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A METHODOLOGY FOR ASSISTING MANUFACTURING ORGANISATIONS TO IMPLEMENT AGILE MANUFACTURING

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Hossein Sharifi

Manufacturing Engineering and Industrial Management,

Department of Engineering

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ABSTRACT

Throughout the history enterprises have always had to deal with continuous changes in their business environment in order to remain competitive. Since 1990s and towards the 21st century, business environments for manufacturing enterprises have become increasingly turbulent, characterised with relentless changes and uncertainties leading to emergence of a new era in business.

As a result the conventional paradigms of manufacturing business have been questioned for their viability. The main issue in the new era of manufacturing management is the ability to cope with and survive unexpected changes, and to take advantage of changes as opportunities.

A new paradigm known as "agile manufacturing" has been promoted by academia as a means for surviving and prospering in a dynamically changing environment. There is however a lack of a cohesive understanding in the literature as to how individual organisations should go about implementing agile manufacturing

This research has focused on studying and exploiting the concept of agile manufacturing aiming at :

1. Developing and validating a conceptual model for understanding and implementing agility and hypotheses associated with the conceptual model based on the realities and real needs of the manufacturing industry.
2. Developing a methodology to assist manufacturing companies to implement agility in their organisations.

The research was conducted through; an extensive literature review; a UK based industrial survey to study the concept in the real world and to validate the proposed conceptual model for agility and its related hypotheses; and case studies to provide further validation for the conceptual model, enhance and deepen the achieved results, and provide more detailed information for the formulation of the methodology. A conceptual model for agile manufacturing and a preliminary methodology for implementing agility in manufacturing organisations were developed. The proposed methodology, which is developed based on the conceptual model for agility, is devised with some decision supporting tools including an assessment tool for agility, and a strategy building tool for identifying the strategic capabilities and the providers (practices) required to address the evaluated changes in a company's business environment. A preliminary attempt has been made to verify the validity, and examine the application of the proposed methodology in manufacturing organisations.

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CHAPTER ONE

INTRODUCTION TO THE RESEARCH

1.1 INTRODUCTION

This chapter will provide a general overview of the research. The discussion includes the backgrounds of the research, the problems to be addressed, the aims and objectives of the research, questions to be answered, and the methodology employed to perform the research. A summary of the chapter will conclude it.

1.2. EVOLUTION OF BUSINESS SYSTEMS AND THE EMERGENCE OF A NEW ERA

As we are approaching the 21st century, manufacturing success and survival are becoming more and more difficult to ensure. This fact is rooted in the emergence of a new business era that has "change" as one of its major characteristics.

Change in business environment and uncertainty have entered management studies and research for a long time. Thompson [1967] argued that one of the most important tasks for organisations is to manage uncertainties. Drucker [1968] described the concept of entrepreneurial task as the search for changes, response to changes, and exploiting changes as opportunities.

Turbulent times and uncertainties in the business environment have been recognised as the cause of most failures in manufacturing industry [Small and Downey, 1996]. Fast and dramatic changes in technology, especially in the field of electronics, were the core concerns in late 1960s and during 1970s, which then extended to other aspects of business economy both in terms of scale and scope in the past two decades. These aspects include market, competition, customer requirements, social factors, etc. that have been subject to relentless and overwhelming changes. Such changes, which had already resulted in tireless evolution of business systems and the creation of new manufacturing and management philosophies, are shown to be occurring faster and more unexpectedly in recent years than ever. The perceived radical changes have

made ground for the emergence of a new business era beyond the traditional systems such as mass production or even lean production.

Competition basis, which used to be the product's price, has moved to quality, delivery time, and finally customer choice or in a more exact way, customer satisfaction. The prevailing strategy of economy of scales has been challenged by the new vision of economy of scope. Mass production systems are being seriously questioned for their viability in challenging the changing nature of the business environment. The new methods that have been used to cure the problems of traditional systems such as Flexible Manufacturing (FM) and Lean Manufacturing (LM) as well as all techniques and tools associated with FM and LM are found insufficient in the way they have been managed and utilised.

The emerging paradigm is agile manufacturing, which in concept is a step forward in generation of new means for better performance and success of business, and in practice is a strategic approach to manufacturing, considering the new conditions of the business environment.

1.3 THE RESEARCH BACKGROUND

From late 1980s to 1990s, and following a widespread economic and political changes across the world, a great amount of efforts have been directed to understanding the roots and causes of the new orders in the world business [Clark and Fujimoto, 1991].

Academic groups and funded research institutes worldwide have carried out research programmes in order to understand and diagnose the roots, causes and effects of the new emerging business circumstances.

Clark and Fujimoto [1991] conducted a five-year study of product development process world wide and reported new forces that drive the new industrial competition. These are known to be: the emergence of intense international competition; the creation of fragmented markets populated by demanding, sophisticated customers; and diverse change in transforming technology. Another outstanding effort that was conducted by a group from Iacocca Institute in USA resulted in a report in

1991[Iacocca Institute, 1991]. The report that soon became a focal point of manufacturing system studies stated that a new competitive environment is emerging which is acting as a driving force for change in manufacturing. The research then introduced a new concept based on its findings, which was called agile manufacturing.

The mentioned works have been supported by a number of studies that generally addressed the subject of change and the ways to cope with chaos and uncertainty. All these works focused on rapid changes in the manufacturing arena and the necessity of employing new visions, and revisiting the traditional philosophies and mindsets. Results of the above-mentioned researches encourage a different approach beyond the conventional ones that can provide manufacturing organisations with the ability to respond positively to, and take advantage of the changing circumstances. This would only be achieved by changing the way manufacturers look at their business, their relationships with customers and suppliers, and their co-operation with competitors [Preiss et al., 1996]. The new mindset required for this purpose should support a new strategic vision beyond the conventional ones, and a move to new dimensions of competition in addition to cost and quality. Surviving and prospering in these turbulent situations will be possible if organisations have the essential capabilities to recognise and understand their changing environments and respond in a proper way to every unexpected change. Opportunistic action in capturing new markets and responding to new customer requirements is another important feature necessary for success in the contemporary business environment.

The opinions on how manufacturing companies could succeed is so diverse that a general consensus could hardly be reached. Emphasis on new priorities of business such as time (achieving speed in delivery and lead time) and flexibility, deploying new technologies (AMT, etc.), methods and tools, utilising information system/technology and data interchange facilities, improving organisational structure and motivating people (knowledgeable and empowered workers), integrating the whole business process, enhancing innovation all over the company, virtual organisation and co-operation, production based on customer order (mass-customisation), etc. are some but a few to name of regularly suggested solutions for increasing the ability of an organisation in responding to change and maintaining the competitive advantage.

In summary it could be said that the main issue in the new area of manufacturing management is the ability to cope with unexpected changes, to survive unprecedented threats of business environment, and to take advantage of changes as opportunities.

According to the initial work in this area such as Iacocca Institute report [1991], Goldman et al [1995], and Dove [1994], agility in concept comprises two main factors. These are:

- Responding to change;
- Exploiting changes and taking advantage of changes.

1.4 THE RESEARCH PROBLEMS

Agile manufacturing that was sometimes mixed up and confused with previous thought schools of manufacturing management such as flexibility and lean manufacturing has been backed for having novel concepts beyond the former remedies. This has happened thanks to the wide concern it received during the past few years, though in place this has been a natural result of the increasing need to resolve problems with the so called remedies and increasing pressures on manufacturing companies in competing for success.

Until now, the proposals towards becoming agile and the characteristics defined for an agile manufacturer are more or less expressed in a Utopian way. Dispersed prescriptions for adopting revolutionised methods and techniques, and restating the ideal or idealistic position for firms as target have constituted the main body of most works in this area. Also as mentioned above, the concept has widely been expressed in terms of the previous manufacturing subjects such as TQM, Lean Manufacturing, Flexible Manufacturing, etc., or even has been reduced to the idea of response time of organisation to market or other stimulating issues especially customer requirements.

The concept was not found to be popular among or accepted by manufacturing organisations in practice as a new and necessary agenda. It was sometimes even thought of as another jargon being spread by the consulting companies and with the least meaning in practice. The work introduced by the initiators, though were claimed to be the results of empirical studies over the real world practices and experiences, did

provide applicable understandings only to a very limited extent which is quite a natural expectation for a newly born concept. The definitions and structures provided by Iacocca Institute [1991] for agile enterprises proposed a new strategic level mindset for organisations in facing turbulence and changes in their business environment. The work, however, did not address the practical sides and implementation issues with regard to agile manufacturing.

Also the major theoretical works following the original one did not dig the concept to sensible practical levels, which could be approached by manufacturing organisations. For instance, Preiss et al [1996], have prompted a new understanding of co-operation as a vital means of survival and prosperity in the new era of business, and have put forward a generic model of approaching agility. The model, as a generic methodological approach to management of business, however, does not incorporate sufficient details and practical guidance towards adopting agility as a characteristic. The remarkable work by Dove [1994-6] which has shed light on the concept of agility and its different aspects and is being referred to by many other works also does not provide the requirements for a practical approach as to what ways would organisations become agile considering their real situation of business.

Considering the above two examples which are among major works in this area, it can be said that no works in this area were reported to address the issue on a subjective and practical ground resulting in practicable methods or methodologies incorporating the transformation of strategies for agility to implementation using appropriate practices.

The above argument is more valid when it comes to the UK manufacturing and the academies observing their behaviour. There was no (official or reported) research work in this area in the UK or European academies when this research was conceived in 1995.

1.5 RESEARCH OBJECTIVES

The preliminary investigations in the subject resulted in the recognition of a lack of a cohesive understanding in the literature as to how individual organisations should go

about implementing agile manufacturing. To address this issue the research has focused on studying and exploiting the concept of agile manufacturing aiming at introducing a methodology for implementation of agile manufacturing in manufacturing organisations.

Main objectives of this research are:

1. to provide a comprehensive conceptual idea of the subject;
2. to identify main factors constituting the concept and relationship between these factors;
3. to develop a methodology for manufacturing organisations to approach the concept in practice;
4. to introduce the methodology to assist manufacturing organisations to adopt agility as a characteristic.

1.6 THE RESEARCH HYPOTHESES

Some hypotheses were considered at the beginning of the work based on the preliminary studies carried out. These are as follow:

- Agility is an ability that manufacturing companies need to have to be able to survive and prosper in the new order of the global business environment.
- Organisations are different in the way they should respond to changing business environment, and their level of agility is a direct function of changes in their business environment, the business environment itself and the company's situation.
- In practice, agility could be achieved through strategic utilisation of business methods, manufacturing and management processes, practices and tools.

1.7 METHOD OF RESEARCH

Considering the problems and backgrounds for the research discussed in previous sections, and based on the conventional and common research methodologies in this area of study a methodology consisting of the following seven main phases was chosen:

- Preliminary investigation
- Literature review

- Preliminary pilot industrial survey and case study
- Developing a conceptual model
- Industrial survey and case studies, and data analysis
- Developing a methodology for assisting manufacturing organisation in achieving agility
- Conducting a preliminary validation of the proposed methodology

A graphical overview of the research methodology is depicted in Figure 1.1 where the research phases are shown in three main blocks.

1.7.1 Preliminary Research

The research was first directed at priorities in the business strategies which some have claimed to have been replaced by time and responsiveness. This starting point was followed by studying the methodologies and methods on which performance time is dependent, such as concurrent engineering. As a result a limited number of publications and articles pertaining to the subject of responsiveness and agile manufacturing were found. The opening of the subject of agile manufacturing to the research raised many new questions which resulted in the initiation of the research agenda (agile manufacturing in practice) during a series of brainstorming with the research supervisor and other academic colleagues.

1.7.2 Literature Review

The review of literature started from development of business systems over the past decades. This was followed by a review of relevant works on manufacturing strategy and priorities, manufacturing philosophies and methodologies, manufacturing methods and techniques, and in particular work related to the concept of agile manufacturing. Chapter 2 provides the full description of the results from the literature survey.

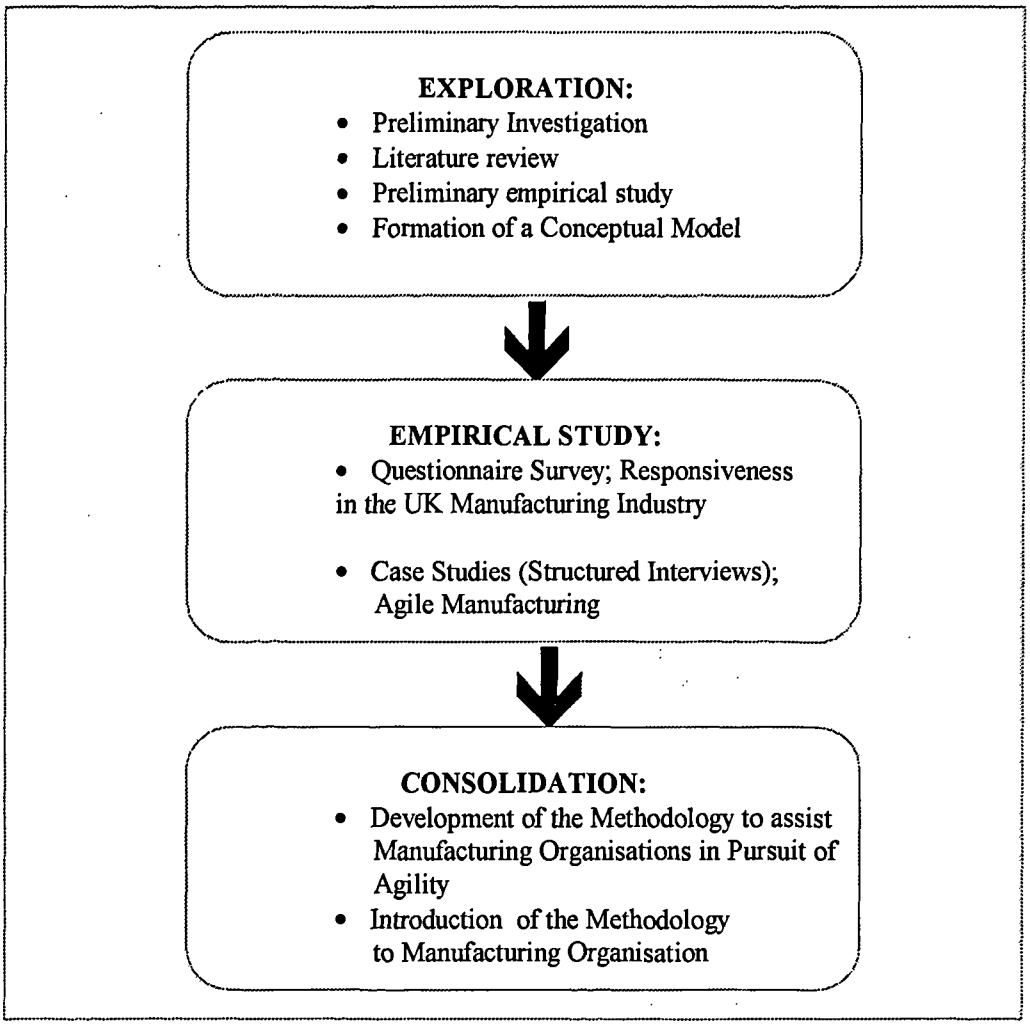

Figure 1.1. An overview of the research methodology

1.7.3 Preliminary Industrial Survey and Case Study

The literature review carried out suggested that there are not sufficient, concrete and comprehensive works in this area of study. In other words the available literature was not found to be supportive enough to establish a conceptual model for agile manufacturing and conduct the determined phases of the research. Therefore, a preliminary industrial study is carried out to provide the required insight and support. The study is conducted through a pilot industrial questionnaire survey and some case studies in the form of semi-structured interviews with some leading and successful manufacturing organisations in the UK. This empirical phase was expected to open the research to the perceptions and realities of manufacturing organisations with regard to the concept of agility. In fact, it was basically quite necessary for the research to understand the stance and perception of the real world of business about the concept, especially in the UK. Also some preliminary identification of the

strategies and strategic movements of manufacturing organisations in response to unpredicted changes, chaos and turbulent situations were expected from this part of the research. The methods of conducting the pilot study, and the results are provided in Chapter 3.

1.7.4 Developing a Conceptual Model

The results from the previous phases were aggregated to provide the necessary building blocks for the establishment of a conceptual model of agile manufacturing, supported by both academic works and real experiences of manufacturing organisations. In fact, the understandings from the literature and academic works in the research area were promoted using the results form the conducted empirical study. A model was developed as a result with which the concept could be exploited and introduced in the form of a practical approach towards becoming agile. The conceptual model comprises three main areas including "agility drivers", which are the changes in the business environment; "agility capabilities", which are the basic and vital capabilities required for becoming agile; and "agility providers (practices)" that are the means by which the required capabilities could be obtained. The model also incorporates integration and powerful support of information systems in the area of "agility providers". In fact, the proposed model strives to transform the fundamental concept of agility, which is "appropriate response to unpredicted or unprecedented changes", to a practical approach. The interpretation of the concept presented in the conceptual model which apprehends the available theoretical basis of agile manufacturing and the realities of the manufacturing business, founds a platform for further investigation of the subject and introduction of a practical approach towards implementation of the concept. The development of a practical approach for adoption of agility in manufacturing organisations is pursued in the form of a methodology which, in general terms, is a generic approach used in the manufacturing management research. The methodology, which is derived from the conceptual model, includes a stage in which the need of organisations for agility and their current level of agility are assessed. To satisfy this purpose, development of an assessment model is found to be crucial for the methodology. Chapter 4 is provided to explain the conceptual model, and discuss the basic structure of the perceived methodology and the assessment model for agile manufacturing.

1.7.5 Industrial Survey and Case Studies

To study, evaluate and validate the developed conceptual model for agile manufacturing and the hypotheses considered in the research, and provide some information with regard to the practical approach towards agility, further empirical studies were carried out. An industrial questionnaire survey of a subset of UK manufacturing companies from three sectors was first conducted. The survey results were analysed statistically based on various methods including cross-tabulation. This provided a preliminary validation of the conceptual model and the research hypotheses. Following the survey a series of in-depth case studies involving 12 selected companies was carried out to provide more examination of the subject and to study the aspects of the research, which were not accommodated by the questionnaire. The employed methods in conducting the empirical studies, and results are described in Chapters 5 and 6.

1.7.6 Developing a Methodology to Assist Manufacturing Organisations in Achieving Agility

A methodology to assist manufacturing organisations in achieving agility, which was among the research objectives, was developed at this stage. The methodology was derived from the developed conceptual model, and as a result of the previous understandings gained from reviewing the literature, and the data and analysis provided in the empirical phases of the research. Based on a brief discussion of the results from the empirical studies the methodology is developed and introduced in chapter 7.

1.7.7 Preliminary Validation of the Methodology

In an attempt to study the practicality of the proposed methodology, two companies from the collaborators of the research were chosen and the methodology was introduced within these two companies. This was conducted based on data already gathered from the case companies during the questionnaire survey, and case study phase. The method and the results of the introduction step can be found in Chapter 7.

SUMMARY OF THE CHAPTER

This chapter provided an introduction to the conducted research including the research background, the problems and questions to be addressed, the assumed hypotheses, and the methodology employed to accomplish the research. The following is a summary of the chapter;

1. A preliminary reference to the literature and original works in the area of manufacturing systems was made first to capture a preview of the subject of the research. As a result some background of the research, the problems to address and the questions to answer were identified. Some discussions are made to address the mentioned issues.
2. As a part of the preliminary understandings it was found that
   - 2.1. There is a need to investigate about how individual organisations could go about implementing agility, and that
   - 2.2. A conceptual model aggregating the different aspects related to the concept, and a methodology based on the conceptual model are needed to assist manufacturing organisations to implement agile manufacturing.
3. The research will focus on studying and exploiting the concept of agile manufacturing aiming at introducing a methodology for implementation of agile manufacturing in manufacturing organisations. Four main objectives are set to be addressed and achieved during the research to satisfy the research aim.
4. Three hypotheses are considered to be studied during the research and their validity be verified.
5. The research will be carried out using a methodology consisting of seven main phases including literature review, industrial survey and case studies, developing a conceptual model and a methodology for implementation of agility in manufacturing organisations.

CHAPTER TWO

A REVIEW OF THE LITERATURE

2.1 INTRODUCTION

This chapter reviews in detail, the literature associated with the subject of the research. The issue of agile manufacturing incorporates a wide range of titles pertaining to the management of manufacturing, so this chapter analyses and reviews the literature to obtain the necessary background to carry out the research in pursuit of the first objective of the research which is to provide a comprehensive conceptual idea of the subject.

The evolution of business environment from the beginning of the industrial age to present has resulted in the emergence of a new era in business, especially in manufacturing. Issues related to the evolution of various aspects of business environment and manufacturing systems are studied first. This has revealed that business environment has turned extremely turbulent, and manufacturing industry has responded to the increasing turbulent environment by revolutionising the concepts, methods, and tools of managing the business. Necessities of competing in the contemporary business environment are also clarified, and answers to questions such as how companies may achieve success in the chaotic world are sought.

A brief history of the emergence of the concept of agile manufacturing, as a new paradigm and a recent answer to the requirements of the new order of the world business is discussed. To provide a basis for a better understanding of agile manufacturing, various recognised work in this area are introduced and critically discussed. Crucial aspects such as the relationship between agile manufacturing and well-known concepts such as lean manufacturing and flexibility, and also the measurement of agility are discussed to reveal areas, which need further investigation. The chapter ends with a conclusion summarising the discussed subjects.

2.2 TURBULENT BUSINESS ENVIRONMENT; EMERGENCE OF A NEW ERA

Change in the business environment and uncertainties have challenged management studies and research for a long time. According to early works in management science, managing uncertainty and searching for changes and responding to changes have been seen as one of the most important tasks for organisations [Thompson, 1967][Drucker, 1968]. The world is experiencing dramatic and accelerating changes in almost every aspect especially in manufacturing.

The issue has received an increasing amount of attention from the research community in recent years [See for example: McCann and Selsky, 1984; Hayen, 1988; Clark and Fujimoto, 1991; Clemson, 1992; Souder and Moenart, 1992; Bessant et al., 1992; Maull et al., 1992; Levary, 1992; Graves, 1993; Warnecke, 1993; Hall, 1993; Burgess, 1994; Sprague, 1995; Kruse and Berry, 1995; Iansiti, 1995; Drucker, 1995; Davis, 1995, Gould, 1997]. The main argument is that businesses are facing a substantially different challenge from those experienced a decade ago. In particular a new competitive environment for industrial products and services is emerging and is forcing a change in manufacturing [Iacocca Institute, 1991]. The issue of emergence of a new era has become a political agenda and even developed nations have started to sense the fear of being beaten by new rivals, and hence losing their economic prosperity. The USA has led the recent exploitation of the situation and has realised that a new business era is emerging. The UK has recently questioned the health of its economy and found that its growth rate is decreasing and its manufacturing industry is losing competitive advantage. A nation-wide industrial survey, which took place in 1994, reported that the main root of this problem is the matter of "change" and the inability of UK manufacturing industry to respond to the increasing rate of change in the business environment [London Business School (Made in Britain), 1993]. The recent major recession and economic breakdown in Far East countries show the growing dangers threatening economies, and manufacturing has become the main sector that is affected [The Institution of Electrical Engineers (UK Manufacturing, facing international change), 1992]. A German author Warnecke [1993], supports the idea by saying that it is the turbulent business environment that has caused a drastic challenge for US and Europe in confronting Pacific nations.

