographical area are also viable options

F.2 Emerging

Emerging industry are newly formed or re-formed industries that have been created by technological innovations, shifts in relative cost relationships, emergence of new consumer needs, or other economic and sociological changes that elevate a new product or service to the level of a potentially viable business opportunity. Emerging industries are created all the time with some the invention like video games, fiber optics, personal computers, telecommunication technology etc. The essential characteristic of this industry is the absence of the rules of the games which presents both risks and opportunities to firm who could manage and prosper under them.

Common structural factors characterises this industry type. Most of them are related either to the absence of established bases for competition or other rules of the game or to the initial small size and newness of the industry. For example,

- Technological uncertainty
- Strategic uncertainty
- High initial costs but steep cost reduction
- Embryonic companies and spin-offs
- First-time buyers
- Short time horizon
- Subsidy

Emerging industries usually faces limits or problems, of varying severity, in getting the industry off the ground. Some of these problems are, the inability to obtain raw material and components, periods of rapid escalation of raw materials prices, absence of infrastructure, absence of product or technological standards, perceived likelihood of obsolescence, customer confusion, erratic product quality, image and credibility with the financial community, regulatory approval and high costs.

Formulation of strategy in emerging industries must cope with the uncertainty and risk of this period of an industry's development. The rules of the competitive game are largely undefined, the structure of the industry unsettled probably changing, and competitors hard to diagnose. However, the strategic degrees of freedom are the greatest and when leverage from good strategic choices is the highest in determining performance. Possible strategic moves are,

- Shaping the industry structure by setting the rules of the game in areas like product policy, marketing approach, and pricing strategy.
- Induce substitution and attracting first-time buyers by promoting standardisation, police substandard quality, and present consistent front to the suppliers, customers, government, and the financial community.
- Changing the role of suppliers and channels as early exploitation of these changes in orientation can give firm strategic leverage.
- Finding new ways to defend the firm's position and not rely solely on things like proprietary technology and unique product variety which it had succeeded in the past.

F.3 Transition to Industry Maturity

As part of their evolutionary process, many industries pass from periods of rapid growth to the more modest growth of what is commonly called industry maturity. Industry maturity does not occur at any fixed point in an industry's development, and it can be delayed by innovations or other events that fuel continued growth for industry participants. Transition to maturity is always a critical period for companies in the industry as it is a period during which fundamental changes often take place in companies' competitive environment, requiring difficult strategic responses. These responses often hold implications for the organizational structure of the firm as well as the role of it leadership.

Transition to maturity usually signals a number of important changes in an industry's competitive environment. Some of the probable tendencies for change are as follows,

- Slowing growth with the increase is competition for market share
- Increasing selling to experienced and repeated buyers
- Shift of competition towards greater emphasis on cost and service
- Slower rate of capacity addition in the industry as well as overcapacity
- Slower rate of new products and applications
- Increasing international competition
- Fall of industry profit as dealer's margins fall

Rapid growth tends to mask strategic errors and allow most companies in the industry to survive and even to prosper financially. However, strategic sloppiness is generally exposed by industry maturity forcing companies to confront, often for the first time, the need to choose a strategic orientation. Possible choices are,

- Sophisticated cost analysis through rationalizing the product mix and changing the pricing methodology.
- Process innovation and design for manufacture to facilitate lower cost of manufacturing and control.
- Increasing the scope of purchases by existing customer through incremental sales of peripheral equipment and service, upgrading product line, widening the line etc.
- Purchase of cheap assets to improve margins and create a low-cost position if the rate of technological change is not too great.

- Selection of buyers who do not exercise their bargaining power or have less power due to limited product availability.
- Identification of market segment with different cost curve that is advantages the firm's cost base.
- Competing internationally for new markets where the product is relatively new.

F.4 Declining

Emerging industry described here are those that have experienced an absolute decline in unit sales over a sustained period. Thus, decline cannot be ascribed to the business cycle or to other short-term discontinuities such as strikes or material shortages. The decline phase of a business is characterised in the life-cycle model as one of shrinking margins, pruning product lines, falling R&D and advertising, and a dwindling number of competitors.