The literature in this subject is unanimous about the arrival of a different business environment that must be taken into consideration in order to make the right decision for future moves. A number of grounds for the upheaval witnessed by business and especially manufacturing are proposed in the literature. They are briefly explained as follows:

1- Widespread growth of scientific and engineering capabilities. Though the uptake of technology has been the main means of global economic development since the 1930's, building a competitive advantage based solely on the development of a unique technology is more difficult than ever [Clark & Fujimoto, 1991].

2- The revolutionary growth and development of electronics and information system/technology, led by Pacific nations. Micro electronics in general and the microchip in particular will become predominant in the 21st century and lead to the birth of a new economic era focused in the Pacific Rim [Warnecke, 1993].

3- Moving from economies of scale to economies of scope. Emergence of new or refined capabilities such as flexibility, rapid response, greater control, reduced waste, better predictability, faster throughput, and distributed processing directly challenge most older assumptions about manufacturing that stem from the notion of economies of scale. These capabilities rest on economies of scope that is efficiencies brought by variety not volume [Goldhar, Jelnik, 1983].

1. It is now believed that the cost-price driven mechanism of economic growth (as the main indicators of economies of scale) is becoming increasingly irrelevant [Ayres, 1990] [Kidd, 1995]. Economists are now discussing the emergence of a new vision of economic growth based on economies of scope [Goldhar and Jelnik, 1983]. The new manufacturing accounting or to say more accurately "manufacturing economies" differs radically from traditional cost accounting in its basic concepts. The new manufacturing accounting (economies) is aimed at integrating manufacturing with business strategy [Drucker, 1990].

4- Focusing on multi-faceted performance requirements. There has been a shift from focus on optimisation of manufacturing performance around cost or quality

objectives [Dussauge et al., 1994]. This has been brought about by changing customer demands for products and services that are increasingly specific to their needs and wants [Gale and Wood, 1994]. Specifically, the products' quality is now a presumption by the customer.

5- Almost nothing is predictable. Peters [1987] in his well-recognised work, reports that out of $80 trillion a year currency-exchange transactions in 1987, only $4 trillion was required for finance trade in goods and services. The rest was essentially currency speculation. The price of most things is volatile. We do not know whether merging or demerging makes sense and who will be partners in future. New competitors and their origins are not clear to us at all. Nothing can be taken for granted.

6- Intensifying of competition. The appearance of more and more competitors capable of world class manufacturing who have become more aggressive is clearly evident. At the same time, according to expansion of world trade, the competition has become more intense, more rigorous, and more aggressive than ever [Clark & Fujimoto, 1991]. Competition and competitiveness has to be a dynamic integrated process [Kidd, 1995]. Imitative competition is swift and profit-destroying [Goldman, et al., 1995].

7- Rapid shift of markets towards fragmentation and more demand. Customers have become more sophisticated and sensitive to differences in a product. They look for the solution to their problems while they presumably expect performance and reliability. As Clark and Fujimoto [1991] express, a new means of setting a firm apart from its competitors in auto industry, is making new products to match the values and lifestyle of consumers at a deeper level. In order to survive today, a company must link into the customers' business or lifestyle processes [Preiss et al., 1996].

2. Customers are no longer satisfied with a trade-off view of values such as quality, cost, delivery, flexibility, specification, etc. [Maire, 1994] [Blackburn, 1991]. On the other side consumer tastes are changing. Whilst the consumers' awareness of

quality is increased, the number of people demanding greater variety is increasing. As a result, demand for products such as TVs and cars is shifting from a desire for the product *per se*, almost regardless of quality, to the demand for customised alternatives with special feature tailored for ever narrower market segments [Peters, 1987].

8- Shrinking product life cycle time. Many businesses have felt the impact of the compression of product life cycle time in both positive and negative ways. Some manufacturers to have their total sales growing have pursued shrinking product life cycle, which is partly a result of marketplace change. However the consequences of this strategy could be harmful in some respects such as its implications on the cash flow in business and the impact of product failure on liquidity [Kidd, 1995] [Von Braun, 1990].

9- Diverse and rapidly changing technologies with a shorter life cycle. New technologies in areas such as materials, electronics, and biology have the capacity to fundamentally change the character of a business and the nature of competition [Clark & Fujimoto, 1991]. The take up of technology available today has allowed the product differentiation demanded by customers [Peters, 1987]. More sophisticated, efficient, faster, cheaper technologies from production machines to design aids and information networks have revolutionised many aspects of today's business [Pier Abetti, 1993].

10- Internationalisation or globalisation of manufacturing. No geographical borders seem to be valid between business transactions. A trend of expansion of multinational companies, including financial and manufacturing organisations, has been observed which is going on faster and faster [Peter, 1987]. Sprague [1995], and Kruse and Bury [1995] also see the globalisation of manufacturing as one of the main issues to be considered in today's manufacturing business. This globalisation of industry is creating new opportunities for manufacturing enterprises and forcing to make new choices management and society [Goldman et al., 1993].

11- Ever increasing pressure from social factors. This includes environmental issues, workforce/workplace problems, legislation, people lifestyle and social contracts on manufacturing [Goldman et al., 1993] [Peters, 1987].

The core argument comprises some main items which are: the rate of change in the business environment is dramatically increasing; uncertainty and unpredictability have become characteristics of change in today's business; and the prevailing theories, methods, systems, and models are not going to satisfy the requirements of the new era.

A new mind-set is needed in order to be able to survive in the new world of business. Drucker [1990] suggests that a new vision in manufacturing theory is needed, and that patching up old theories have not worked so far and doing more of this will only leave us further behind. Hamel and Prahalad [1994] invite manufacturing managers to understand the new circumstances and compete for the future by changing their approaches to managing their business. Some radical proposals for the new form of the business environment have been put forward since the late 1980's. Among these are the Holonic Manufacturing [McHugh et al., 1995], the German Fractal Company [Warnecke, 1993] and the American Agile Manufacturing [Iacocca Institute, 1991], which have all received some attention. Agile manufacturing, in particular, has been noticed widely. Brought forward as the result of a study into USA manufacturing position in the world by a group of scholars and recognised later in USA policies for future, agile manufacturing has started to become a new paradigm in the world of business and especially manufacturing management. The paradigm is considered to be an adjunct to lean manufacturing, and to have a similar impact on different aspects of people's life as that of mass production in the turn of the 20th century. It is also argued that being agile is a condition of survival in the future. [Goldman et al., 1995]

2.3 BUSINESS SYSTEMS EVOLUTION

2.3.1 Evolution of Manufacturing Paradigms

According to Goldman et al. [1995], transitions between different forms of competition experienced so far by human beings are generally characterised by

changing markets and changing technologies, as well as changes in social institutions and business practices. These changes are inseparably and unquestionably intertwined.

Crafts guilds, mercantilism, factory-based production and ***mass production*** are considered by Goldman et al. as the main stages of the industrial revolution throughout the history until mid twentieth century.

After World War II, and by involvement of many experienced scientists in the manufacturing industry, mass production systems started to be refined.

However, the appropriateness of the mass-production paradigm to present and future industrial situations was questioned, as Piore and Sabel [1984] did for example. A new paradigm was emerging that often was highlighted by the need for production systems with flexible specialisation, i.e. the ability to quickly provide low volumes of customised products [Burges, 1994].

The advent of the ***lean production manufacturing system*** presented a substantial challenge to the established mass-production paradigm [Krafcik, 1988][Womack et. al., 1990]. Rooted in Japanese Toyota production system, lean manufacturing was in fact a major refinement of mass production manufacturing. This refinement was aimed at continuous improvement of operations, elimination of waste, and customisation of products to the needs of customers [Womack et. al., 1990]. As exploited by Womack et al. [1990], lean manufacturing in essence, required less of everything compared with the Fordism paradigm. Lean manufacturing was dealing with lower volume and higher variety than traditional mass production to cope with the ultimate need of the market in course of variety [Berggren, 1993].

Another solution to the problems encountered by mass production systems was pursued by manufacturing companies, specifically in Japan, and formed a second phase of Japanese commercial success. Some authors call it as "mass customisation" [Davis, 1987] [Pine, 1993]. This was in the form of offering almost unlimited variety of products to satisfy the requirements of customers. This has led to a new operational environment for manufacturing companies where increasing variety is the order of the day

and manufacturing systems have to be capable of producing "one of a kind" [Browne, 1992].

The evolution of manufacturing systems/paradigms is also addressed by some other authors in different ways. Booth [1996] has put this in a graph as depicted in Figure 2.1. The proposed model introduces an interpretation of the divisions of responsibility that occurred in different stages of the evolution of manufacturing with regard to three factors; economy (low cost), time (responsiveness), and variety (flexibility).

Doll and Vonderembse [1992] have defined the industrial evolution in a different terminology. Table 2.1 represents their proposal of the evolution stages and characteristics of manufacturing system by state of evolution.

2.3.2 "Scope" vs. "Scale"

The prevailing paradigm of economies of scale gave way to economies of scope from the time when manufacturing companies recognised that they could use existing resources to compete in new markets at a little additional expense [Goldman et al., 1995]. Concerns towards the subject of economies of scope arose as the new advances in technology, changes in marketplace circumstances, and changes in customer requirements started to rise. Notions of economies of scale and in particular the notion that greater production volumes display lower unit costs than do lesser volumes, and their viability were seriously questioned This happened due to introduction and practice of new or refined capabilities such as quality in terms of choice of specification, flexibility, time compression and rapid response, and leanness of manufacturing systems. Economies of scope with notions like producing multiple products with the same equipment, yet more cheaply in combination than separately, as brought forward in order to answer the needs to the new emerging circumstances [Goldhar, Jelnick 1983].

2.3.3 Evolution in Business Priorities

Business priorities or value portfolio has evolved along with the historical change and evolution in industrial competition environment. Achieving the lowest price,

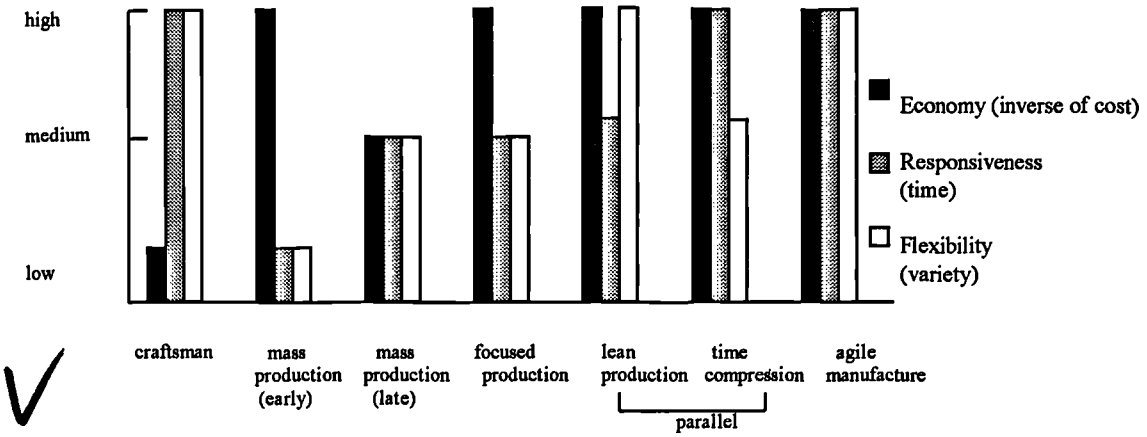

Figure 2.1. Evaluation of Manufacturing [Booth, 1996]

the once major challenge of manufacturers gave way to achieving best quality in the late 1970s and throughout the 1980s. The changing market and shift in customer preferences in favour of quality gave birth to the 1980s quality crusade, which later became a measure of qualification for playing. Flexibility to respond to the requirements of market and customers for variety and customisation was the next issue that was brought up in the new form of competition of the 1980s and early 1990s.

In the 1990s more competitive criteria emerged among which time (delivery time, lead time, first-to-market) received more attention and evolved into new forms such as responsiveness, adaptiveness, productivity. In the new battlefield of competition in today's world, advantage could not be won by adopting only one competitive thrust and concentrating on single priority. A synergy in achieving and exploring the competitive value packages is necessary to accommodate business competitive advantage and win the competition.

To get more insight into the subject the above factors will be explored more in the following sections:

	Craft	Industrial	Post-Industrial
Social system			
Value orientation	Skill	Product	Customer
Norms	Workmanship	Efficiency/productivity	Product development and throughput time
Work system			
Equipment resources	Flexible hand tools	Capital intensive - special purpose	Capital intensive - flexible
Nature of work	Skilled manual work	Unskilled manual work/functionally specialised intellectual work	Information intensive intellectual work
Work group organisation	Task-oriented groupings	Functionally specialised work groups	self-organising and self-directed work groups
Control system			
Performance measures	Customary standard	Single and task specific	Multiple and global
Information systems	Informal and base on learning from experience	Formal information systems to control task execution and co-ordinate sequential activities	Formal and informal systems for control, mutual adjustment and learning
Control mechanism	Craftsman	Hierarchical authority structure	Modified market mechanism (i.e. long term co-operation)

Table 2.1. Characteristics of Manufacturing Systems by State of Evolution [Doll and Vonderembse, 1992]

2.3.3.1 Cost

The rise of the new industrial competition since the turn of the 20th century, later called mass production era, was originally established on large-scale operations and vertical integration. Reaping profit from the high investment costs and the high operational costs was only possible by establishing long, high-volume production runs of uniform (or identical) products [Goldman et al., 1995]. The trend was continued after Word War II when a significant increase in demand and insufficient supply encouraged a massive automation of production processes. The only factor that determined customer preferences was price [Draaijer, 1992]. So manufacturers aimed at a single objective, which was producing in lower prices. As corollaries, mass-marketing forecasts and long product development followed the philosophy of mass production. Later in 1960s, as the market became more demanding, some newly

understood imperatives such as low manual labour, and economies of scale was pursued by adopting more automation [Crowe, 1992].

2.3.3.2 Quality

Shift in the customer expectations from satisfaction with reliable uniform products to gratification from products and services that could match their requirements began to take place rapidly. In practice, what producers, customers, and consumers alike mean by quality evolved [Goldman et al., 1995]. The 1980s quality crusade was conceived as the result of the changes in the market. Quality that was primarily meant reliability, transformed into customer satisfaction. This shaped the first phase of post-World War II Japanese economic miracle [Goldman et al., 1995].

The drive to improve quality led to the introduction and popularisation of concepts such as Statistical Process Quality (SPC), Total Quality Management (TQM), and Quality Function Deployment (QFD).

Beginning in the late 1980s, however quality was no longer considered as a weapon for winning the competitive game, but merely a qualification for attending market [Lorenz, 1989] [Clark, 1989][Ferdows, 1989][Voss, 1990][Goldman et al., 1995].

However, despite this emerging view, many recent studies still show a strong emphasis on quality as the first priority of the business [Ferdows, 1989][Lorenz, 1989]. This is, however, justified as quality is being taken as a presumed priority, which is out of question.

2.3.3.3 Flexibility

The changing circumstances of market and customer demands in the 1960s forced all manufacturing companies to improve their competitive positions. Rigidity of the mass automated manufacturing systems, which was accelerated after World War II to produce unique or uniform products, and a perceived overspecialisation of manufacturing systems, could not stand the increasing rate of demands for more varieties and specialised products. To respond to the rising problem of more demand for specialised products, the concept of flexibility emerged in the 1970's. Two main

reasons for this as reported by Correa [1994] are to cope with uncertainty in manufacturing environment, and to produce variability in outputs. Goldhar [1984] adds truncation of product life cycle and increasing complexity of products to these. Keighobadi and Venkatesh [1994] point to the increased competition, particularly international competition as the main reason behind the new surge of attention to automated form of factory such as Flexible Manufacturing System (FMS). Also Goldhar [1984] considers the emergence of flexibility in manufacturing in the line of development of interest in concept of economies of scope.

Further technological advances especially with regard to computer-controlled production assisted efforts for becoming more flexible and establishing self contained flexible manufacturing system [Baker, 1996]. There has been little disagreement on necessity of moving towards automation of manufacturing process and establishment of such systems as FMS [Buffa, 1984]. Goldhar [1984] argued that FMS can help US economy to recover and bring tremendous advantages to batch manufacturing. Other incentives for implementing FMS include reducing costs in production and adaptability to ever changing environment [Buffa, 1984].

Further studies on flexibility resulted in a broader view of the subject and extended to include management systems. It was stated by Jaikumar[1986] that over emphasising on automation technology and exclusion of management systems could hinder the achievement of flexibility in practice. Lack of a clear and global definition for flexibility has been felt, and studies have been directed to clarifying the concept. Two approaches are recognised by Ettlie and Penner-Hahn [1994], one is to rationalise flexibility of operations under theories of manufacturing scope, and the other is to study flexibility as a dimension of manufacturing strategy. Classification of flexibility as "machine" and "labour" flexibility as proposed by Buzacott [1982] was still insufficient. Slack [1987] undertook a research which resulted in the suggestion of a typology which addressed flexibility in three ways; level, type and dimension. For level of flexibility he found two tendencies, which are total manufacturing system, and individual structural and infrastructural resources. Recent studies have gone farther in extending the rationalisation of flexibility. Aaker and Mascarenhas [1984] have defined flexibility as "the ability of the organisation to adapt to substantial, uncertain

and fast-occurring changes in manufacturing environment that have a meaningful impact on the organisation's performance".

The concept is still a subject of research and practice, and in some circles is taken for the newly emerged concept of agile manufacturing. This will be discussed later in this chapter.

2.3.3.4 Time

In the late 1980s when the scramble for market became very serious and the competition became more and more fierce, it was realised that "time" is on the cutting edge [Stalk, 1988]. Looking at Japanese manufacturing industries' strategies through the perspective of time, Stalk [1988] believes that the shift to time-based competitive advantage represents a logical evolution from the earlier stages. The incredible story of Honda in devastating Yamaha by the introduction of new products raised a question on how such a rapid change could be accommodated. The answer was time-based competitiveness. By conducting structural changes Honda managed to speed up its operations and hence time became a new source of competitive advantage for the company. The concept of time as a competitive advantage has been studied widely since then and practical efforts have been made to materialise the ways to take advantage of time as a competitive weapon. Many studies including works of Collins et al. [1990], Peters [1990], Ebner and Volman [1988], Vessey [1991], Tunc and Gupta [1993], Stalk and Hout [1990], Youssef [1992], Ehie and Stough [1995], Hart and Berger [1994], Vastag et al. [1994], Kumar and Motwani [1995], Daugherty and Pitman [1995], Tersine and Hummingbird [1995], Booth [1996], Ittner and Larcker [1997], Hendricks and Singhal [1997] are based on a consensus that time is the next source of competition in the 1990s. The concept of time-based competition refers to the ability of providing products and services faster than competitors. This can include time to bring new products to market, manufacturing time, and delivery time to customer [Tersine and Hummingbird, 1995]. This is expressed by Stalk [1988], in a different way. He puts time-based manufacturing, time-based sales and distribution, and time-based innovation as constituting parts of time-based competition. Daugherty and Pittman [1995] argue that firms with fast cycle capability make decision faster, develop new products earlier and convert customer orders to deliveries sooner than

competitors. They define lead-time as the measure of speed or length, which could determine the competitiveness of a company with regard to time. Lead-time is, according to them, the total time that elapses from placement of an order until receipt of goods, and could be broken down into manufacturing lead-time and distribution lead-time. Kumar and Motwani[1995] propose three primary sources from which the strategic value of time stems. They are: price premium; attraction of more customers and encouragement of brand loyalty; and higher contribution and profitability as a result of production and logistical cost economisation. The extensive review of literature on time-based management conducted by Kumar and Mutwani [1995] which is shown in Table 2.2 clarifies the extent to which time has been recognised as an important winning order in the new world of competition of the 1990s. They have grouped the research works in four streams that are cited in the table.

Another pertinent aspect of time-based competition, as a manufacturing competitive advantage, is the first-to-market strategy. The general belief of considerable advantage of first-to-market companies is questioned for its strength. Lambert and Slater 1996] claim, based on a critical study on the literature supporting the idea, that the average market share for pioneers is not significant enough to justify the risk involved in the strategy. It is also resulted from Cooper's [1995] study of cycle time that time efficiency only takes 18% of the variability in profit. Cooper has also found that the correlation between timeliness (on-time schedule performance) and success is very low [Cooper, 1995]. Lambert and Slater [1996] have concluded that first, fast, and on-time schedule must be rethought and replaced by more general, overarching principles to incorporate time-based strategies. They propose new concepts as first-to-mindshare that suggests to win the mind of market and customer, effective market introduction which requires an ability to control the window of opportunity, and managed responsiveness which refers to an effective responsiveness to both internal and external market conditions. Their graphical model is depicted in Figure 2.2, which shows an integrated form of the proposed tenets.

Author(s)	Article intent	Stream	Methodology	Findings
Azzone *et al*[7]	Theory building	3	Discussion	Suggests a model for selecting effective set of measures for time-based companies
Evans[31]	Theory building	3	Discussion	Provided pointers for speeding up processes in an organization
Inglesby[32]	Theory building	3	Discussion	Concurrent engineering and manufacturing help assure that the end product gets out quicker and at a higher level of quality
Port[33]	Prescription	2	Discussion	Making factories agile, linking them to computers, and collaborating are necessary for US firms to stay competitive
Blackburn[14]	Theory building	3	Discussion	Leading time-based competitors have developed and are applying JIT to their white-collar processes
Hall[34]	Theory building	1	Discussion	Improving visibility is one of the simplest ways to stimulate time-based organization in offices and plants
Inman[24]	Theory building	3	Discussion	To have an advantage in time-based competition, firms must reduce the consumption of time through the system
Stalk[35]	Prescription	2	Discussion	Suggests strategies for competing in today's competitive environment
Thomas[18]	Prescription	2	Discussion	Shortening cycle time improves response to customer and quality
Valovic[21]	Prescription	2	Discussion	Strategic networking is the key for US firms competing on speed
Weimer *et al*[16]	Theory building	1, 3	Discussion	Integrated manufacturing compresses time-to-market
Youssef[36]	Theory building	1, 3	Discussion	Shows how speed can be effective in providing substantial competitive advantage
Barker[10]	Theory testing	4	Case study	Time-based manufacturing strategies offers a framework to develop the total input/ output chain in isolation of selling price
Goldsbrough[28]	Theory building	3	Discussion	Illustrated how time-based competition can bring greater profits and faster growth
Dumaine[17]	Prescription	2	Discussion	Time-based strategy can result in increased market share
Merrils[29]	Theory testing	3, 4	Case study	Illustrates how Northern Telecom competes on time
Stalk[2]	Prescription	2	Discussion	Demonstrates how time-based policies differ from those of traditional manufacturers
Geber[19]	Prescription	2	Discussion	Illustrated how different companies are trying to compete on time
Blackburn[13]	Theory building	1, 3	Discussion	Reducing the time required to reach the customer must play a major role in a firm's competitive strategy
Isenhour[22]	Theory building	3	Discussion	Identified specific (1990) problem areas and analysed approaches designed to meet the competition
Musselwhite[3]	Theory building	3	Discussion	Proposed a cross-functional approach to product development
Ruch[15]	Theory building	1, 3	Discussion	Suggested seven basic principles to achieving time-based management
Stonich[4]	Theory building	3	Discussion	Outlined a three-step process for building a time-based organization
Stalk *et al*[8]	Theory testing	4	Case study	To become a time-based company, management has to learn to think as an integrated system
Stalk *et al*[9]	Theory building	3	Discussion	Suggested 13 time-based performance measures
Tyndall[20]	Prescription	2	Discussion	In order to achieve time compression, the physical operations of the business should be well understood
Valentino[30]	Theory testing	4	Case study	Showed how time-based management can create a competitive advantage

Table 2.2. Summary of Literature on Time-Based Management [Kumar and Mutwani, 1995]

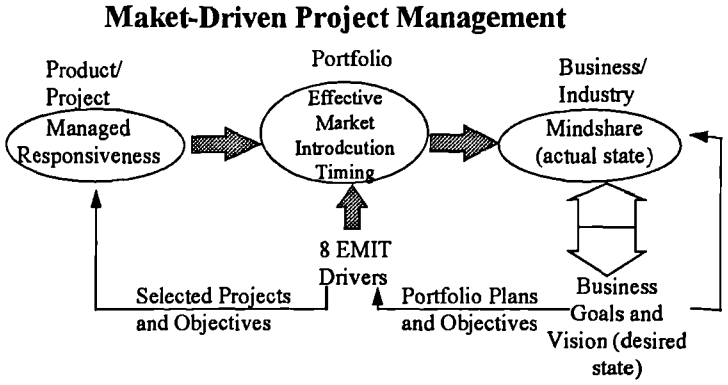

Figure 2.2. New concepts related to time factor
[Lambert and Slater, 1996]

Now, it is time for responsiveness to become a new capability that includes the time-based competition as one of its factors. Responsiveness is the extended form of time as a business priority. Youssef [1992] cites the modified definition of "quick response" from Blackburn as: " The ability of the firm to plan for, develop, produce and deliver a quality product or a quality service at the right time, and the right price, given the willingness of customers to value speed and pay for it". Barclay et al [1996] has defined responsiveness as a newly emerging and potentially vital issue, in this way: " The ability to react purposefully and within an appropriate timescale, to significant events, opportunities or threats (especially from the external environment) to bring about or maintain competitive advantage."

This extended view of timeliness will result in intertwining of the whole package of business priorities. The time for the old belief that grabbing one priority in the business necessitates acceptance of loss on others, i.e. making quality products take time, or reducing cost could affect timeliness or flexibility, has gone forever. Although as Tersine and Hummingbird [1995] contend companies must use a mixture of factors to achieve a unifying directional force for competitive advantage, because no company can excel simultaneously in all of them. The new wisdom of the manufacturing systems urge manufacturers to realise the new requirements of the

competition and move towards an adaptive approach with which the changing circumstances are met and resolved.

It is interesting to note that according to recent studies performed to determine business priorities in manufacturing companies, quality still holds the first place and this will remain the same for the 1990s [Tunc and Gupta, 1993]. This is also in conformance with the results reported by Ferdows[1989] from his survey, in which top priority for non-Japanese companies is determined to be quality, while manufacturers in Japan had put cost (low prices) on top of the list.

2.3.4 Evolution in (New) Product Development System (Innovation)

Along with the evolvement of business systems and criteria, supporting systems such as manufacturing control systems (MCS), product development Process (PDP) and New Product Development Process (NPDP) have evolved which provide manufacturers with the potential and practical capabilities to adapt to changing circumstances.

Innovation was not a well-known subject before the 1960's and technological innovation was regarded as a linear process through which science is transformed to products via a series of sequential manufacturing processes. It was more or less synonymous to R&D, where the marketplace demand was taken as granted for introduction of products [Rothwell, 1992]. This was later called technologic-push innovation in contrast to the new term of "market-pull" or "needs-pull" models of innovation, which started to question and replace the former. It was in the late 1960s that studies showed a major role for marketplace in the introduction of new and improved products and led to introduction of market-pull innovation [Myres & Marquis, 1969].

During the 1970s, the two models of innovation began to be regarded as a more general process of coupling between science, technology and the marketplace [Rothwell, 1992]. Later a new approach to innovation called dual drive, replaced the single drives of technology or markets [Crawford, 1991]. This was due to the widespread growth of scientific and engineering capabilities that made other

competitors comfortably able to either duplicate technologies or find alternative ways to get the same result. The intensified competition and sophistication of technology resulted in a new vision of organisations, which recommended the emphasis on core competency as a successful strategy [Hamel & Prahalad, 1990].

Success in NPD or innovation and bringing new products to market as a major problem of organisations has become a focal point of managerial studies since the 1960s and great efforts have been applied to determine the success factors associated with it. Poolton [1994] has summarised these factors after Rothwell and Cooper in a table that is shown in Figure 2.3.

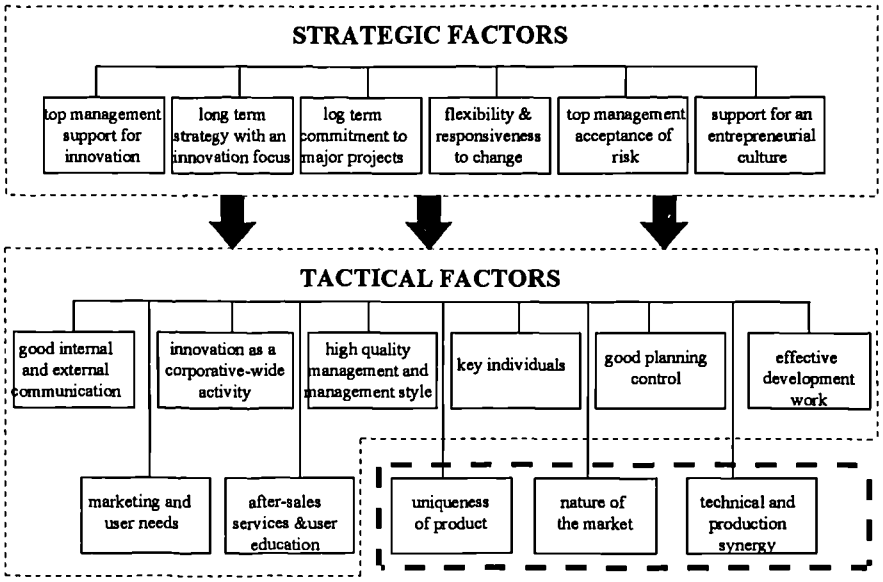

Figure 2.3. Factors for a successful new product development [Poolton, 1994].

Studies later pointed out the increasing rate of reduction in new products life cycle. For example the life cycle of new products in the pharmaceutical industry dropped to 8 years from 24 years [Von Braun, 1990]. This reality, to settle with further changes in the business environment, resulted in the consideration of new measures of success and prosperity in the competition for product development. Wheelright & Clark [1992] suggested a new set of imperatives, which is depicted in Table 2.3.

DEVELOPMENT IMPERATIVES		
REQUIRED CAPABILITY	**DRIVING FORCE**	**IMPLICATIONS**
Fast and responsive	Intensive competition: changing customer expectations; high rate of technological change	Shorter development cycles; better targeted products
High development productivity	Exploding product variety; discerning customers; technical diversity	Leverage from critical resources; increased successful projects per engineer
New products with integrity	Demanding customers; crowded markets; intense competition	Creativity + total product quality; true customer integration in NPD process

Table 2.3 Product development imperatives for the 1990's,
[Wheelwright and Clark, 1992]

2.4. RESPONSE TO CHANGING BUSINESS ENVIRONMENT

It is clear from previous discussions that the world of competition, and the environment of business are extremely tied up with change, and characterised as one which changes continuously, and also the trend of change is growing higher and higher.

Change and uncertainty are not new agendas for business organisations. Thompson [1967] has considered change or uncertainty as one of the most important subjects for organisations to manage. Business priorities, successful operations imperatives, and critical factors for prosperity have long been studied and various work has been carried out to provide conceptual frames for analysing and understanding factors related to success in business, and accommodate achievement of these factors by introduction of methods, tools, techniques, etc. A cumulative list of business priorities since the turn of the 20th century could be summarised from the previous sections of this chapter as follows:

1- Cost

2- Quality

3- Flexibility

4- Time-Based Competition

5- Responsiveness/Proactivity

6- World Class Manufacturing

These have formed the core of many works in academia and industry over the past 100 years. The emergence of each concept has resulted in new managerial/technical concepts and tools for effective management of resources. Total Quality Management (TQM), JIT, Concurrent Engineering (CE), Lean Manufacturing, Re-engineering, MRPII, OPT, and Automated Manufacturing Technology (AMT) are some panacea-driven approaches to name some [Berry and Hill, 1992]. However, as Hayes and Pisano [1994] contend majority of the developed means for improvement have not been as successful. According to Hayes and Pisano [1994], even Japanese companies that pioneered these approaches are having second thoughts. In their argument, Hayes and Pisano [1994] stated that the problem is not with the programmes nor with the way they were implemented. In today's turbulent competitive environment, a company more than ever needs a strategy that specifies the kind of competitive advantage that it is seeking in its marketplace and articulates how that advantage is to be achieved.

It is now, as Meredith and Vineyard [1993] conclude, well accepted that installing advanced manufacturing technologies in a plant without first having a well-thought-out business strategy can be a very expensive mistake for a firm. New technologies or methods could be a technical success but business failure [Voss, 1984].

Some of the approaches towards more effective management of business have generally emerged in the form of new visionary of manufacturing in response to pressures from business environment and industrial problems. Some important ones will be discussed in the following sub-sections.

2.4.1 Just-In-Time (JIT/Kanban)

As a combination of management philosophy and factory floor control approach, the JIT/Kanban method was developed in the 1960s by Toyota in Japan [Sohal et al, 1989]. The philosophy aimed at zero inventories and continuous improvement, emphasising continuous pursuit of improved quality through process improvement, simplicity, reduction in set-up-time and close relationship with suppliers. The basic logic on which JIT was established is that suppliers would make regular, small batch deliveries to customers so that required goals would arrive "Just-in-Time".

Sohal et al [1993] suggest that the essential parts or elements of JIT are: small batches; set-up time reduction; cellular manufacturing; multiskilled workers; quality at the source; preventive maintenance; Kanban/Pull production scheduling; and JIT delivery/Purchasing.

2.4.2 Total Quality Management (TQM)

In response to the tremendous mass-production requirements of World War II, statistical quality control (SQC) was introduced for quality control [Feigenbaum, 1983]. Japan, when facing the post war industrial challenge, attempted to make major development in quality, of which SQC initiated by Ishikawa was one bold result [Flood, 1993]. This was in line with extending quality control to quality assurance, resulting in involvement of more business functions in the management of quality [Kehoe, 1996]. TQM emerged as the result of the need for seeing quality beyond the shop-floor inspection, and getting arms around the really big quality problems, which were started to be felt by business managers [Feigenbaum, 1983]. It was in essences led by the fierce international competition for goods and services during the 1980s and 1990s [Kehoe, 1996]. TQM is a high level "holist" approach, which focuses on customer-supplier relationship as the basis for improvements.

2.4.3 Flexible Manufacturing System (FMS)

As a result of increasing market and technological pressures on manufacturing which force international competition to move towards greater flexibility [DeMeyer et al., 1989], the adoption of flexible manufacturing systems (FMS) to respond quickly, smoothly, and cheaply to as yet unknown changes in products markets and production technology is becoming a recent trend in manufacturing industries [Chen & Chung, 1996]. Although there is not a consensus on the definition of FMS, the one given by Ranky [1983] is used in many references [Keighobadi & Vankatesh, 1994]. It defines FMS as a system dealing with high level distributed data processing and automated material flow using computer-controlled machines, assembly cells, industrial robots, inspection machines and so on, together with computer integrated material handling and storage systems. A general perception of components and characteristics of FMS, as described by different authors are as follows [Ranky, 1983]: potentially independent NC machine tools; an automated material handling system; and an overall

method of control that coordinates the functions of both the machine tools and material handling system. Dallas [1984] reports that a FMS can succeed if: it is functioning in the right economic context; the company's organisational structure has been redesigned to accommodate the special requirements of FMS; there is close cooperation between vendors and users of the technology; and the management understands that the rules of the game have changed.

FMS is considered as one main practice of Advanced Manufacturing Technology (AMT). AMTs represent a shift in the way in which things are done. These technologies are integrative in nature and must be considered appropriately with a different way of thinking about manufacturing as compared to traditional non-integrated technologies [Lindberg, 1992]. So there is a need for understanding of the strategic objectives, as well as the potential and use of these technologies.

2.4.4 Integration

Basically defined as bringing things together and coordination between different parts, integration is rooted in the scientific management theories and was used as a crucial means of achieving better productivity since the emergence of modern manufacturing systems in the late 19th century into the 20th century. Vertical integration was used to accommodate exploitation of the economies of scale at the beginning of the modern industrial corporation [Goldman et al., 1995].

Many attempts have been reported in integration of various aspects of business, which have resulted in great advantages. Ross Operating Valves is one distinguished case reported by Goldman et al. [1995]. The company created a facility called Ross/Flex by integrating design, sales, and production processes to respond to custom-designed demands, and as a result they reduced both the cost and time needed to develop prototype valves to one day and $3000 respectively, instead of ten days and $30000.

The importance of integration has always been notified by different authors, especially in the matter of uptake of new technologies and automation. Gupta and Somers [1993] have concluded from an industrial survey that highly integrated organisations tend to realise more of the strategic benefits of factory automation compared to

organisations that are not that integrated. It is also emphasised by Schile and Goldhar [1989] that using factory automation as a competitive weapon is subject to integration of all functions of the organisation into a focused, integrated, enhanced delivery system.

Integration of different areas of the organisation is considered widely in order to improve company's capabilities. Lindberg [1992] has proposed a framework based on the integration of technology, control systems and work organisation in manufacturing to achieve strategic capabilities in manufacturing.

Integration of design, production, and services with a focus on customer is proposed as a representation of integrated product development (IPD), which is an approach to responding to difficulties in traditional product development process. The research conducted by Yusuf [1996] to study the extension of MRPII to respond to the growing complexity and uncertainty of the business environment has concluded that a high level of integration is a necessary condition for competitive performance in today's manufacturing.

However, the sufficiency of integration to achieve flexibility is being questioned by Crowe [1992] who argued that integration is not synonymous with flexibility. Crowe differentiate unsuitable integration by calling it "hard integration" meaning integrating using rigid information interfaces. This type of integration would fail as product and process modifications become necessary.

2.4.5 Cooperation

In facing a world of relentless and accelerating change, one effective strategy considered by many authors in recent years is cooperation. Champy [1995] indicates that reengineering did not usually lead to success, and suggests that a company's relations with customers, its internal structure, and its relation with suppliers must be managed in a coordinated way.

Preiss et al. [1996] propose that coordination of following areas is the key to a successful interprise (a new term coined against enterprise): interacting with customers; interacting with suppliers; and changing internally.

An advanced form of cooperation which has recently been discussed and practised in some organisations is "***virtual organisation***". Virtual organisation is defined as a temporary relationship with one or more participants that is formed and operated to accomplish specific short-term goal, i.e. a market opportunity or customer new requirement, and then dissolved [Reid et al., 1996]. Goldman et al. [1995] suggest six reasons to use virtual organisation. They are: sharing infrastructure, R&D, risk and costs; linking complementary core competencies; reducing concept-to-cash time; increasing facilities and apparent size; gaining access to markets and sharing markets or customer loyalty; and selling solutions instead of products.

2.4.6 Information System/Technology

Information technology (IT) is a critical organisational resource that supports a firm's competitive advantage [Montazemi and Miltenberg, 1991][Powel, 1992]. Advances in information system/technology (IS/IT) in the past decades have brought about a great deal of improvements in manufacturing management. Computers form a significant portion of most manufacturing companies [Montazemi and Miltenberg, 1991]. Themes such as CIM (Computer Integrated Manufacturing) is squarely established based on computers and as Montazemi & Miltenberg [1991] indicate differ qualitatively from earlier advances in product technology. Large manufacturing system vendors have also proposed architectures [IBM, 1987] as frameworks to develop computer based manufacturing.

IT and information integration incorporate achievement of adaptiveness in manufacturing as a necessary ability in the world of competition [Pant et al, 1994]. However, to be supportive and efficient, information systems must be based on a strategy, which has to be aligned with a firm's strategy [Gupta et al., 1997]. As quoted by Gupta et al [1997], Ward et al. believe that higher levels of IT management sophistication represent the evolution of a firm's IS function from the traditional role of supporting data-processing operations to that of being strategic to the firm.

2.4.7 Strategy, and Strategic Planning

Strategic planning arrived in the scene in the mid-1960s and was embraced as "the one best way" to devise and implement strategies that would enhance the competitiveness of each business unit, though it was only based on the scientific management thoughts of Taylor [Mintzberg, 1994]. Defined as "a coherent pattern of actions to improve the organisation's long term competitiveness" by Davies [1993], and as "the pattern of structural and infrastructure directions" by Hayes and Wheelwright [1984], strategy or manufacturing strategy is based on the basic idea of guiding the decisions in manufacturing to support a common overall goal.

A generic model of strategic management includes three primary stages: strategy formulation which is concerned with the future direction of the firm; strategy implementation during which organisational structures and processes are modified to ensure the achievement of the planned results; and strategy evaluation that is set to control the performance to achieve plans and objectives [Preble, 1992].

Hamel and Prahalad [1993] suggest that Western companies' perception of strategy is centred on three elements: the relationship between the company and its competitive environment; the allocation of resources among company investment opportunities; and a long-term perspective in which "patient money" figures prominently. Hayes and Schmenner [1978] have suggested four "attitudes" that shape those aspects of a company's corporate strategy, which are relevant to manufacturing. They are: dominant orientation; pattern of diversification; corporate attitude toward growth; and competitive priorities. Competitive priorities are defined as: dependability; price; product flexibility; quality; and volume flexibility. Porter [1980] put forward a set of competitive strategies including low cost, high differentiation, and focus.

2.4.7.1 Strategy for competing in a changing and turbulent environment

The traditional patterns and perceptions of strategy and strategic planning have been questioned as the business environment turns more and more chaotic [Hamel and Prahalad, 1994]. However, Hamel and Prahalad argue that the prevailing dominant perceptions of strategy, though not wrong, is unbalanced. Strategic planning is more taken and practised as strategic programming, not strategic thinking [Mintzberg,

1994]. Meredith and Vineyard [1993] have examined the hypothesis that the higher the environmental uncertainty, the lower the role of manufacturing managers in strategic decision making, and have found the hypothesis valid which, according to them, refers to the inapplicability of the traditional approaches in the new business environment.

Also as already mentioned, according to Hayes and Pisano [1994] the problem of performance in business organisations is not with the way improvements have been planned, but appropriate strategy is necessary to streamline the advantages sought in the business environment.

Mintzberg [1973] defined that strategy can be divided into proactive and reactive behaviours, of which proactive, entrepreneurial behaviour is needed in a turbulent environment. Hill [1985] argued that manufacturing in its present situation is largely reactive. He then suggested that a proactive manufacturing strategy is needed in response to the changing circumstances.

Hayes and Pisano [1994] also declare that unlike a stable environment in which company's strategy is to stake out a position and define it by manufacturing strategy, a turbulent environment requires strategic flexibility. Becoming world-class is not enough; a company has to have the capability to switch gears from, for example, rapid product development to low cost quickly and with minimal resources. A different approach is suggested for strategy by Hamel and Prahalad [1989]. They claim that the new global competitors approach strategy from a perspective that is fundamentally different from that which underpins Western management thoughts. They argue that these companies have created some kind of obsession in winning at all levels, which is called "strategic intent". They follow by stating that currently strategy is seen as a positioning exercise in which options are tested by how they fit the existing industry structure. But as the structure of industry is based on the strength of industrial leaders, playing by the leaders' rules is usually a competitive suicide. In another work, Hamel and Prahalad [1991] suggest that the battles of the 1990s can be won only by those companies that can build and dominate fundamentally new markets. According to the two authors, a company will strive to create new competitive space only if it

possesses an opportunity horizon that stretches far beyond the boundaries of its current business. Building one new business after another, faster than competitors is the only way to stay ahead. It is suggested that four strategic elements are needed to be combined to speed up a company's corporate imagination: escaping the tyranny of served markets; searching for innovative product concepts; overturning traditional assumptions about price/performance relationship; and leading customers rather than simply following them [Hamel and Prahalad, 1991].

The idea is stretched by Porter [1996] who pointed out that positioning (as traditional strategy perception and once the heart of it) is rejected as too static for today's dynamic markets and changing technology. He suggests that a company can outperform rivals only if it can establish a difference that it can preserve, and that competitive strategy is about being different; it means deliberately choosing a different set of activities to deliver a unique mix of values.

Hamel [1996] also placed emphasis on radical movements instead of incrementalism, which is going to reach its limits. He states that never has the world been so hospitable to revolutionaries and more hostile to industry incumbents. According to him a third kind of manufacturing companies such as Dell Computer, Swatch, as rule breakers have emerged who are shackled neither by convention nor by respect for precedents. He suggests that strategy must be considered as revolution and it has to be subversive.

2.5 AGILE MANUFACTURING AS A NEW ERA; A RESPONSE TO THE NEW REQUIREMENTS OF THE CONTEMPORARY BUSINESS WORLD.

The increasing turbulence, uncertainty, and change in the business environment, the pitfalls of the dominant strategies of past decades, and the flaws observed in the prevailing panacea-driven mind sets and practical tools have created new challenges for manufacturing organisations. A new set of imperatives has been created that are seen to differ considerably from traditional models [Iansiti, 1995]. Emergence of the turbulent environment of today's business, which is classified by McCann and Selsky [1984] as hyperturbulent or type 5, requires organisational responses far from the

accepted modes of functioning in manufacturing companies if they are to adapt to, cope with and survive [Bessant et al, 1992]. Drucker [1990] proposed to build a new theory of manufacturing. Stacey [1993] claims that the conventional wisdom that encourages manufacturers to focus on uniformity, stability and regularity leads to failure rather than success in rapidly changing and highly competitive conditions, and suggests a new strategic management approach that sees the dynamics of the organisation, and handle the uncertainty in the business environment.

Values, measures, principles, and rules of the new business game are different from those with which enterprises used to work. Sustaining competitive advantage and staying in business is now subject to coping with change. Augustine [1997] describes that the most important lesson from the recent battle in economy and manufacturing of USA became self-evident: there are only two kinds of companies- those who are changing and those who are going out of business. He adds that adapting to a rapidly changing business environment is not fun, and managers most assuredly should not treat it like a spectator sport.