A number of structural factors take on a particular importance in determining the nature of competition in the decline phase of an industry. These key conditions will influence how easily capacity will leave the industry and how bitterly the remaining firms will try to stem the tide of their own shrinking sales. For example,

- Demand uncertainty
- Rate and pattern of decline
- Structure of the remaining demand pockets
- Causes of decline like technological substitution, demographics and shifts in needs
- Exit barriers like liquidation value of assets, cost of exits, interrelatedness to other businesses of the firm, etc.
- Degree of vertical integration with other business of the firm
- Volatility of rivalry

Typical strategic prescription for decline is a “harvest” strategy that eliminates investment to generate maximum cash flow from the business, followed by eventual divestment. However, in-depth study had revealed a range of strategic alternatives for this industry type which include adopting a leadership position to creating or defending a niche other than harvest and divest strategy. These strategic approaches are described below,

- Leadership – Seek a leadership position in term of market share. Aim at being the only firm or one of the few firms remaining in the industry. Such move requires competitive actions in pricing and marketing, acquiring market share of competitors, and raising the stakes for other competitors to stay in the business.
- Niche – Create or defined a strong position in a particular segment. Aim at reducing competitors’ exit barrier or reduce the uncertainty concerning this segment.
- Harvest – Manage a controlled disinvestment, taking advantage of strengths. Common tactics include reducing the number of product models, shrinking the number of channel employed, eliminating small customers, eroding service in terms of delivery time (inventory), speed of repair, or sales assistance.
- Divest Quickly – Liquidate the investment as early in the decline phase as possible.

F.5 Global

A global industry is one in which the strategic positions of competitors ub major geographic or national markets are fundamentally affected by their global positions. Global industries require a firm to compete on a worldwide, coordinated basis or face strategic disadvantages. However, a firm need not compete internationally to be successful as the extend of the strategic advantages that accrue to firms that compete internationally can vary a great deal from industry to industry.

Fundamentally, an industry becomes a global industry because there are economic (or other) advantages to a firm competing in a coordinated way in many national markets. Sources of global competitive advantage are,

- Comparative advantage like producing in low cost country and export to other parts of the world
- Economies of scales from the size of major national markets
- Global experience to shorten the experience curves
- Logistical economies of scales from global networks
- Marketing economies of scale through the spreading of fixed advertising cost over many national markets
- Economies of scale in purchasing through the increase in bargaining power or lowering suppliers' cost in producing long run
- Economies of scale in R&D by gaining technological advantage over less advance national markets
- Mobility of production through the sharing of skilled resources like people or mobile equipment.

Competition in global industries presents some unique strategic issues compared to domestic competition. A number of basic strategic alternatives are proposed. The fundamental choice for a firm in this industry type is whether it must compete or whether it can find niches where it can build a defensible strategy for competing in one or a few national markets. These alternatives are,

- Broad line global competition – To compete worldwide in the full product line of the industry. Implementing this stategy requires substantial resources and a long time horizon
- Global focus – Create or defined a strong position in a particular segment. Aim at reducing competitors' exit barrier or reduce the uncertainty concerning this segment.

- National focus – Take advantage of national market differences to create a focused approach to a particular national market that allows the firm to outcompete global firms.
- Protected niche – Seek out countries where governmental restraints exclude global competitors by requiring a high proportion of local content in the product, high tariffs, etc. Place extreme attention on the host government in order to insure that protection remains in force.

Appendix G: Checklist to determine the Industry Types

Checklist presented in this appendix can be used to determine the type of industry the company is in.

- F1 ☐ No firm with significant market share
- F2 ☐ Large number of small and medium-sized companies
- F3 ☐ Absence of market leaders to shape/influence the industry
- E1 ☐ Newly formed or re-formed industries created by technological innovation
- E2 ☐ Emergence of new consumer needs
- E3 ☐ Social of economical changes creates potentially viable business opportunities
- E4 ☐ No rules of the game
- T1 ☐ Evolutionary stage from rapid growth to modest growth
- T2 ☐ Period of changing competitive environment which requires difficult strategic responses
- T3 ☐ Changes required on organisational structure of the firm and the role of its leadership
- D1 ☐ Decline in unit sales over a sustained period
- D2 ☐ Slow economic growth, high product substitution, rapid cost inflation, and technological change
- D3 ☐ Shrinking margin, pruning product lines, falling R&D and advertising, and declining no. of competitors
- D4 ☐ Product reaching the end phase of its life cycle
- G1 ☐ Competitors in major geographic or national markets
- G2 ☐ Firms have operations in many countries
- G3 ☐ Wide pool of potential entrants and a broad scope of possible substitutes
- G4 ☐ Diversification in firm's goal and personalities as perception of strategic importance differ

F1 – F3 : Fragmented Industry
E1 – E4 : Emerging Industry
T1 – T3 : Transition to maturity
D1 – D4 : Declining Industry
G1 – G4 : Global Industry