This, from another angle is interpreted as the emergence of a new competitive environment in which the prevailing mass production system of manufacturing is at a disadvantage [Goldman et al., 1993]. The new system achieves agility, against low unit cost achievement of mass production. *Agile manufacturing is the emerging paradigm of business.*

2.5.1 The Emergence of Agile Manufacturing

In response to the calls for reconsideration of the prevailing principles and philosophies of business, especially in the area of manufacturing, and aiming initially at increasing the global competitiveness of US business, a study was conducted by Iacocca Institute in Bethlehem, US, leading to the coining of the term "agile manufacturing". In a report of the conducted study [Iacocca Institute, 1991] the ultimate objective of the research is stated as to provoke the actions that need to be taken in order to restore US world leadership in manufacturing. The report emphasises that: " the fact that all of the world's leading manufacturers have to build a new infrastructure to make the transition from mass production to agile

manufacturing provides a unique opportunity for US industry to regain the leadership it lost in the 1970s and '80s." It adds that competition in the 21st century will be dominated by agile enterprises, and that " those nations that focus now on speeding the transition to agile manufacturing will become the strongest competitors in the global marketplace."

The originators believe that implementation of agile manufacturing is equivalent to unlearning of some currently held "thrusts" such as: cooperation is less desirable than succeeding on one's own; labour management relations must be adversarial; trust is power and can be shared only to one's detriments; there are single technological solution to complex problems; markets will appear by themselves "once better mousetraps" are invented and so on.

The work which had taken advantage of many case studies, interviews and mind-share of leading representatives of industry, government and academia, was welcomed by the US government and led to the formation of "Agility Forum" in Bethlehem University with the mission of pursuing the ideas and providing the soft facilities for implementing the work in the US manufacturing and other businesses. The terms "agility" and "agile manufacturing" then started to enter the manufacturing management and technology literature. Some efforts have been made to clear the idea, build the theoretical principles, introduce the concept in the form of frameworks, and provide practical guides to implement agility. The issue later received attention from European countries, in particular Germany and the UK, but not much significant work has been reported yet in this relation. Apart from a few publications by individuals in academies, the only government related effort in the UK was performed by CEST [1996] under the title of "OSTEMS agility mission to the US" to find out about the subject and its practical aspects in relation with industries in the US.

The work of Warnecke et al [1993] in Germany under the name of "Fractal Company" is seen to support and give substantiation to the work of the Agility Forum [Savage, 1997]. In other words it can be called a German type of agile manufacturing.

2.5.2 Agile Manufacturing; Perspectives, Definitions, Models So Far

After being introduced by the Agility Forum, agile manufacturing which incorporates a wide range of ideas, was ended with the famous story of the elephant in the dark room. As Litsikas [1997] states, its proponents and practitioners are not all reading off the same sheet of music yet. Expressions such as: the next level of effective business practices; a practice including smart equipment and robots [Litsikas, 1997]; a customer focused manufacturing and proper response to changing customers' requirements; total integration of business components [Kidd, 1995]; flexibility of manufacturing, people, and organisation [Montgomery and Levine, 1996], etc., have formed parts of the body of ideas, and readings of different people from the concept. Suggesting that the new competitive foundations of the agile manufacturing environment are: continuous change, rapid response, quality improvement, and social responsibility, Iacocca Institute's report introduced a frame for agile enterprise in year 2006 which is presented in Figure 2.4. Agile manufacturing later was defined in the Agility Forum as: "a strategy for profiting from rapidly changing, continually fragmenting global markets for individual, relationship-based products and services".

The Bethlehem centred research also suggests that agility is accomplished by integrating three resources: technology, management, and workforce into a coordinated interdependent system. By referring to ideas of Hamel and Prahalad [1989] the report emphasises that agile manufacturing enterprises employ a dynamic and organisationally comprehensive planning style. Some important features projected as characteristics of agile manufacturing are found already discernible, at least in early stages of development. Among those, following are mentioned by the Iacocca Institute's report [1991]:

- The formation of virtual companies, enabled by information exchangeability
- Modular, "plug compatible" organisational structure and production facilities
- Network of alliances among suppliers, producers, and customers, characterised by close operations
- Shared production capabilities and (to a less extent) shared production facilities
- Pursuit of absolute process control through closed loop monitoring, real-time sampling and analysis, and diagnostics software built into sensors.

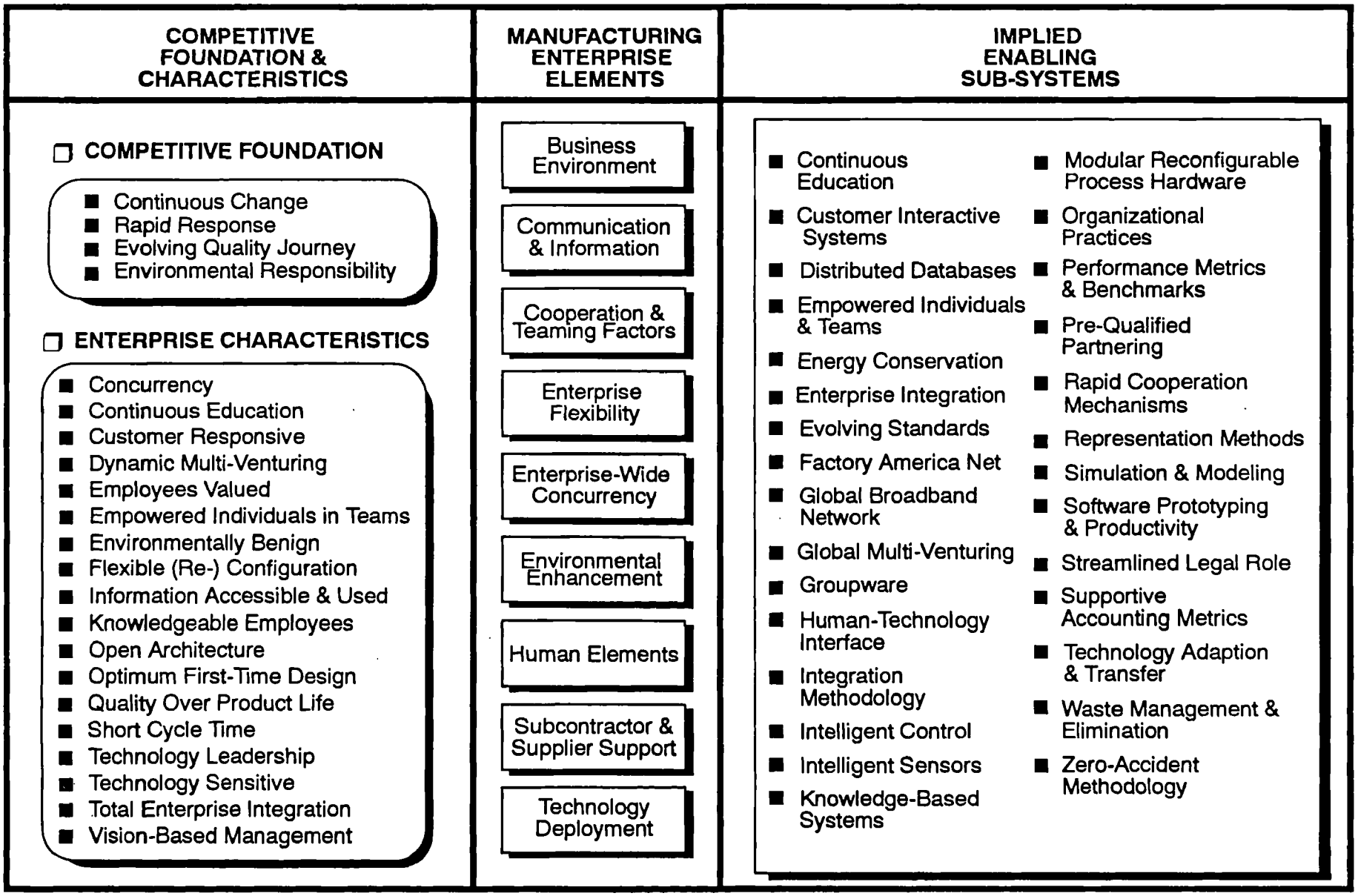

Figure 2.4. Competitive Leader 2006 - The Agile Enterprise [Iacocca Institute, 1991]

- Direct feedback of sales and customers, and using information in production decision process.
- Research into computer simulation of reaction kinetics with the objective of "design" chemicals.
- A central role for manufacturing in corporate planning and in engineering.
- Manufacturing research directly linked to "basic" R&D.

Also to mention, highly flexible production machinery is viewed as a necessary but not sufficient condition for the emerging agile manufacturing. These technologies are seen to include currently existing or foreseeable techniques such as: flexible, programmable machine tools grouped as reconfigurable, modular, and scaleable manufacturing cells; "intelligent" manufacturing process controllers; closed loop monitoring of manufacturing processes by employing sensors, samplers, and analysers coupled to intelligent diagnostic software; the computer power; and the manufacturing knowledge base. These technologies must be linked within an organisational structure to achieve short production cycle time (the rapid creation, development, and manufacturing of new products), to fully exploit their power.

The research adds that a seamless flow of information among manufacturing, engineering, marketing, purchasing, finance, inventory, sales, and research departments must be guaranteed in an agile manufacturing enterprise as a totally integrated organisation. In agile manufacturing, work precedes concurrently including new product development, manufacturing, and marketing. Every product can be dealt with on a highly interactive network. Physically dispersed and organisationally segregated personnel from the same company can work collaboratively with one another and with personnel distributed across the companies. This would be possible by strict, universal data exchange standards, by robust groupware, and by broadband communication channels. Agile enterprises can make and implement many decisions at the point and time of receiving information.

According to the same research, the concept of manufacturing in an agile manufacturing environment expands from a narrow focus on production of

consumable/dispensable goods to the comprehensive process of creating, developing, selling, and maintaining products over their entire life cycle. For many products this new vision will be highly extended by reconfiguring and upgrading compatible ties between the products' parts and modules.

The report goes to the extent that identifies the transition to the new era as a social task, which must be led by industry. Reminding the impact of the rise of mass production on the societies that adopted industrialisation, the research concludes that change in social institutions and in social and personal values are anticipated, and that the rise of agile manufacturing will exert an influence on society analogous to that by industrialisation.

Goldman et al. [1995] as members of the core research group in the Agility Forum, provided another dedicated work on agile manufacturing. In line with the initial work of the Iacocca Institute, and sharing the same concept of agile manufacturing, Goldman et al. [1995] claim that the competitive power of the modern industrial corporation came from the way that people, organisations, and technologies were systematically coordinated, not from the individual items mentioned. Four dimensions are suggested for agile competition by Goldman et al., which are as follows:

- Enriching the customer. Customers in agile manufacturing environment expect to receive solutions to their problems and be enriched in a significant way. Goods and services are only the means for implementing solutions. A graphical display of the degree of interaction between customer and supplier is put forward and referred to as Enrichment-Reward-Linkage diagram. Figure 2.5 represents the model.

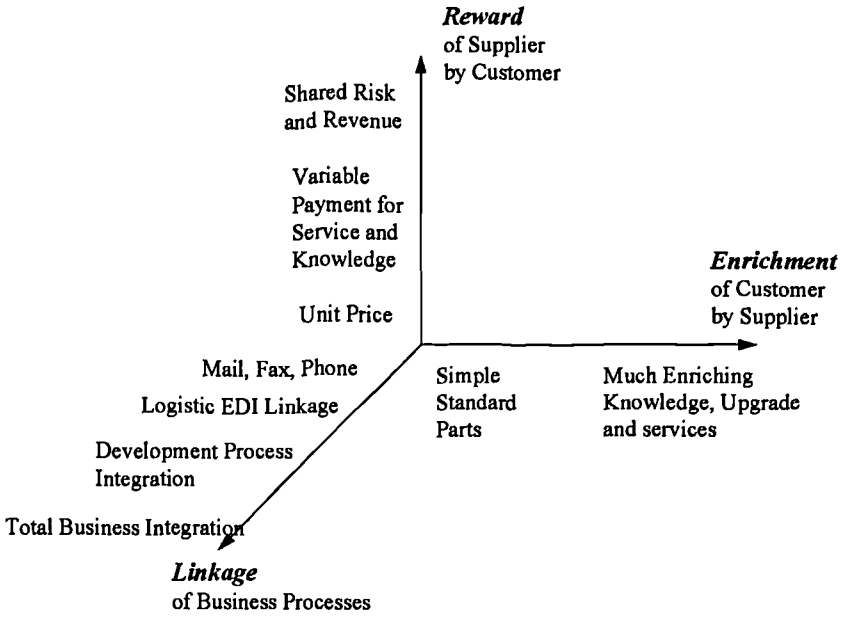

Figure 2.5. Enrichment-Reward-Linkage Diagram [Goldman et al., 1995]

- Cooperating to enhance competitiveness. Cooperation, internally and with other companies, is an agile competitor's operational strategy of first choice. Bringing products to market as rapidly and as cost-effectively as possible is an expected result of this cooperation. Means of this strategy are cross-functional teams, empowerment of people, reengineering of business processes, virtual companies, and partnership even with direct competitors.
- Organising to master change and uncertainty. The flexible structure, and the innovative character of an organisation in agile manufacturing environment, will let it to make rapid decisions, support concurrent organisational configurations keyed to the requirements of different customer opportunities.
- Leveraging the impact of people and information. People and information are the differentiators between companies in agile competition environment. To leverage the impact of these factors, management in an agile manufacturing company nurtures an entrepreneurial company culture.

This concept of agility is based on a holistic approach to the business, with the customer, design, development, manufacturing and suppliers working together and being supported by appropriate information systems [Keen, 1988].

However, Goldman et al. view agility as a not yet explored area with no specific prescriptions due to some reasons including:

- The concept is still new.
- Each organisation's ability to succeed with agility depends on different situations and skill sets.
- The situation in each industry and in each company is different, so no single formula is possible. Each unit has to allow the direction that is right for it.
- The competitive environment is different and constantly changing. The target dealt with is a moving one.

They also suggest that benefits from agility include:

- Shrinking the concept-to-cash time, where time is a key competitive factor. Also reduction in cost and inventory are foreseeable.
- Taking leadership in pricing and the resultant advantages.
- Increasing in people productivity and higher employee morale.
- Increasing customer satisfaction bringing in new customers, and hence bigger market share.
- Better asset utilisation resulting in less capital required and improved ROA/ROI results.
- Better competitive advantage and going above most competitors.
- Creating means to distinguish the company from its competitors.

According to Goldman et al. [1995], strategy making and strategic planning in agile manufacturing are different from those conducted in prevailing systems. Change in an agile company is dealt with as a matter of routine, and the strategic plan deals not with product but with enhancement of capabilities. Strategic planning has to deal with new and far-reaching issues that previously did not need attention. These issues include:

- Evaluating the core competencies of the company and the directions in which these core competencies should develop.
- Constant evolution of the skill base of employees and their compatibility with the designed core competencies of the company.

- Finding potential partners, evaluating them and positioning the company such that it is attractive for alliances.
- Constant analysis of the value-added chain as it changes and fragments from year to year.
- Constant search for profitable opportunities, and review of the new products and services offered by competitors.

Finally Goldman et al. suggest some barriers to assimilating agility which include: outdated management accounting system; internal barriers such as performance measurement systems, non-definition of core competency knowledge, budgeting procedures, dysfunctional organisation and information system, etc.; external barriers such as legal systems assuming a mass production system environment, artificial dichotomy of product and service, lack of access to information, and adversarial mind-set.

Another significant work was introduced by the same group, which put emphasis on cooperation [Preiss et al., 1996]. Coining a new term "Interprise" as opposed to "enterprise" which is applied to extend the traditional perception of organisation to an organisation that exhibits increased integration of the business processes with customers, more cooperation with suppliers, and an entrepreneurial environment.

Pointing to the fact revealed by Anderson Consulting, which is depicted in Figure 2.6, and the argument that most companies streamline or restructure their processes without changing their strategic aim, Preiss et al. [1996] suggest that manufacturing firms should become part of their customers' processes. Through this, manufacturers can incorporate tactical responses, such as restructuring and reengineering, while establishing the strategic advantage.

Preiss et al. devise a change in the concept of world-class supplier towards world-class enabler of customers, and consider the new concept as the basis for manufacturing organisations to obtain a sustainable strategic advantage in the early twenty first century.

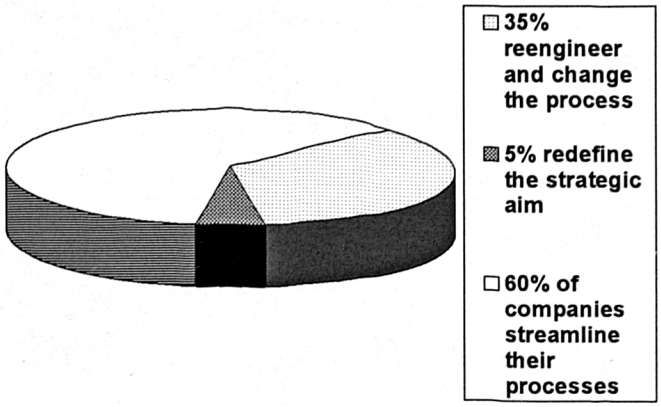

Figure 2.6. How Companies are Responding to Today's More Competitive Environment. [Preiss et al., 1996

Reducing time of production, and competing on time is strongly recommended by Preiss et al.[1996]. It is suggested that time reduction is an opportunity for organisations to restructure themselves so as to discover new market opportunities.

Virtual relations with customers and suppliers are also found by Preiss et al. to be effective weapons to expand the business and help the move towards agility. The work of Preiss et al. ends with a primitive method to measure the change in the business environment of the company and drive the company towards agility. The method is devised to help companies who want to move from arm's length business to the interactive, agile, and competitive interprise, in formulating an action plan. The method is based on a generic model of an interprise. It consists of a series of worksheets that must be filled out and guides a company to formulate prioritised list of issues to be dealt with. The method is intended to identify the distinctive kinds of market forces, the attributes of an enterprise capable of thriving in that market, and the organisational infrastructure required to support these attributes.

The generic model and its associated factors are depicted in Figures 2.7 and 2.8. The method in essence follows answers to four questions by any company that attempts a move towards a more powerful competitive position. These questions are:

- What are the relevant drivers of change to which the company is responding- either reactively or proactively- by becoming agile?
- What are the attributes that the company should possess in order to assimilate those drivers into its operations?
- What new capabilities should the company acquire if it is to possess these attributes?
- What business process changes will be necessary to support the new capabilities?

These questions are directed through some tables to achieve insight into the processes and practices that the company need for attaining a better position.

Other works in this area have tried to exploit the concept and derive conceptual and practical models/methods for agile manufacturing. Kidd [1995], based on the original report of the Iacocca Institute, suggested that agile manufacturing is achieved through the integration of three resources; organisation, people, and technology into a coordinated, interdependent system. Figure 2.9 represents his proposal. He also proposed a conceptual framework for agile manufacturing. This is shown in Figure 2.10.

The competitive foundations he put forward is the Iacocca Institute's research proposal plus "total customer focus".

The conceptual framework for agile manufacturing bears four core concepts:

1. A strategy to become an agile manufacturing enterprise
2. A strategy to exploit agility to achieve competitive advantage
3. Integration of organisation, people, and technology
4. An interdisciplinary design methodology to achieve the integration of organisation, people and technology.

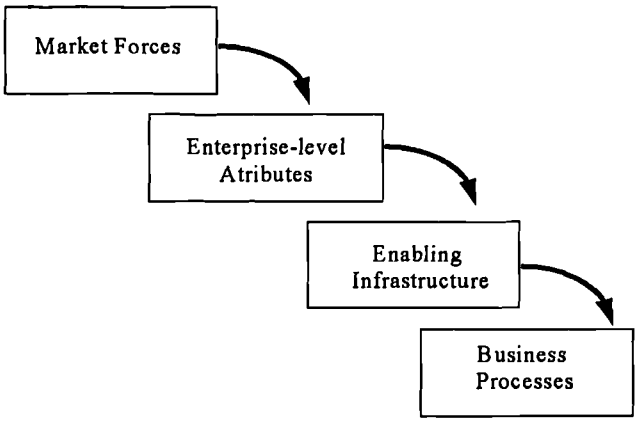

Figure 2.7. The Generic Model. [Preiss et al., 1996]

THE GENERIC MODEL

I. Market Forces Driving Business Change

1. Intensifying Competition
2. Fragmentation of Mass Markets
3. Cooperative Production Relationships
4. Evolving Customer Expectations

II. Enterprise-level Attributes

1. Solution Provider
2. Collaborative Operations
3. Adaptive Organisation
4. Knowledge-Driven Enterprise

III. Enabling Infrastructure

1. Interoperability
2. Reconfigurability
3. Flexibility

IV. Business Processes

1. Demand Identification or Creation
2. Product and Services Realisation
3. Demand Fulfilment
4. Enterprise management
5. Metrics

Figure 2.8. The Generic Model Factors [Preiss et al.]

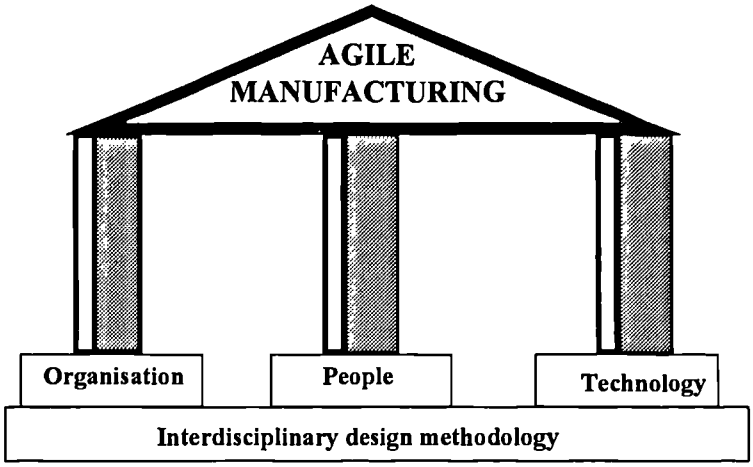

Figure 2.9 Agile manufacturing supporting by organisation, people and technology and founded on an interdiscipilinary design methodology. [Kidd, 1994]

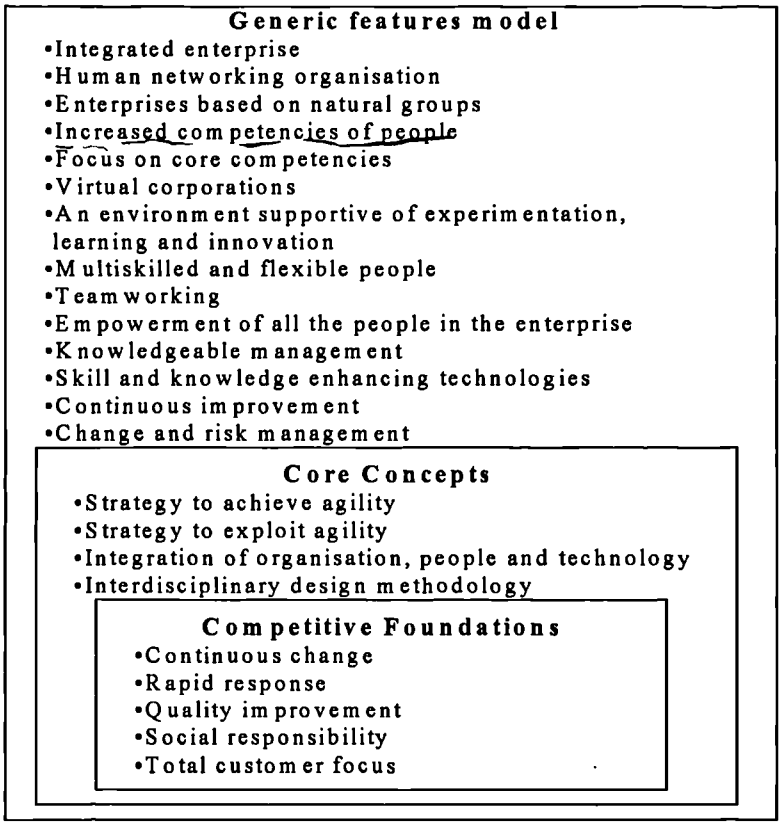

Figure 2.10. A conceptual framework for agile manufacturing [Kidd, 1994]

Kidd adds that the road to agility is lined with hundreds of methods and techniques. This is graphically shown in Figure 2.11.

Dove [1994], a member of the Iacocca Institute research group, defines agility in the simple phrase of: "being agile means being proficient at change." He finds the word agility very seductive, so that it receives immediate and personal definition from almost everyone. Dove presents a graphical form of this definition of agility, which is shown in Figure 2.12. According to Dove new organisational strategy of agile manufacturing is based on reusable, reconfigurable, and scaleable systems, which make change proficiency possible, and accommodate more new production with less new processes.

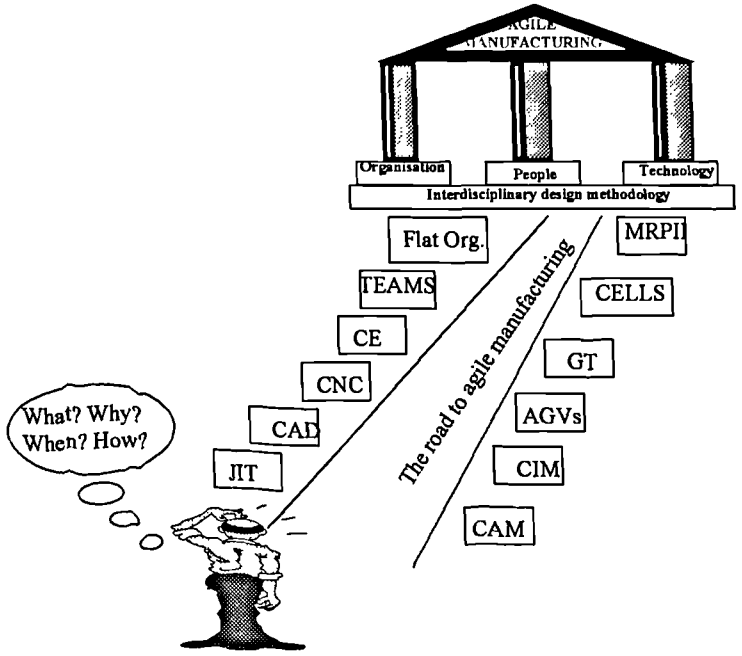

Figure 2.11. The road to agile manufacturing is lined with panaceas. [Kidd, 1995]

Dove lists the current challenge towards sustaining the ability of an organisation to thrive in an unpredictable business environment as illustrated in Figure 2.13. He also proposes two dimensions for agility, reactive and proactive. Dove in the form of practices that could be expected from systems with strategic purpose of reusability, reconfigurability, and scaleability observes some agile system principles. They are shown in Figure 2.14. Based on a survey of two hundred industrial organisations

during which high priority change-proficiency issues were ranked, a summary is presented by Dove [1996], which is depicted in Figure 2.15.

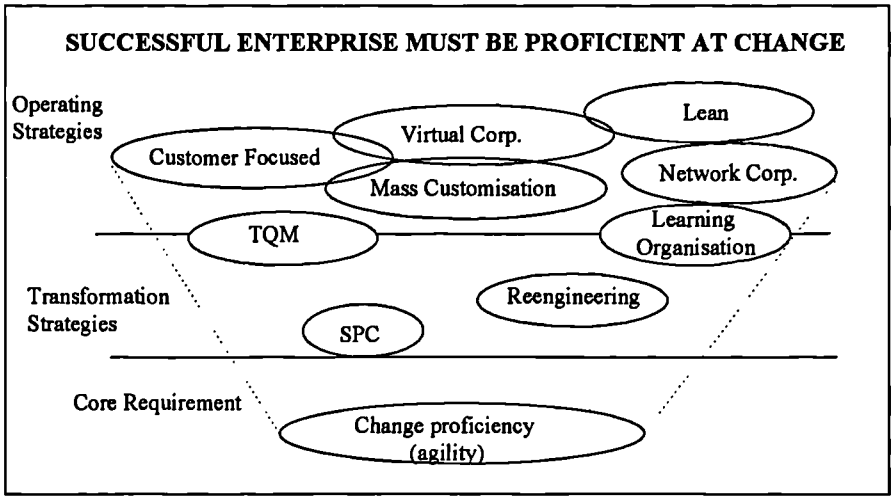

Figure 2.12. A graphical representation of agile manufacturing [Dove, 1994]

AGILITY	CURRENT CHALLENGES
The ability of an organisation	Product Realisation
to	Contract Agreement
Adapt Proficiency (Thrive)	Staff Up/Downsizing
in a	Technology Diffusion
Continuously changing,	Expedited Production
Unpredictable	Skill and Tool Training
Business Environment	Demand/Surge Tracking
	Organisational Learning
	Production Changeover
	Computer Virus Cleanup
	Small-Lot Manufacturing
	Business Reengineering
	New Process Installation
	Continuous Improvement
	Software System Upgrade
	Process/Equipment Failure

Figure 2.13. Current challenges towards sustaining agility [Dove, 1994].

Agile System Principles

Any organization of interacting units is a "system": an enterprise of business resources, a team of people, a cell of workstations, a contract of clauses, or a network of suppliers.

- Encapsulated Modularity
  The system is composed of distinct separable units that are capable of interacting with each other but are not intimately integrated. The internal workings of a module are unknown and unimportant to the external environment.
- Plug Compatibility
  Units within the system share a standardized compatible interaction framework.
- Non-Hierarchical Interaction
  Units within a system may communicate, negotiate, and interact freely and directly among themselves without concern for hierarchy.
- Dynamic Late Binding Relationships
  All relationships will be transient whenever possible; if permanent binding is required it will occur as late as possible in a relationship.
- Distributed Control & Information
  Units will respond to objectives rather than methods, decisions will be made at point of maximum knowledge, data and knowledge will be captured and retained locally but accessible globally.
- Self Organizing Unit Relationships
  Unit behaviors will include dynamic alliances and teaming, dynamic scheduling, open bidding, and other self-adapting techniques.
- Scalable Size
  Unrestricted unit populations can increase or decrease without restriction or limit.
- Unit Redundancy
  Duplicate unit types or capabilities that provide capacity fluctuation options and fault tolerance.
- Facilitated Unit Reusability
  Standardized unit replication information, unit modification tools, and accessible unit capability catalogs.
- Evolving Extensible Unit Framework
  Evolving, open system physical framework that accommodates any type of unit: legacy, common, or completely new.

Figure 2.14. Agility System Principles [Dove, 1995]

Table 1: Top Nine Change-Proficiency Issues in Four Industry Sectors
(Bold type shows sector-unique priority among four sectors - data from AMEF Q1-95 VOI survey)

Eight-Sector Average	Motor Vehicles	Electronics	Aerospace/Defense	Metal Products
Identify Opportunities	Evolve Culture	Improve Product Quality	Identify Opportunities	Identify Opportunities
Improve Product Quality	Improve Product Quality	Product Realization	**Add New Core Competency**	Improved Product Quality
Create New Ideas	Identify Opportunities	Identify Human Resource Needs	**Correct Customer Problems**	Create New Ideas
Product Realization	**Adaptable Process Tech.**	Acquire Human Resources	Product Realization	Acquire Human Resources
Acquire Human Resources	**Adaptable Teams**	**Identify Capital Needs**	**Adaptable Org. Structure**	Correct Supplier Training
Improve Cycle Time	Product Realization	Improve Cycle Time	Create New Ideas	Improve Cycle Time
Identify Human Resource Needs	**Evolve Organization Learning**	**Real-Time Worker Variation**	**Identify Core Comp. Needs**	Identify Human Resource Needs
Correct Customer Problems	**Create Strategy for Change**	**Surge in Product Development**	**Add Customer Relations Skills**	**Improve Product Cost**
Evolve Culture	Correct Supplier Training	Create New Ideas	Evolve Culture	**Continuous Learning**

Figure 2.15. Change Proficiency Issues [Dove, 1995]

Finally Dove proposed some critical business practices for agility in six areas: strategic planning, investment justification, organisational relationship, innovation management, knowledge management, and performance metrics. They are illustrated in Figure 2.16. Dove argues that if we can identify the critical set of business practices that determine our abilities to thrive in uncertainties, and measure our competency with these practices, we would have a powerful way to evaluate ourselves against the competitors, and a road map for improvement.

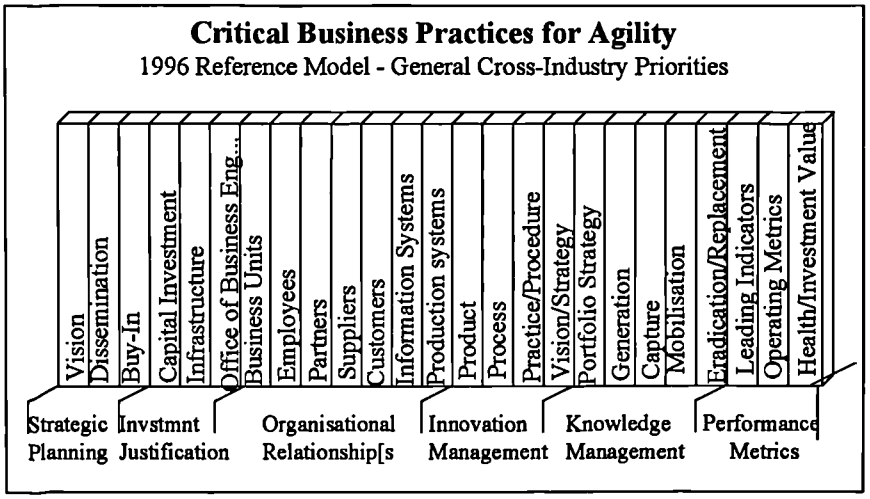

Figure 2.16. Critical Business Practices for Agility [Dove, 1996]

Montgomery and Levine [1996] assume that agile manufacturing is an adjunct to lean manufacturing and that agile manufacturing is built on a foundation of some, but not all of the practices common to lean manufacturing. Agile manufacturing and lean manufacturing are differentiated by the time factor, which is critical in agile manufacturing. According to Montgomery and Levine [1996] agile manufacturing is based on a central integration of people, technology, and organisation/business elements. This integration is referred to as alignment. Denying the widely emphasised impact and importance of virtual organisation as a main element of agile manufacturing due to its being still premature, the two workers defined the components of agile manufacturing system as those shown in Table 2.4. The table is a

list of technical capabilities that must be enhanced in the aligned (integrated) form of the manufacturing.

Component	Description
Small batch size	Maintain small production runs.
Minimal buffer stock	Reduce buffer inventories to expose system problems.
Total quality control	Catch and correct errors at the source; avoid final inspections. Workers assume responsibility for quality.
Elimination of waste	Dispense with any activities not directly related to production. Use the minimum amount of time, equipment, parts, space, tools, and so on that add value to the product.
Setup reduction	Reduce work that must be done when machinery is stopped. Eliminate adjustments, simplify attachment and detachment. Train and practice to minimize time requirements.
Redesign of workflow	Adopt a product-oriented, rather than a process-oriented layout. Eliminate unnecessary transportation, work-in-process buffers, multiple handling of materials.
Improved work processes	Adopt cell manufacturing and statistical process control. Analyze and improve process routes. Obtain worker ideas for continuing improvements.
Visual control	Adopt line stop systems, trouble lights, production control boards, foolproof mechanisms, control charts.
Preventive maintenance	Have operators perform routine repairs and maintenance. Have maintenance staff support operators and perform difficult maintenance and repair.
Leveled/mixed production	Maintain steady rate of output using different product mix.
Reduced cycle time	Balance operator time utilization, reduce time needed to complete product.
Kanban system	Use kanban cards to pull products through system.
Continuous improvement	Employees find better ways to improve work processes.

Table 2.4. Components of the agile manufacturing system [Montgomery and Levine, 1996]

Booth [1996] recognises agile manufacturing as a concept emerging due to the changing circumstances of business. The turbulent and changing circumstances require a manufacturing business, which is able not only to produce in volume but also to deliver products to a wide variety of market niches simultaneously. Emphasising that agility begins with strategy, Booth proposes a path to agility, which is shown in Figure 2.17. The transition to agile manufacturing from mass production encompasses lean production and time-based competition, which will be reached by increasing flexibility and responsiveness of a company to a certain level. According to Booth, agility must be approached by changes in three aspects: organisation, by organising around processes and reforming the framework of performance measures; people's working methods, by forming concurrent teams or operating cells; and information systems, by radical improvement in utilising information systems in automation of middle management functions.

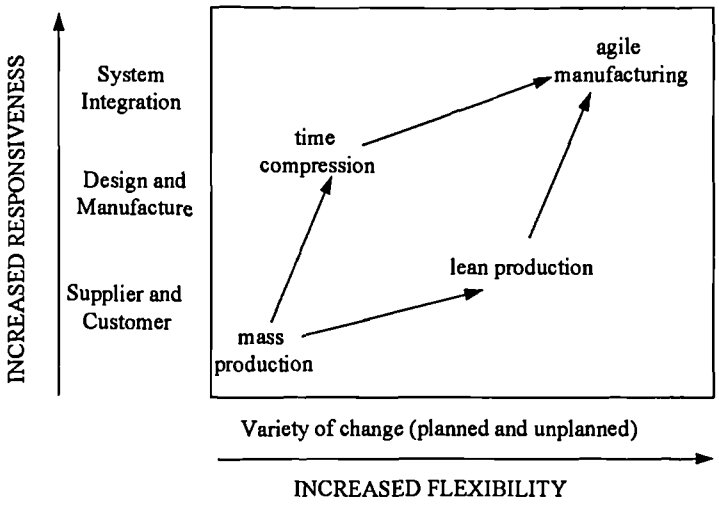

Figure 2.17. The path to agility. [Booth, 1996]

Youssef [1992] likens agility almost synonymous to speed, and suggests three pillars of achieving speed as: customers, internal capabilities, and suppliers. He proposes a model for agile manufacturing as illustrated in Figure 2.18. Youssef [1992] also extends the definition of agile manufacturing from the Iacocca Institute by interpreting

the main attributes of agile manufacturing as follows : (the italics represent Youssef's remarks)

> .... A manufacturing system with extraordinary capabilities (*internal capabilities, hard and soft technologies, human resources, educated management, information*) to meet the rapidly changing needs of the marketplace (*speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness*). A system that can shift quickly (*speed, and responsiveness*) among product models or between products lines (*flexibility*), ideally in real-time response to customer demand (customer needs and wants).

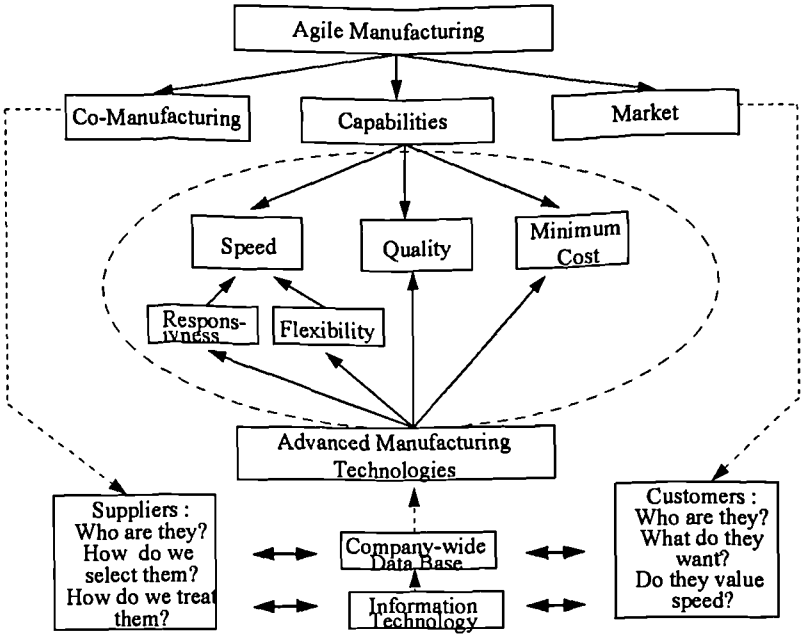

Figure 2.18. Model of agile manufacturing. [Youssef, 1992]

Hilton and Gill [1994] who reported the findings of a benchmark study conducted by Arthur D. Little Inc. define agile manufacturing as the ability to create and produce customised products economically in small lots.

Kumar and Motwani [1995] define agility as a firm's ability to accelerate the activities on critical path, and conclude that agility is a direct indicator of a firm's time-based competitiveness. However they differentiate between time and agility, by putting agility as the representative of how fast activities are completed, while time is the elapsing time in completing activities.

Ward [1994] claims that agile manufacturing is the first proactive national (American) business strategy that has ever emerged. Ward defines agile manufacturing after Dove as the ability of a company to thrive in an environment of continuous and unpredictable change.

Gehani [1995] highlights time as a critical factor of competitiveness, and takes agility as the ability of a company for time-based competition. He defines abilities such as : quickly satisfying customised orders; introducing new product frequently in a timely manner; and getting in and out of strategic alliances speedily, as main requirements of agility. An illustration of the interdependence of tactical and strategic time-based decisions towards agility and competitiveness performance is given which is demonstrated in Figure 2.19. Gehani also classifies the actions to be taken for implementing agility-based strategy in the following areas: empowerment for front-line decision making; cross-functional team sharing; modular integration of available technologies; delayed design specification; product succession planning; and enterprise-wide integration of learning.

Vastag et al. [1994] view agile manufacturing as the convergence of time-based competition and flexibility. According to them agile manufacturing hinges on streamlining organisations with a strategic focus, enhancing integral integration, and re-evaluating company's culture. The key drivers of agile manufacturing were thought to be new product development and customer services.

Tracy [1994] in reporting research into achieving agile manufacturing in the automotive industry defines the agile manufacturer as: "Fastest to market, with lowest total cost and the greatest ability to meet varied customer requirements. The final measure is the ability to "delight" the customer."

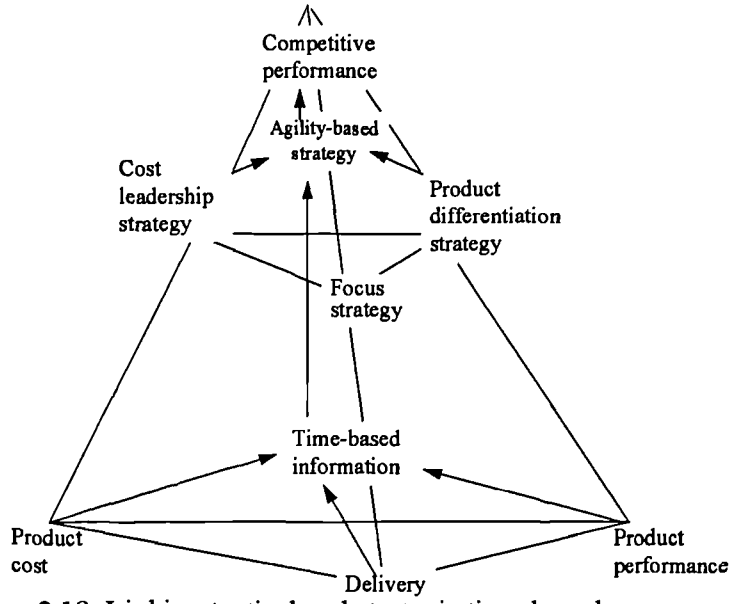

Figure 2.19. Linking tactical and strategic time-based management [Gehani, 1995]

Noaker [1994] proposes a definition for agility which is: "The measure of a manufacturer's ability to react fast to sudden, unpredictable changes in customers' demand for its products and services and make a profit.

Studying the tremendous increasing pressures on manufacturing, Ross [1994] argues that in the next century companies adopting agile manufacturing will accommodate pressure on manufacturing in certain industries. He views agile manufacturing as the natural evolutionary confluence of three key business concepts, enabled by a fourth. These key concepts are : flexible manufacturing; integrated product development; and strategic partnering. In the heart of this new structure of business, as Ross argues, is the key concept of virtual organisation as the fourth constituting concept of agility which enables different companies to work together. According to Ross, the concept of agile manufacturing is based on the need to meet successfully the requirements of market, for which the manufacturer must provide innovative, often customised products with the flexibility to adjust the products and deliver rapidly, and with high level of efficiency to remain competitive. The concept will be materialised through the utilisation of information and in particular those of CALS, as a proven tool for promotion of information sharing and enhancing integration.

Burges [1994], based on the work of Doll and Vonderembse, introduced a stage model of IT's ability to enable major organisational change with specific connections to agile manufacturing. This is shown in Table 2.5.

IT enabled process	Manufacturing outcome
Level 1 : Localised exploitation	Island of automation
Level 2: Internal integration	Computer integrated manufacture
Level 3 : Business process redesign	Agile manufacturing enterprise
Level 4 : Business network redesign	Virtual agile enterprise
Level 5 : Business scope redefinition	Redefined virtual agile enterprise

Table 2.5. Linking IT-enabled processes to manufacturing outcomes. [Burges, 1994]

Puttick and Gillis [1993] in reporting the findings of the EUREKA project "factory for the future", sponsored by the UK and French governments, indicate agility as one necessary condition for the establishment of the future factory and associate agility with the rapid changing factors or drivers that affect the business.

Sanderson et al. [1994], introducing a project at Rensselaer Polytechnic Institute called EAMRI (Electronic Agile Manufacturing Research Institute), view agile manufacturing as a method to provide a framework for the improvement of manufacturing productivity and quality through the integration of organisations, technologies, and information resources. The authors point to the methods such as FMS, and concurrent engineering as means by which significant improvements have been achieved in manufacturing productivity. It is suggested that the demand for global competition have brought about issues such as the coordination of customers, suppliers, contract designers, contract manufacturers, and the information infrastructure to support these interaction, in the focus of new innovations to further improve the ability of manufacturing enterprises to compete at the global level. A frame for agile manufacturing enterprise is suggested by the research group, which is shown in Figure 2.20. They also introduce multipath agility as one extended concept for agility to encompass the access to alternative resources and information pathways, which are available due to the improvements in information infrastructure. As illustrated in Figure 2.21, improved throughput is achieved not by shortening the

response of individual entities of a single path, but by selecting alternative routes to maximise the responsiveness of the whole process.

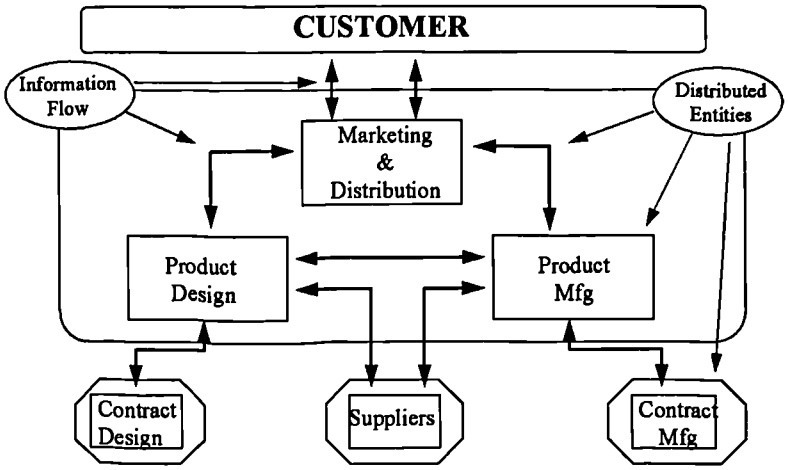

Figure 2.20. Agile Manufactruing Enterprise
[Sanderson, et. al, 1994]

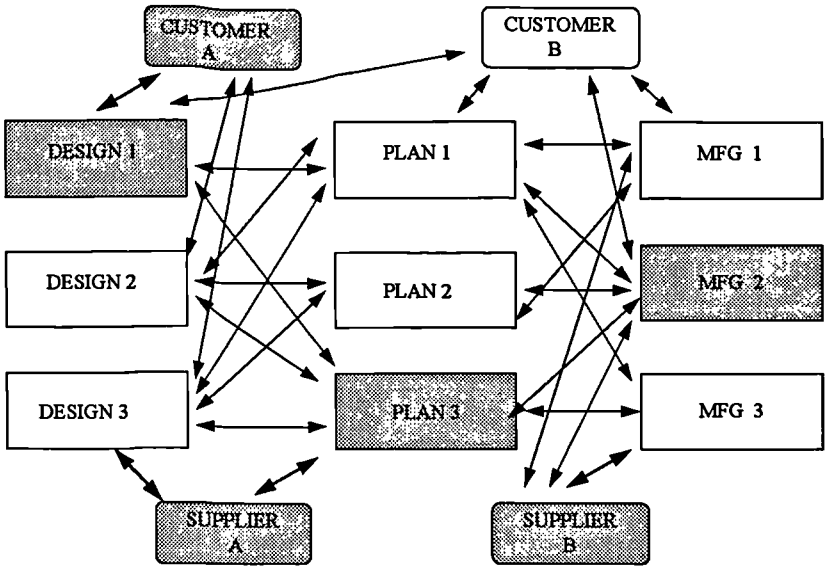

Figure 2.21. Multipath agility through improved access to alternative resources and selection of information sources [Sanderson et al., 1994]

Reid et al. [1996] in exploring the concept of virtual organisation and the mechanisms involved in operating this type of cooperation, indicate some operating characteristics or skills that agile firms typically exhibit. These include: sensing and anticipating change; learning and improving the organisation; adaptability; resilience or the ability to recover from changes; quickness; innovation; flexibility; concurrency; and efficiency. They argue that fully integrated firms, yet operating in a decentralised manner are more likely to demonstrate these characteristics.

2.5.3 Discussion of the Reported Works on Agile Manufacturing

As a new concept, which was erected against the threatening business circumstances, agile manufacturing has been examined widely . However, as it can be found in the previous section from the reported works on the subject, the domain of issues concerned within the context of agile manufacturing is so dispersed, many of which are only speculations of the circumstances observed in the business environment. Exploratory efforts towards conceptualising the subject and providing definitions mostly have stopped at a general level, giving theoretical and in some cases Utopian expressions of agility. Using the same arguments, terms and terminology as many other prevailing classes of thought in the manufacturing management area such as FMS, Lean Manufacturing, JIT, CIM, Integration, etc. has been common amongst most works on agile manufacturing. This resemblance could have easily been interpreted as saying old things in new words, which has been tried by some critics of the concept. However, distinguished works may be addressed which have relatively settled the dilemma of taking agile manufacturing as a serious matter with new vision over the whole business of manufacturing. The core difference between the idea of agile manufacturing and other similar concepts is that agile manufacturing concerns seriously the matter of changes in the business environment and the time frame of responding appropriately to changes.

The same argument goes to the frames, frameworks, and practical approaches, which have been suggested for agile manufacturing. Although some of the proposed ideas about agile manufacturing are based on realities extracted from studying the business of the manufacturers in research programmes, it is not convenient to find convincingly

empirical-based works that address the factors pertaining to real business and provide sufficient quantitative or analytic study of those factors.

The review of literature suggests few areas in which the subject of agile manufacturing can be framed in order to obtain a realistic, comprehensive and applicable insight into the subject. These are: the core concept of agility or agile manufacturing; the structure of the concept; and the practical approach or methodology in pursuit of agile characteristic. Some discussions are hereby provided to clarify the stance of the literature in these areas.

Agility Concept

The original workers such as Iacocca Institute [1991], Goldman et al. [1995], and Preiss et al. [1996] have put forward some basic elements, which exhibit the newly born phenomenon of agile manufacturing as a distinguishable idea. Also Dove [1995] has presented a simple and straightforward definition for agility as "being change proficient". However, despite the above points it seems that the overall context of agility is still immature and in specific terms suffers from the lack of direct ideas and perceptions of manufacturers. In forming the concept and conceptualising the original idea of agile manufacturing, many works have gone astray to provide or add only some concepts from the past to the basic ideas of the originators. Example can be given when agility is expressed by an obsessive overemphasis on integration or solely taken as integration of some basic elements of an organisation. Also finding agility as an extension to MRPII or TQM are other misinterpretations, which can be added to other cases such as taking it synonymous to speed, customer satisfaction, etc. However, conceptually it can be said that a concrete theoretical basis is founded for agility which is not disputed and it is: a new business environment is emerging with change as one of its major characteristic, within which prosperity is possible only through responding appropriately to changes, and taking advantage of changes.

There are agendas with regard to the concept of agile manufacturing about which the literature has remained silent or only paid superficial attention to. One of these aspects is the question whether agility is a necessity for every business and in every circumstance, and also what the dimensions are to which agility could be extended in

different organisations and different circumstances. Although Goldman et al. [1995] have dealt with this side of the concept; no specific proposal is made in this regard. Preiss et al. [1996], James-Moore [1996], Tracy [1994] and Dove [1995] have noticed the point of necessity and dimension of agility for different organisations and measuring them, however only Dove has put forward a structure for this purpose.

Structure

A concept to be understood properly and exploited further needs to be expressed in a structured way using realistic terms. According to the available literature, efforts in exploiting the concept of agile manufacturing have generally been directed in this way, but seemingly most of the introduced works lack sufficient details to satisfy the aim of translating the concept into a structured frame.

The original work of Iacocca Institute has defined an integrated form of some organisational elements as the structure for an agile business, which must be equipped with a series of attributes to respond to the competitive foundation. Goldman et al. [1995] have analysed and extended the same structure by adding the important dimension of virtual organisation and cooperation. Kidd [1995] has stressed the importance of strategic intent in the same frame as suggested by the originators, still giving a blur vision of what agile manufacturing is in real world.

Works by Dove [1995, 1996] gave new and substantial dimensions to the concept in terms of structure, but still remained disabled in translating the core concept of agility into a fact-based structure. Defining pressures in the business environment as pushing forces for becoming agile and reorganising the attributes and practices, and suggesting a path to destine the future of the organisation are valuable aspects of Dove's work. However, it seems that the proposal of Dove have turned somehow complicated as a way in following the path for achieving agility in an organisation.

Attempts by Preiss et al. [1996] provided a clearer vision and proposed a generic model, which conveyed the concept in a more realistic way. Originating the concept's structure with a series of drivers to which the organisation must respond, and proposing a few steps from enterprise-level attributes to business processes justify the

model to be judged as the most straight proposed structure yet with regard to agility. The work, however, tends to be somehow futuristic where concepts such as "solution providers" and "knowledge-driven enterprise" are inserted in the model as some accepted values and even measures.

Other works that could be found in this line of research have not made significant contribution to the subject and have not added much to the few works previously mentioned. However, they have shed light on some facts and factors, which were considered marginally elsewhere. Youssef [1992] though expressed the concept of agility synonymous to speed, proposed a model (Figure 2.18) which represents an advanced form of manufacturing resulting from taking in flexibility, speed, quality and minimum cost as capabilities which in turn depend on advanced manufacturing technology. However, Youssef's model does not consider the drivers in response to which agility can be defined.

Booth's work [1996] gives a novel structural view of agility that is basically the utter point of both responsiveness and flexibility. In practice Booth has expressed agility as the result of combining lean production and time compression, but the proposal stops at this level.

Most of other proposals in suggesting a structure for agility could be categorised in the frame of the above-mentioned cases. Each of these works, however, has placed emphasis on a certain domain or point. The practical project of EAMRI, which is directed and reported by Sanderson et al. [1994] does not go much farther than expressing agile manufacturing as the integration of organisation, technology, and information resources. The proposed model for agile manufacturing enterprise by Sanderson et al. as given in Figures 2.20 and 2.21 depict the ordinary form of an organisation with unlimited interrelationships which apparently should be managed by integrating the whole system.

Practical Approach

The literature does not appear to be helpful in this way either. As for a relatively new concept it might be natural to take a long time to find it in practice with a handful of

support for application in organisations, however, the reported works which date back to 1990 do not seem to have dealt with this agenda seriously yet.

The original research of Iacocca Institute [1991], which was later transformed to "agility Forum", was followed to practice some identified aspects of agile manufacturing in manufacturing companies. Most of these attempts, as could be traced in the Agility Forum's Web Site, are application of certain practices or methods in collaborating partners of the research programme.

Among the works reviewed in section 2.3.1, only proposals by Dove [1995, 1996] and Preiss et al. [1996] could be pointed out as valuable practical approaches to agility. Dove's proposed infrastructure contains elements of a practical approach, which can be used as a decent basis for designing a movement towards agility. However, the work is not followed further to introduce a practical and factual approach.

Preiss et al. have tried to translate their proposed generic model into a practical frame, which is briefly introduced in the appendix of their work. The proposed approach is basically a preliminary show of the way that the model could be set into practice using some standard forms.

Summary

In summary, agile manufacturing as a newly developed concept needs to be exploited to make it stand as a new philosophy for manufacturing. Areas, which seem to need more work, are identified to be:

- The meaning of the concept in real world of business and the kind of perceptions it could receive from manufacturing organisations.
- Which organisation and in what circumstances need to be agile.
- What are the extents to which an organisation may need to be agile?
- How strategies in support of becoming agile could be designed and devised.
- How agility could be translated to a simply understandable and clearly structured form.

- How agility concept could be put into practice in terms of factors which manufacturing organisations deal with in their real business.

2.5.4 Agile Manufacturing VS. Lean Manufacturing and Flexibility

As Chester [1996] argues, certainly no competent strategist would argue against any enterprise, manufacturing or otherwise, becoming agile. However agile manufacturing is not sufficiently distinguished from the admittedly related forms of flexible, virtual, and lean manufacturing?

Taking agile manufacturing for time-based competition, flexibility or FMS, integrated factory, lean manufacturing, mass-customisation, and virtual organisation is a common approach that can be easily traced in the previous sections of this chapter, when reviewing different views and ideas about agile manufacturing. However, the concept as introduced by the originators would not be limited to the prevailing concepts named above as equivalents.

Chester [1996], restated that FMS, virtual organisation (not virtual manufacturing which refers to simulation of the manufacturing process), reengineering, and in particular lean manufacturing are all proven facilitators of a successful management of manufacturing and business. However, he argues that whereas these methods have been generally created by concentrating mostly on mechanics of the factory floor, losing sight of customer and competitors, they cannot be taken for the concept of agile manufacturing. He proposes another interpretation of an agile manufacturer which goes as: "A lean producer that has extended the concept to improve its ability to function as an open system (observer), change its worldview accordingly (orient), and make timely and effective decisions.

Preiss [1997], using analogies between physical systems, such as bridges and electric circuits, suggests a terminology for differentiating mass production, lean manufacturing, and agile manufacturing. According to Preiss, the move from mass production and marketing to agile manufacturing is a strategic, inexorable change in system characteristics from uncoupled systems to dynamic, coupled system. He recasts the words craft, mass, lean and agile as:

- Craft - dynamic, decoupled system
- Mass - Static, decoupled system
- Lean - Static, coupled system
- Agile - Dynamic, coupled system

Based on this terminology he defines the following terms:

- To be lean is a capability of a system that may or may not have coupled demands made upon it.
- To be agile is a capability of a system that may or may not have dynamic demands made upon it.

He concludes that lean or agile properties are what a system could obtain when needed, and that any one company can be operated in different modes - mass, lean or agile - at different times.

Ward [1994] in finding the difference between the words lean and agile, defines them in this way: "a lean company may be thought of as a very productive and cost efficient producer of goods or services, and an agile company is primarily characterised as a very fast and efficient learning organisation if it was not first a productive and cost efficient."

Baker [1996] raises the same problem in the literature of agile manufacturing and attempts to resolve the confusion of flexibility and agility. Based on a typology of flexibility in manufacturing proposed by Slack [1987] including level, type, and dimension, Baker [1996] adds two levels of flexibility to Slack's model which are organisation flexibility (or strategic flexibility), and business network flexibility (a network comprising the company and its customers, suppliers and partners). He also extends the two dimensions of range and response from the Slack's model to the new added levels, and introduces an extended framework, which is shown in Figure 2.22. The model puts agile manufacturing as a higher level over flexibility where strategic views and network of relations are the issues to be considered in managing the manufacturing.

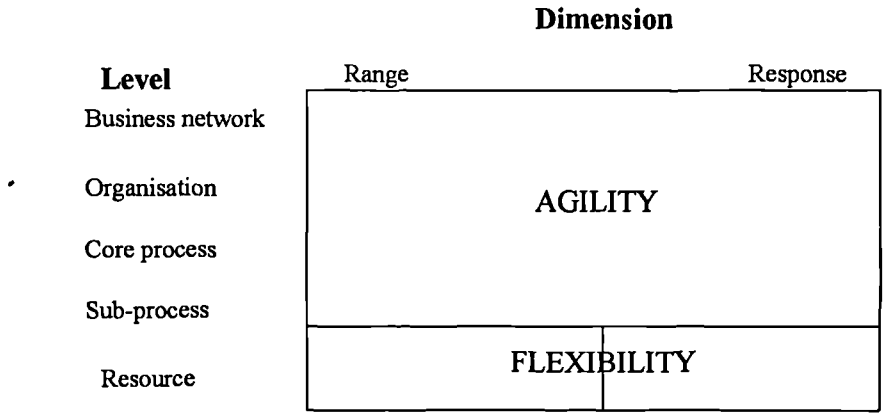

Figure 2.22. Agility vs. Flexibility. [Baker, 1996]

2.5.5 Measuring agility

As a newly emerging concept, agile manufacturing is still under the challenge of theoretical discussions and practical examinations. Some workers have marginally discussed measuring agility for both the need for it and the position of the company.

Preiss [1997] believes that different companies will create different structures. Using the analogy of earthquake, he argues that it is meaningless to say "the structure is earthquake resistant." This should be rephrased " the structure can resist earthquake up to Richter 7.0 level". Similarly, it is meaningless to say, "the company is agile". One must specify which dynamic characteristics can be dealt with and what the scope and magnitude of the change is, rather than use the all-embracing term "agile". This in fact is an invitation to work for a more rigorous method in measuring agility when approaching it.

James-Moore [1996] suggests that a varying level of agility is required by different market sectors. He adds that to develop this perhaps an agility index could be developed covering issues such as production uniqueness, volume, quality, speed to delivery and cost. Then he argues that, if this is possible, companies should consider how agile they need to be when developing manufacturing strategies for the future.

Tracy [1994] also considers the issue of measuring the agility of a company. They suggest that understanding how agile a manufacturer is, could only be accomplished through benchmarking.

The subject is also exploited by Dove [1995, 1996] based on the definition he has for agility. According to Dove, being agile means being a master of change and based on this he suggests that how agile a company or any of its constituent elements is, is a function of both opportunity management (reactive strategy) and innovation management (proactive management) - one brings robust reliability and the other brings preemptive leadership. Raising the question of how much of each is needed at any time, he relates the answer to the dynamics of the competitive environment. He believes that a company must be as agile as the competition requires, though recommends being more agile as a great advantage. In trying to quantify the concept he puts forward the grid shown in the Figure 2.23. Considering the constraints in quantifying concepts such as agility, Dove suggests to first ask how well the company respond to critical types of unexpected situations, how often the company leads with meaningful innovation, and how proficient is the company at a variety of identified changes which are felt strategically important. The grid, however, can only be used qualitatively, by locating the company in the agile space and then determining the point it wants to go.

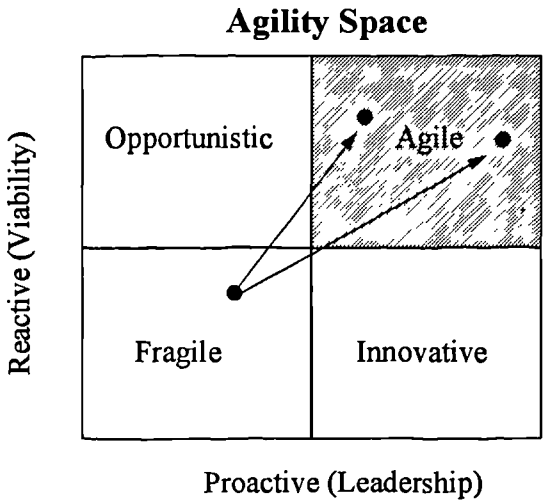

Figure 2.23. Agility Measuring Grid. [Dove, 1996]

Kumar and Motwani [1995] who define agility as the speed and the ability to accelerate the activities suggest a strategic framework or rather a methodology for determining agility index of a firm. The methodology, which basically is aimed at determining the time-based competitiveness of a manufacturing company, uses an agility matrix whose cells represent all combinations of time-segments and agility-determinant. An indicator called the agility index is finally derived from the matrix that indicates the effectiveness of a firm to compete on time. The matrix is illustrated in Figure 2.24.

			Time segments				
			Product design and engineering	Prototyping and process development	Production	Manufacturing	Delivery
Factors	Sub-factors	Agility weight	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
			W1	W2	W3	W4	W5
Material and information flow discipline	Pull system	U11					
	Product or cellular layout	U12					
	Minimal sourcing	U13					
State of technology	Computer-aided technology	U21					
	Flexible manufacturing systems	U22					
	Agile manufacturing systems	U23					
	Information technology	U24					
	Integrated database	U25					
Specialized functions	Concurrent engineering	U31					
	Group technology	U32					
	DFMA	U33					
	Design and process optimization	U34					
Human resource factors	Training and education	U41					
	Employee empowerment	U42					
	Flexibility of workforce	U43					
	Number of hierarchical levels	U44					
	Flexible information flow	U45					
Quality	Quality function deployment	U51					
	Statistical quality control	U52					
Flexibility	Product and process innovation	U61					
	Economies of scope	U62					
	Process flexibility	U63					
	Program flexibility	U64					

Figure 2.24. The Agility Matrix [Kumar and Mutwani, 1995]

SUMMARY OF THE CHAPTER

Chapter two provided a review of the literature pertaining to the subject of agile manufacturing. The chapter is virtually presented in two parts. Part one presents a historical view of the evolution of manufacturing business and its associated concepts and systems, and in part two the limited number of available works in the area of agile manufacturing are reviewed and critically investigated. The work carried out constitutes a major part of the required investigation in order to achieve the first objective of the research. In the next chapter preliminary empirical studies will be carried out to complement the efforts of this chapter and fulfil the achievement of the objective one of the research. Some conclusions could be drawn as the summary of the findings achieved in this chapter, which are as follow;

1. The evolution of business systems has arrived at another new era in which success and survival is difficult to ensure.
2. The main characteristic of the new era of business is unpredictable and unprecedented changes in the business environment.

3. The prevailing panaceas, which used to be prescribed to achieve competitive advantage, are no longer valid in their original forms considering the changing circumstances.
4. Business strategic priorities have evolved from once cost-based only to a combination of several factors including time and responsiveness.
5. Understanding the dynamics of the new circumstances of business and strategic aligning of the systems to the new conditions are vital for success.
6. Agile manufacturing is being proposed as the response to the new order of the world business.
7. Agile manufacturing, as a new agenda in manufacturing, needs further exploitation and explorations to become a viable theory for manufacturing. Areas such as the concept of agility or agile manufacturing, structure of agile manufacturing systems, and methodology for achieving agility in manufacturing organisations are more concerned. The existing works in these areas do not provide sufficient support for the concept to become reality for organisations.
8. The need of an organisation for agility and its level of agility are important issues, which must be considered in developing any practical approach towards agility.
9. Pressures in the business environment of an organisation are the main cause for becoming and acting agile. These forces drive organisations to move towards agility. The driving forces could be in any form and from various origins, predicted or unprecedented.
10. Strategy of an organisation must be adjusted to the new understanding of the ongoing trend of change in the business systems and towards becoming agile.
11. Attributes or characteristics of an agile organisation could be achieved through acquisition of some strategic abilities.
12. Integration (organisational and technological), and utilisation of information systems/technology are vastly recommended as important actions in approaching agility.

CHAPTER THREE

PRELIMINARY INVESTIGATION OF AGILITY CONCEPT AND PRACTICES IN MANUFACTURING ORGANISATIONS

3.1 INTRODUCTION

The review of literature in the area of the research subject, as reported in the previous chapter, led the author to realise that the establishment of a foundation to pursue the first objective of the research would be more practical if the understandings from the literature are complemented by observation of the real world and the experiences of industry.

An empirical study at a pilot level was conducted to provide some data and information about the subject, and to examine the comprehended general views from literature in practice. Also a preliminary validation of the assumed hypotheses of the research, and hence gaining some support from industry for continuation of the research work was also of concern in this attempt. The empirical study was based on some understandings and conclusions from the works published to date in the research area. A short questionnaire was sent to a number of manufacturing companies, followed by six preliminary (mini) case studies in the form of semi-structured interviews with company managers and directors.

The major concerns of the pilot study consisted of: examination of the fundamental concepts of agility; study of the perception and awareness of agility in UK manufacturing factories; study of the importance of agile manufacturing and its elements in individual organisations; and investigation of the difference in the level of agility in different types of companies.

The results especially those achieved in the preliminary case study phase proved to be very useful and informative, and effectively facilitated the formation of a conceptual model which will be described in the next chapter. This chapter will briefly report the details of the pilot empirical study.

3.2. PILOT SURVEY

Study of the literature related to agile manufacturing showed that not much work has been carried out in this area, especially at empirical levels. Most work was either philosophical approaches or review of the previous concepts in a different way. Almost no academic work was reported in the UK and the subject seemed basically to be a novel idea to the UK manufacturing organisations and also academics.

In order to obtain further insight into the subject and provide a platform for achieving the objectives of the research, it was found necessary to examine the ideas compiled during the literature survey in practice by studying real experiences and evidences in manufacturing companies. The findings from the practice-based study together with the understandings from the literature then could be rearranged and converted into a model for understanding and outlining agile manufacturing.

As it was discussed in chapter 2 (section 2.5.3), the background for the research subject in literature has been brief and with shortcomings in some areas. Some important aspects, which have not been sufficiently addressed in the literature, were considered to be the subject of a preliminary empirical study. The concerned issues included: the perception of real contenders of the competition battlefield especially those from the UK; the strategies with which manufacturers respond to the stimulation from the business environment (to examine the strategic aspects of agility); the structure of an organisation and areas from which the appropriate responses should be originated (to study the typical responses in an organisational level); and the kind of practices adopted in response to harsh and unpredicted changes in the business environment (to identify the practices related to agility and compare them with those discussed in the literature).

After precise examination of the situation and reference to the research methodologies in the same areas it was decided that a pilot survey would be a suitable means to start the exploitation of the research subject. For this purpose, thirty companies were selected most of which were in contact with the University's research and training programmes including Teaching Company Scheme (TCS) and Product Innovation and Development Centre (PIDC). Availability of information about these companies and

their business situation in the mentioned centres of the University would have provided the opportunity to choose the companies with certain criteria in order to obtain better results. These criteria included the companies' size (at least 200 employees), performance and relative success of the companies in the marketplace and competition, and the companies' business environment (for being challenging and highly competitive). A questionnaire, which comprised the following parts, was sent to the targeted companies:

1. Company profile
2. Company's business environment, strategy, manufacturing characteristics
3. Basic concepts of agile manufacturing
4. Information system

The questionnaire was designed to be as simple and brief as possible. As the subject was new to the surveyed companies it was titled as "responsiveness in manufacturing organisations". However, an explanatory sheet was provided to explain the idea and the aims behind the survey, specifying the main target of the research as agile manufacturing. Also some simple definitions were used to clarify the phenomenon for the respondents. A sample of the questionnaire is exhibited in appendix A. The questionnaire followed the structure mentioned above and sought answers to some of the questions raised before.

In response, thirteen completed questionnaires were received. The responding companies which mainly were UK-owned manufacturers were distributed among many sectors including aerospace, chemical, medical equipment, ATM (electro-mechanical), machinery and tools, and engineering.

The results from a quick analysis of the returned questionnaires provided the following facts and figures. The business priorities for the average respondents were quality, sales, cost, time, and flexibility as expected. The surveyed sample gave an average score of 8.5 out of 10 (= highly important) for the importance of changing and being responsive to the changes in the business environment. However, the awareness of the agility concept on average was not scored more than 4.5 out of 10 (= completely familiar). This was interpreted as due to the novelty of the concept to

the manufacturing companies. This result was already expected, however it is necessary to mention that the concept was carefully defined and put into question so that its fundamentals could be conveniently understood by the surveyed companies.

Most of the respondents indicated a good above medium level of responsiveness for their companies, which was introduced as a synonym for agility in the questionnaire. 6.8 out of 10 (highly responsive) was the average of the responding companies' responsiveness based on the provided definition in the questionnaire.

Responses from companies with regard to drivers of agility (responsiveness) in terms of external drivers and internal drivers are summarised in Tables 3.1 and 3.2.

In another part, where the companies were asked about the providers of agility and the areas that these providers could origin from, respondents provided the information as depicted in Table 3.3. People and practices aiming at leveraging, empowering and valuing people were the most concerned areas. Innovation and continuous change at all levels of the organisation as a strategic plan is found to be the second important area followed by organisation and technology as other areas to be considered in providing the necessary facilitators of being agile and responsive.

Also in answering a question about the importance and the role of integration in achieving responsiveness (agility) the respondents put a high emphasis of 8.2 out of 10 (= highly important) on the issue.

Studying the extent of utilisation of information system/technology was also considered in the questionnaire. The following points can be extracted as the result:

- 70% of the responding companies used some sort of information management plan or model,
- 78% of the respondents were using Management Information System (MIS) and Manufacturing Information System,
- Interface and access of external users such as customers and suppliers to the companies' information system was very low on average (2.3 out of 10, where 10 = complete interface),

- An average level of about 5 out of 10 was appointed as the extent to which the following factors with regard to information system/technology were considered by the respondents:
    - Sufficient information technology,
    - Using facilities and tools to access external information,
    - Using tools for capturing customers' information and requirements.

External Drivers	Mean rank of influence on the company's business . From 1= Not important to 10= Highly important
Turbulence of the environment (marketplace)	7.5
Various changes in competition bases and criterion	7.5
Fast changes and improvements in technology	5.8
Ever-changing customers requirements	6.7

Table 3.1. External drivers for agility and their influence on the surveyed Companies' business

Internal Drivers
• Being perceived as innovator
• Continuous improvement
• Squeeze on margins
• Loss of technical differentiation advantage
• Capital investment
• TQM
• Keeping people employed (Investment In People, IIP)
• Urgency culture (family business)
• Policy of successful continuity

Table 3.2. Internal drivers for agility. Comments from the respondents

Agility providing areas	Mean rank of importance 1= Not important 10= Highly important
People	7.9
Innovation and change	7.1
Organisation	6.8
Technology	5.8

Table 3.3. Agility providing areas indicated as important by the respondents

Another aim of the pilot survey that was looking for contributing firms for conducting detailed case studies (in the form of interviews) was achieved successfully. Ten of the respondents accepted involvement in the next stage, case study.

3.3 MINI CASE STUDIES

The analysis of the returned questionnaires provided only some superficial aspects of the subject. So it was quite essential to follow the attempt with some in-depth study of the manufacturing companies in order to obtain more constructive and decisive information for the development of a conceptual model for agile manufacturing.

Six companies from the surveyed sample were chosen to carry out further study and investigation into the research subject. These companies had accepted to participate in the next stage of the research and mainly were characterised as successful companies (a good market share and prospect for the future) which were competing in a turbulent business environment including harsh competition in the market, frequent and unpredicted changes in customer requirements, etc.. The criteria for selecting the case companies were examined based on the information provided from the questionnaire survey.

An introduction to the subject, definitions, and outcomes of the pilot survey was sent to the contact person in each company together with a semi-structured questionnaire for interview. During an average of two hours, the respondents were interviewed. In

most of the cases the interview was performed after a short visit and introductory tour of the company.

3.3.1. Aims of the Case Study:

1. Examining and validating the basic factors and structure of the concluded frames for agility concept obtained during the previous phases of the research by looking at:
    1.1. The perception of manufacturing companies about the subject of agility, and different views of them in this regard.
    1.2. Specific criteria for different companies regarding various aspects of agility; Change (Drivers), Strategy, Components of agility.
    1.3. Characteristics/Abilities, Business Structure (Providers), Practices.
    1.4. The level of complexity and turbulence of the business environment and the companies' position to determine the level of their need to be agile.
2. Establishing a base for further in-depth survey and case studies.
3. Extracting details of current application of methods, tools, etc. in companies in response to the matter of change in the business environment.

3.3.2. Results From the Case Studies

3.3.2.1 A provisional review of the results from the case studies

Manufacturing companies, even those in relatively more stable conditions and with good position in the market, are facing fast and unanticipated changes in their business environment. These changes drive organisations to act more consciously and quickly, and to adopt an agile and nimble character. Threats imposed by competitors and new entrants to market, change in competition methods, change in technology and introduction of new, more effective and faster tools, increasing rate of change in customer's requirements, and change in social factors are important causes of problems as well as opportunities for manufacturers. Manufacturing companies need to perceive, receive, respond or react to these changes so that their strategy for prosperity, success, expansion, and also their ethics and cultural values may be met.

Companies are different in the type or severity of change in their business environment and circumstances. Market leaders have a problem with customer requirements change. High technology (high-tech) companies face the problem of popularity and commercialisation of current technologies and their availability to whoever requires it. This type of manufacturers also receives significant impacts from the problem of fragmentation of marketplace. Some companies that have been used to supplying to a specific, increasing in need and guaranteed market, now face change in the nature of business and competition they are involved in.

Subject to the specific conditions of a company, different actions could be taken. Being responsive (reactively and proactively), fast, cost effective and productive, flexible, high quality, etc. are some main perceptions of manufacturers as the necessary responses to the changing conditions. Each company acts in a specific and different way. All of the studied cases found to possess some aspect of the necessary characteristic of being agile. However, almost in all cases there are areas that suffer from the lack of enough attention, which potentially could be sources of failure for the organisations.

Agile companies generally rely on their core competencies, value their people, enhance flexibility in their people, organisation and manufacturing systems, accelerate innovation, and move on with new technologies. Cooperation with customers and suppliers and even competitors in some ways, free and open communication across the supply chain and availability of valuable information over the company, concurrency of activities, customising products and inclusion of information in products, and providing a reliable servicing system are among the more costume strategies when it comes to respond to change in the business environment.

Obviously no specific definition or perception is advisable about agility for every company. Based on some factors such as a company's situation in the environment, nature of the market the company competes in, history of the company, the sector that the company belongs to, the company's specifications such as size (number of employees, turnover, facilities, etc.), level of technology in use, nature of the processes in development of products, innovative character of the company, and

perhaps few more factors, the company needs to meet a certain level of agility using different means and in different practical ways. But there could be a general or generic path through which agility must be approached. This path may comprise several items such as: understanding the necessity of acting differently from traditional ways and the emergence of the new business criteria; determining the position of the company and the level of agility it needs; taking agility into the company's strategy and redefining the strategy of the company considering new priorities and circumstances; and finally transformation of the structure of the company to an agile form by applying appropriate practices and enhancing the prioritised strategic abilities in the company's business structure. This movement affects the set of measures and metrics already used by companies and must lead to a new performance measurement system that considers the new strategy and the matter of change.

3.3.2.2 Brief story of the case study number one

In this section, the result of study of the case company number one will be described to provide an example of the conducted study. The rest of case studies are reported in appendix B.

Case study company number 1

1- Company's profile:

1-1- A subsidiary of a European food company with around 200 employees and annual turnover of between £ 40-50 million.

1-2- Works with big retailers and is active in most of local and European markets with a high percentage of market share that reaches 70% in some sectors, and is market leader in almost all markets it presents.

1-3- The company has introduced more than 10 new products in the past five years with an average success of 60%.

1-4- Production is being carried out in batch production form, and products are intermediate products for other manufacturers.

2- Company's Characteristics :

2-1- Business Priorities :

Quality - Consistency - Cost - Profit - Sales - Time

2-2- Perception of the company's responsiveness: 7 out of 10 (Highly

responsive)

2-3- Core competencies of the company:

- Modern manufacturing technology,
- Cost effectiveness

2-4- Product development complexity: Not very complex

2-5- Problems:

- Lack of adequate understanding and realisation of the real state and situation of the company.
- Lack of cooperation in people (not good response to training and empowerment programmes).
- Change in customers' requirements and lack of sufficient flexibility to respond to them.

3- Company and Change:

3-1- Importance of change in the environment and being responsive to it :

7 out of 10 (Highly Important)

3-2- Change areas in the environment as "Drivers of agility":

- Customer requirements
- Social Factors (People (employees), health and environment)
- Technology Change
- Market Change

3-3- Complexity of the environmental change: relatively high

3-4- Strategy of the company in responding to change:

- Becoming more flexible
- Improvement of people's competency, adopting new technologies, maintaining and improvement of quality, and getting more cost effective
- Being fast

4- Areas in the company where response to changes are originated from (in order of importance)

- People
- Organisation

- Enough authorisation from top to bottom
- Recruiting young motivated people

- Technology
- Innovation
- Communication (integrated information system)

5- Practices (Performed to achieve characteristics of responding to change):

- Investment in technology to reduce cost and improve the total competency
- Organising the company around multidiscipline teams to improve responsiveness and quickness
- Empowering people and continual training and establishment of a friendly environment
- Improvement of Information Systems
- Enhancement of flexibility by investing more in technology, and by cooperating closely with suppliers and competitors (Establishing mutual service relationship with competitors in developing new products or innovation (VIRTUAL ORGANISATION).

COMMENTS FROM THE INTERVIEWEE:

1- *We are quite successful but not fascinatingly successful.*
2- *We have to watch change and target at continuous improvement, as if we don't we will die.*
3- *We have gained good results out of thinking this way, but we can be ways ahead and we need to be agile*

3.3.2.3 Findings from the case studies

Agility has been perceived by different industries in different ways. The nature of the business environment around the companies, the kind of markets in which they compete, customers they serve, technology they use and competitors they fight with, affect their understanding of the subject and hence the way they express their position and their actions.

In most cases agility is seen or expressed as "responsiveness" which is perceived in place as responding to customer requirements. Some of the companies think of agile

manufacturing as being fast and a few that do not face severe challenge in their market look at it as being more competent, including providing good quality, being cost-effective or having structured processes. Flexibility and innovativeness are also other perceptions about agility among the studied companies.

According to the conducted interviews although agility has not been taken as a serious subject in manufacturing management concerns yet, it is quite meaningful to industries and they seem to feel it as a necessary consideration in their process of competing and survival. There are barrier in the way of understanding agility one of which is lack of a deep and purposeful view of the matter of change, and benefiting from change. This could also be rooted in some other reasons such as:

- Relativity of environment conditions for companies so that it is not taken as a presumed subject to be considered in company's business.
- Not involving in a competition level in which change means important factor for success. In other words, it means working not as a world-class firm. This, as well, is not very evident according to the studied cases.
- Competing in a sole market with the least possible threats.

Evidently most companies face various levels of chaos, uncertainty and change, which conform to the perceptions, achieved during the previous phases of the research. Also different perceptions by different companies can form a basis for a differentiating model to measure the agility need level and current agility level.

Further conclusions can be summarised as follows:

1- Not many companies consider the agility subject and agility drivers strategically, and apparently lack of this vision is the cause of some problems.

In cases that strategy view in the company is reasonably comprehensive or some initiatives have been taken to enhance the strategy making process, the company more likely lived in a state of peace and prosperity.

2- Drivers of agility are as follows, which are mostly external (environmental);

- Change in marketplace or turbulence of the market, including entrance of new competitors, growth of the niche market, political changes, high rate of changes in products features, etc.
- Change in customer requirements on technical specification, delivery time, quality, services, demand for individualised products etc.
- Change in competition basis, such as formation of new organisation and cooperation methods, economic and financial plays in competition, new types of services, changing market, increasing pressure on cost, more and more innovation, pressure on products time-to-market, etc.
- Change in technology, including soft and hard technologies and specially automation, which provides more efficient, faster, and economic production facilities, and inclusion of information technology in new hard technologies.
- Social factors such as people welfare level and standard of life, politics, legislation, environmental pressures, etc.

Some internal drivers also have been mentioned as pushing forces to be agile. Drivers such as:

- Strategy of continuous improvement
- Transmission from traditional business to excellence, beyond customer expectations.
- Readiness for stepping into the next millennium.

3- Strategy of companies in responding to environmental change and in the line of approaching success and leadership in market.

- Responsiveness to customers requirements, market conditions, social events and competitors movements.
- Becoming more and more flexible in manufacturing, in capacity, in people,

and in organisation.

- Increasing competency of people, getting more cost-effective, increasing quality level, streamlining products, etc.
- Deployment of new, appropriate and necessary technology in place, or standing on high-technology as a differentiator where applicable.
- Being faster/urgent/quicker
- Continuous improvement
- Fast track of products
- Changing the strategy view of the company towards new environment of competition
- Being competent enough
- Attacking threats and new opportunities as fast as possible
- Compacting time
- Focusing on customers and good relationship with them
- Concrete relationship with suppliers (supply chain)

4- Providers of agility.

Considering the vision employed in conducting the empirical study, and the conclusions extracted from the preliminary survey and case studies, following items can be identified as main areas in companies from which practical approaches could be managed to provide the necessary abilities for being agile and responding to changes:

- Organisation (flexible, with enough authority, young,...)
- Process
- People
- Technology
- Innovation (Innovative product development)
- Close relationship with customers and suppliers (external connection with the organisation)
- Communication

Communication and close relationship with customers and suppliers can be considered as other providing areas in an organisation. But it was found that communication is better to be expressed as an infrastructure of integrated use of information company-wide through which all necessary information is available to where it is needed including customers and suppliers. Information system as the means of providing complete integration is undoubtedly greeted by companies and in most cases attempts have been made to provide a better and wider use of information.

Lack of "integration" which was evident in most of the cases seems to be a cause of many problems such as low productivity, high costs, and consequences such as inflexibility, unadaptability and waste of resources.

5- Practices towards agility

As explained earlier, no specific action has been observed to be taken under the name of agility. But considering the strategic aspects and items of agility, some initiatives, methods, planning, and actions are reported in response to the changing circumstances of the business environment, and in the general line of successful competition and taking the competitive advantage. These typical actions are generally aimed at quality improvement, time reduction, competency improvement, cost effectiveness, flexibility, answering to customer requirements, etc. which nevertheless are important issues of agility. Summarised list of practices are provided as follows :

- Investment in technology [To reduce cost, improve competency, enhance flexibility in manufacturing, and take competitive advantage]
- Enhancing teamworking and organising around multidiscipline teams [To improve responsiveness and quickness, supporting and expanding communication between people and organisation, bringing concurrency in operations, ...]
- Empowering people, continual training for people, establishing friendly environment [To improve people and so total competency]
- Improvement of information system, communication infrastructure and company-wide database [To assist integration of the whole company]

- Close cooperation with customers (sending employees to them for introduction of new improvements in products and/or solving their problems, getting customer's data and information and using these in correcting problems and bias in decision), quick reaction to customer's requirements dealing positively with them)
- Working and cooperating with suppliers as partners, managing the supply chain optimally (feeding information to suppliers constantly)
- Defining new ways of cooperation with competitors (mutual services, common development of products, merging sites, ...) [in assisting mass-customisation environment]
- Customising products and the production system, and moving towards mass-customisation instead of mass production
- Establishing new sites or merging separate sites into one in response to specific threats or opportunities [To be more responsive]
- Encouraging and investing in innovation (formal R&D and informal forms of innovation) [To be more responsive]
- Using modern manufacturing systems such as FMS or cellular manufacturing, CIM, JIT, etc., customised to company's needs [To increase responsiveness, compact time, get more flexible and competent]
- Keeping delivery integrity [To maintain quickness]
- Focusing on quality by initiating long term plans for quality such as TQM [To improve competency]
- Using CE or SE [To Quicken activities and perform processes effectively]
- Relying on company's core competencies and trying to make them more powerful
- Concurrent performance of marketing and engineering (bringing together people of two sections and redefining processes)
- Reviewing and redefining company's strategy and initiating long term planning considering the new environment of competition
- Organising around process instead of products.
- Making organisation flexible and adaptable to change of marketplace and focusing on a specific goal in responding to a certain threat or opportunity

- Taking any efforts to reduce costs (cost-effectiveness or optimising cost/performance) including a rewarding system for encouraging people
- Focusing on customer
- Establishment of councils or teams for controlling the whole business including benchmarking the company, evaluating and ranking suppliers and vendors, etc.
- Combining inspection in operators job.
- Giving responsibility of all activities and problems to people in any section and asking them to resolve their problems [Competency]

SUMMARY OF THE CHAPTER:

This chapter reports the results from the preliminary empirical study, which was conducted to provide further insight into the subject of agile manufacturing from a practical point of view in pursuing the first objective of the research, and also to study the validity of the hypotheses of the research. A preliminary empirical study is conducted to complement the understandings provided by literature survey about the concept of agile manufacturing. In particular:

1. A questionnaire was sent to a chosen number of relatively successful manufacturing companies resulting in 13 responses. Some facts and figures were obtained as the result of the questionnaire survey.
2. The questionnaire survey was followed by six case studies to complement the empirical study phase.
3. The findings of this study are mainly in conformance with the understandings from the literature survey about the concept and its constituting elements. Based on the findings a company in order to become agile must understand the circumstances of its business environment, adjust its strategy in responding to the changes, provide the abilities required for responding appropriately to the changes and implement those abilities using the available methods and tools.
4. Some business practices have been identified as effective on the surveyed companies' ability in responding to changes, among which integration and information system/technology are stressed as important means.

5. Some valuable information was gathered during the study, which could be summarised in the following items as findings of this chapter.

1.1. Still the business priorities for most of manufacturing companies begin with quality. Also, although time and responsiveness do matter for the manufacturers, they are not perceived as more important than cost.

1.2. Change and turbulence is witnessed by most of manufacturers, some of which have received severe impacts from unpredicted changes in their business environment. Being alert to these types of changes and timely responding to them are accepted beliefs among almost all manufacturers. This conclusion supports the hypothesis number one of the research.

1.3. There is a wide range of factors, mainly external, which could affect the position of a company in the market and drive it to adapt to a different stand in response to them.

1.4. Different companies are different in the way they could receive impact from changes in the business environment. Hence, the way that a company should respond to the situations is different and depends on the specific circumstances of that company. Different companies need different levels of agility, which in turn are specific in the way they are meant for the companies. This conclusion provides support for the second hypotheses of the research.

1.5. Strategic intent, and moving based on a strategic plan are decisive in achieving success in the business.

1.6. There are some generic capabilities, which are essential to be possessed in responding to changes.

1.7. There are areas in the organisation, which have the duty of providing the required capabilities for agility. These areas will be represented by practices from the past and newly developing ones, which are the real means by which the necessary capabilities for being agile could be accommodated.

The results from this chapter together with the understandings from the literature study will be combined in the next chapter to materialise the objective number one of the research which is to develop a conceptual model for agile manufacturing.

CHAPTER FOUR

A CONCEPTUAL MODEL FOR AGILE MANUFACTURING

4.1 INTRODUCTION

This chapter represents the formation and formulation of a conceptual model for agile manufacturing as the first objective of the research. The proposed conceptual model is a result of the conducted review of the literature, and the supports and information obtained from the preliminary empirical study reported in chapter three. The conceptual model will be validated and completed further through the remaining phases of the research.

The major issues with regard to agile manufacturing which were discussed in chapter two are briefly recollected, organised and discussed to identify the basic building blocks of the conceptual model. This part is followed by a discussion of the information and support obtained during the preliminary industrial survey.

The conceptual model of agility in manufacturing organisations is then introduced in more details, and the interrelationships and connections between different parts of the model inferred from the studies are discussed. It is then argued that the conceptual model should necessarily be transformed into a practical form to assist manufacturing organisations in the implementation of agile manufacturing. This part is discussed to support the achievement of objective number three of the research, which is to develop a methodology for manufacturing organisations to approach the concept in practice. A generic methodological approach recommended by some authors in manufacturing systems area is employed and used to establish the structure of a methodology for achieving agility. The proposed methodology contemplates a route from assessing a manufacturing organisation's need for agility and its current level of agility to adoption of practices for capturing the required agile characteristics.

4.2 AGILE MANUFACTURING FROM THE PERSPECTIVE OF LITERATURE

The review of the literature pertaining to the management of manufacturing provided a considerable deal of arguments, reasoning and evidences which stand to show that the evolutionary trend of business in the past two centuries has resulted in the emergence of a new era.

Responding to the new terms and conditions of the modern business, being vigilant for changes that could occur in the business environment, and being proactive and a step ahead of business are now vital conditions of surviving in the world of business. The word describing the ability for taking and maintaining competitive advantage under such conditions is "agility".

The new emerging agenda disapproves the conventional wisdom of focusing on uniformity, stability and regularity, and suggests an approach that sees the dynamics of the organisation, and handles the uncertainty in the business environment.

Agility in essence is expressed by some main workers in the area as a strategic direction for the organisation. It is suggested in the literature that a strategy is needed to exploit agility throughout the system. According to the literature this strategy forms around the fundamental ideas of:

1. Responding appropriately to change and being change proficient
2. Taking advantage of change

Major works in the area of agile manufacturing concept have employed some main factors as the constituting elements in interpreting the new paradigm. These factors include strategy, proactivity and reactivity, strategic characteristics or attributes, integration (of main resources or providers such as technology, management, workforce or people, organisation, etc.), enhanced cooperation, modernised information system/technology, and innovation as a dynamic characteristic.

However, the main subjects, which are widely considered as the core concept of agility, are change and responding to changes.

Responding to changes, which has brought about a new set of competitive foundations, requires possession of some attributes that differentiate the organisation as an agile system. These attributes encompass the type of abilities that manufacturing organisations have been thriving to capture for decades, however, in isolation and not strategically targeted. The attributes in general can include:

- Being alert to the advents of the changes in the business environment by creating a reliable interface between different elements involved in the business

- Responding to events in the shortest possible time
- Delivering a sophisticated performance in terms of cost, quality and time
- Enhancing changes in the organisation for the purpose of recovery and correction of the organisation's direction, performance, operation, etc.
- Influencing the business environment by proactive programmes and plans, and promoting the business.

These attributes would be sustained and be effective for an agility strategy if the system is organised, re-arranged and re-defined around the core concept of agility which is "change proficiency" or responding appropriately to change.

As mentioned the attributes have been propounded in the prevailing manufacturing philosophies as solutions to the problems in manufacturing. Agile manufacturing concept attempts to take all these considerations and reorganise them to provide some major characteristics such as adaptivity, speed, flexibility, responsiveness, and resilience.

The attributes have been a focal point in most of the studies carried out on the subject, some of which are given in section 2.5.2. A summary of the attributes of an agile organisation stated by various authors is listed in Table 4.1.

On the other hand, restoring and providing the agility attributes, is seen practical through employing, adopting and deploying methods, tools and techniques. The practices, methods, tools and techniques form an endless list of business processes and operations, which have been in use and in the process of progress and development for decades among manufacturing organisations. However, the appropriateness of each and every practice should be verified and determined according to an organisation's strategies, situations and specific circumstances.

1. **Iacocca Institute [1991]** ;
- Concurrency
- Customer responsiveness
- Dynamic multi-venturing
- Knowledgeable, Empowered, valued people
- Environmentally benign
- Flexible (Re-) configuration
- Open architecture
- Quality over product life
- Short cycle time
- Technology leadership, sensitive
- Total enterprise integration
- Vision-based management

2. **Goldman et al. [1995]**;
- Enriching the customer
- Providing solution instead of product
- Cooperation to enhance competitiveness including virtual organisation and partnership
- Quick introduction of products to markets
- Cost effectiveness
- Empowered people

3. **Preiss et al. [1996]** ;
- Interoperability
- Reconfigurability
- Flexibility
- Providing solution
- Collaborative operations
- Adaptive organisation
- Knowledge-driven enterprise

4. **Kidd, [1995]** ;
- Integration
- Human networking organisation
- Competent and empowered people
- Virtual corporation
- Innovation and learning supportive environment
- Knowledge management

6. **Montgomery and Levine [1996]** ;
- Small batch production capacity
- Total quality
- Waste management
- Short cycles time
- Improving and re-engineering work processes
- Continuous improvement

7. **Youssef [1992]** ;
- Flexibility
- Responsiveness
- Speed
- Quality
- Cost-effectiveness
- Advanced technology
- Company-wide information system/technology
- Customer and supplier strong relationship and cooperation

8. **Gehani [1995]** ;
- Quickly satisfying customised orders
- Frequent introduction of new products in a timely manner
- getting in and out of alliances speedily

9. **Vastag et al. [1994]** ;
- Streamlining organisation with a strategic focus
- Integral integration
- Improved company's culture
- New product introduction frequency

10. **Tracy [1994]** ;
- Fast entrance to market
- Cost-effectiveness
- Ability to meet customised orders
- Delighting customers

11. **Ross [1994]** ;
- Innovation

Table 4.1. Attributes related to agility according to various authors

• Skill and knowledge enhancing technologies • Change and risk management 5. **Dove [1995]**; • Modularity • Plug compatibility • Non-hierarchical interaction • Dynamic relationships • Distributed control and information • Scaleable size and redundancy of units/organisation • Reusability of facilities • Open system physical framework	• Customising products and services • Flexibility to adjust deliveries • High efficiency to remain competitive • Virtual cooperation 12. **Reid et al. [1996]** ; • Sensing and anticipating changes • Adaptability • Ability to recover from change • Quickness • Innovation • Flexibility • Concurrency • Efficiency

Table 4.1. Continued

The emergence of the new concept of agility as extracted from body of the available literature can be restated briefly as follows:

- A new business era is emerging in line with the evolution of the business
- The new era is characterised with relentless, unpredictable and in some ways unprecedented change in every aspect of the business.
- Strategic intent is essential to overcome the tyranny of the new circumstances
- Agility is the term that can define the required ability for sustaining and maintaining the competitive advantage.
- Agility, basically, is the ability to respond properly to and take advantage of the changes in the business environment.
- Agile organisations are those who are not only capable of responding to changes but also able to proactively stimulate the business environment to their benefit.
- Agile companies have certain abilities, which can be considered as attributes. These are the characteristics, which can bring about the ability to respond appropriately to changes and take advantage of them.
- The agility attributes could be achieved through taking appropriate actions and practicing suitable means such as manufacturing/management methods, tools, and techniques.

4.3 BUILDING BLOCKS OF THE CONCEPTUAL MODEL FOR AGILE MANUFACTURING

As it was noticed in chapter two and is stated by some authors on the subject of agile manufacturing, the lack of a generic and comprehensive model for understanding the concept and translating it into a practical approach is evident.

The review of the literature from which some items were recollected in the above section led to some conclusions. The resulting understandings from the literature were articulated into some building blocks to be used to establish a basis for defining agility in manufacturing organisations. Three main constituent parts are essential in defining and designing a frame. These are agility drivers, agility strategy, and agility providers. These are discussed briefly as follows:

a) Agility drivers; The structure of the new era of business has a changing and chaotic characteristic. This situation is forcing the contenders in the business environment to reconsider their position in order to sustain the competitive advantage. The emerging position or ability, which is going to become a vital condition for survival, is agility. Agility is the ability to respond appropriately to (and take advantage of) changes in the business environment. The changes are in fact the forces, which drive the manufacturing organisations to move towards agility. These drivers comprise all factors and forces that exist in the environment in which a company lives, and can affect the company's business in a way. Factors such as marketplace, competition and competitors, customers and suppliers, technology, and social factors are the most important items according to the literature.
b) Strategy; Agility can also be considered as a strategy. However, two steps can be involved in defining the strategy. First is a strategy to become agile which refers to the evaluation of the situation enforced by the agility drivers and also the company's position. The second step is defining a strategy to exploit agility. This would consist of steps with which agility can be defined to the specific conditions of a specified organisation and customised with the needs of that organisation. The strategy for exploiting agility is also about determining the strategic means and attributes needed in order to respond to the forces and pressures of the business environment.

c) Agility providers; The abilities and capabilities that an agile organisation needs in order to be able to respond to the agility drivers would be provided in this part of the model. In fact agility providers are the practical means with which an organisation move towards agility. These providers, as discussed before, are the practical solutions, which are typically being utilised in manufacturing industry and also include the advances in manufacturing/management methods, tools and techniques that are on their way to completion. The agility providers, according to the literature, can be obtained from three main sources or areas in an organisation. These are organisation, people, and technology. However, two important factors as essential basis for achieving the expected results from these providers of agility are also emphasised, which are integration and information system/technology. Although the two mentioned factors can be considered as practices concerned in the agility providers, there seems to be the need for an extra emphasis on them. This emphasis relates to the vast consideration of integration as a necessary action in utilising practices, and also the increasing importance of information system/technology and advances in them in the contemporary world.

4.4 SUPPORT FROM THE PRELIMINARY SURVEY AND CASE STUDIES

As it was described in chapter three, the conclusions from the literature survey were put into examination through a preliminary and pilot survey, which was complemented with six case studies.

The questionnaire survey was mainly aimed at achieving a realistic understanding of the new circumstances of the business environment in the manufacturing industry, and examining the stressed concepts, factors and elements in the literature within the real world of manufacturing business.

The results from the questionnaire survey were supportive to the extracts from the literature.

However, the results from the pilot survey were found to be in need of refinement. This was pursued by conducting six mini case studies, which were reported in chapter three. The case studies were carried out by introducing the conclusions with regard to agility achieved during the previous steps of the research to the companies. The aim of this

stage was to study the recognised elements within the frame of manufacturing companies' experience, and search for more details to complete the model.

The results from the case studies, reported in chapter three, provided the required details needed for the construction of the conceptual model.

4.5 REVISED BUILDING BLOCKS OF THE CONCEPTUAL MODEL FOR AGILE MANUFACTURING

The building blocks of the agility conceptual model which were introduced first based on the literature, were redefined and extended using the results, conclusions and understandings from the empirical study phase. The modified building blocks of the agility concept are as follows:

Agility drivers; A set of forces from the business environment which urge manufacturing organisations to reconsider their position and become agile in order to respond to these forces appropriately. The detailed list of factors and sub-factors are listed as follows:

1- Changes in MARKET; including items such as:

- Growth of the niche market
- National and international political changes
- Increasing rate of change in product models
- Product lifetime shrinkage

2- Changes in COMPETITION criteria; including items such as:

- Rapidly changing market
- Increasing pressure on cost
- Increasing rate of innovation
- Increasing pressure of global market competition
- Decreasing new products time-to-market
- Responsiveness of competitors to changes

3- Changes in CUSTOMER REQUIREMENTS; including items such as:

- Demand for individualised products and services

- Quicker delivery time and time-to-market
- Quality expectation increasing
- Sudden changes in order quantity and specification

4- Changes in TECHNOLOGY; including items such as:

- Introduction of more efficient, faster, and economic production facilities
- Introduction of new soft technologies (Software and methods)
- Inclusion of information technology in new hard technologies

5- Changes in SOCIAL FACTORS; including items such as:

- Environmental pressures
- Workforce/workplace expectations
- Legal/political pressures
- Cultural problems
- Social Contract changes

Agility strategy ; The strategy with regard to agility, as mentioned before, is seen to have two dimensions. One is the strategy to become agile which refers to the evaluation an organisation would carry out in order to determine its situation, assess its business environment and determine the extent to which the company needs agility.

The other dimension is the strategy the organisation can take in facing the changes and responding to them. These strategies in fact are the attributes an organisation should aim to sustain, or in other words are the strategic capabilities which are necessary for responding to changes. This branch of the agility strategy is extended to form another dimension to the conceptual model, which is explained in the next part.

Agility (strategic) capabilities; The literature and the performed empirical studies revealed a list of capabilities, which are necessary and should be possessed by an organisation in order to sustain the characteristics and attributes of an agile system. The capabilities, in fact, are the kind of abilities required for dealing with the excessively wide range of changes in the business environment, which in turn can occur with different degrees of severity. Based upon the extracted results the following capabilities are required in response to the changes:

1. The ability to sense, perceive, and anticipate changes
2. The ability to make immediate reaction to changes
3. The capability of recovering from changes
4. Possessing and deploying strategic vision in planning and in action
5. Utilising and possessing appropriate technology
6. The ability to provide quality in products and services
7. The ability to be cost-effective
8. Capacity for introducing new products into the market at a high rate
9. The ability to manage changes in the organisation, overcome the resistance to change, control the consequences and directing changes towards stability in the system
10. Having knowledgeable, empowered, well-motivated, skilled and competent human resources
11. Possessing leanness or the ability of operating effectively and efficiently
12. The ability to cooperate both within the organisation and with external entities including customers, suppliers, competitors, etc.
13. The ability to integrate the organisation's plans, programmes, modules, operations, etc.
14. Having the flexibility to produce various volumes of products any time they are needed.
15. Having the flexibility to produce various models/configurations of products any time they are needed.
16. Having sufficient flexibility in the organisation to reform and reshape it according to the changing situations.
17. Having flexible people able to switch to different jobs and tasks to cover the required changes in programmes and operations.
18. Being fast in introducing new products to market.
19. Being fast and on-time in delivering products and services
20. Being able to accomplish operations and fulfil programmes in the minimum period of time.

The list can be extended further or reduced down depending on the way the capabilities are viewed or categorised. We have divided the whole set introduced in the above into four main categories, which are responsiveness to contain items 1-3, *competency* to

contain items 4-13, *flexibility* to contain items 14-17, and *speed or quickness* to contain items 18-20.

Each of the main titles is defined to deliver a part of the major capabilities, which are perceived to be essential for agility. In the following paragraphs the definitions and capabilities under each category are listed:

Responsiveness: This is the ability to identify changes, respond rapidly to changes either reactively or proactively, and recover from changes. This is itemised as:

(1) Sensing, perceiving and anticipating changes.

(2) Immediate reaction to changes.

(3) Recovering from changes.

Competency: This is an extensive list of abilities that provide a company with productivity, efficiency, and effectiveness in achieving its aims and goals. Following items form the major part of the list:

(1) Strategic vision.

(2) Appropriate technology, or sufficient technological capability.

(3) Products/service quality.

(4) Cost effectiveness.

(5) High rate of new products introduction.

(6) Change management.

(7) Knowledgeable, competent, and empowered people.

(8) Operations efficiency and effectiveness (leanness).

(9) Cooperation (internal and external).

(10) Integration.

Flexibility: This is the ability to perform different work and achieve different objectives with the same facilities. It consists of items such as:

(1) Product volume flexibility.

(2) Product model/configuration flexibility.

(3) Organisation and organisational issues flexibility.

(4) People flexibility.

Speed: This is the ability to carry out tasks and operations in the shortest possible time. Items include:

(1) Quickness in new products time-to-market.

(2) Quickness and timeliness in products and services delivery.

(3) Quickness in operations (short operational lead-times).

In total the defined capabilities should provide the required ground for acting in an agile manner by an organisation. However, among the four categories of capabilities responsiveness is the most essential one for any organisation, which need to become and remain agile.

There is also some interaction between the capabilities, which in some cases make them intertwined and inseparable. This relationship can be considered as an open problem to be studied for the purpose of further refinement of the model.

Agility providers; Agility practices is perhaps a more directly related word for this part of the model. As discussed before the providers of agility are the means with which the capabilities could be gained or restored. This part of the model can contain unlimited number of practices including methods, tools and techniques in the domain of manufacturing industry. From very old methods and practices to the newest and even unborn practices may be included in this set. A summarised list of practices, which have been found to be popular and related to the matter of responding to changes, is shown in Tables 4.2 and 4.3. Table 4.3 demonstrates the practice indicated during the case studies

4.6 THE CONCEPTUAL MODEL OF AGILITY

The discussed items of the agility concept are then brought together to form the conceptual model as was aimed in the research objective number one. In developing the model a definition concluded from the current ideas and perception of agility is used which is: Agility is the ability of an organisation to

- Respond to changes (anticipated or unexpected) in proper ways and due time, and
- Exploit changes and take advantage of changes as opportunities.

The conceptual model is graphically shown in Figure 4.1 and Figure 4.2. Figure 4.1 displays a general view of the model and its constituting parts and Figure 4.2 provides the model in its full detailed form. The model determines a structural relationship between the introduced parts of the frame as discussed in previous sections of this chapter. The conceptual model of agility has three constituting elements. The first element is concerned with "agility drivers", which are the changes/pressures from the business environment that necessitate a company to search for new ways of running its business in order to maintain its competitive advantage. The second element is concerned with "agility capabilities", which are the essential capabilities that the company needs in order to positively respond to and take advantage of the changes. The third element is concerned with "agility providers" that are the means by which the so-called capabilities could be obtained. These providers are to be sought from four major areas of the manufacturing environment, i.e., organisation, people, technology, and innovation. It is also strongly believed that providing the mentioned providers would not be possible without attempts to integrate the whole set, and without a powerful support of information systems/technology.

Based on this model, a manufacturing enterprise experiences a variety of changes/pressures in its business environment, which drives the enterprise to identify "agility capabilities" that needs to be acquired or enhanced in order to take advantage of the changes. This in turn forces the enterprise to search for ways and tools to obtain/enhance the required capabilities. Obviously, different organisations will experience different sets of changes as well as different levels of pressures resulting from each change. Consequently, different combinations of capabilities will have to be obtained for different organisations.

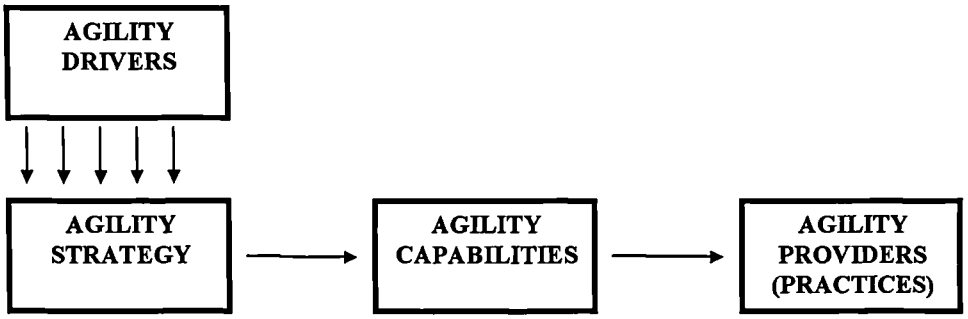

Figure 4.1. The Proposed Conceptual Model of Agility; General Presentation.

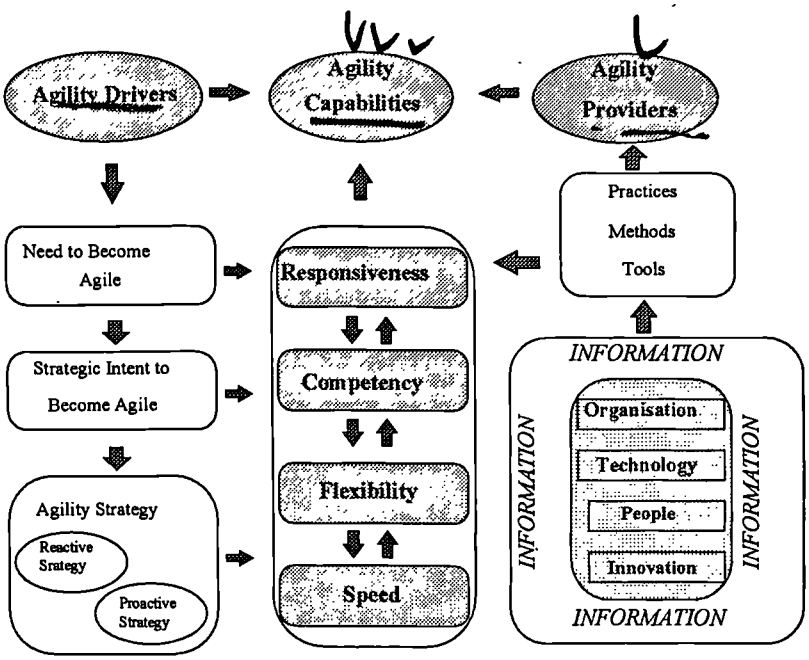

Figure 4.2. The Proposed Conceptual Model of Agility in Manufacturing Organisations; Detailed Presentation.

The conceptual model, which was aimed as the first objective of the research, is achieved at this stage. To provide the remaining objectives that are based on this model further investigation will be carried out in next chapters.

GENERAL BUSINESS PRACTICES	INFORMATION SYSTEMS	TECH/ TOOLS
• Establishing partnership with suppliers and/or customers • Close relationship with suppliers/ customers, and involving them in co.'s planning and product development process • Establishing Virtual Organisation • Adoption of advanced technology • Mass-customisation through utilising adequate technology integration of inter-organisational systems, modules and the manufacturing system • Flexible, responsive to changes, flat, and learning organisation • Continuous reengineering of the organisation and business processes based on benchmarking • Informal, coaching, and encouraging management style • Structured and flexible manufacturing processes • Concurrent and team working methods/ models • Empowerment of people throughout the company • Continuous training and education of all people	• Establishment of an Information Management Plan or Model • Strategic use of information system through the company's information management plan • Using Internet and related information tools as a means of communication with outside • Using an Internal Information Network, that makes information available company-wide • Using Integrated Computer-based Product Development Process • Using Computerised Manufacturing Information System • Using Computerised Manufacturing Information System, compatible to International standards of data exchange and transfer such as STEP • Information System Interface with suppliers • Information System Interface with customers	• JIT/Kanban • CIM • TQM • Concurrent Engineering • Flexible Mfg. System (FMS) • Lean Mfg. • CAD/CAM/ CAE • Robot Technology • Joint Venturing • Rapid Prototyping

Table 4.2 A List of Agility Providers

- Investment in technology [To reduce cost and improve competency, enhancing flexibility in manufacturing, and taking competitive advantage]
- Enhancing teamworking and organising around multidiscipline teams [To improve responsiveness and quickness, supporting and expanding communication between people and organisation, bringing concurrency in operations, ...]
- Empowering people, continual training for people, establishing friendly environment [To improve people and so total competency]
- Improvement of information system, communication infrastructure and company-wide database [To assist integration of the whole company]
- Close cooperation with customers (sending employees to them for introduction of new improvements in products and/or solving their problems, getting customer's data and information and using in correcting problems and bias in decision), quick reaction to customer's requirements (dealing positively with them)
- Working and cooperating with suppliers as partners, managing the supply chain optimally (feeding information to suppliers constantly)
- Defining new ways of cooperation with competitors (mutual services, common development of products, merging sites, ...) [in assisting mass-customisation environment]
- Customising production and moving towards mass-customisation instead of mass production
- Establishing new sites or merging separate sites into one in response to specific threats or opportunities [

Table 4.3. List of Agility Providers identified during the case studies

To be more responsive]

- encouraging and investing in innovation (formal R&D and informal forms of innovation) [To be more responsive]
- Using modern manufacturing systems such as FMS or cellular manufacturing, CIM, JIT, etc., customised to company's needs [To increase responsiveness, compact time, get more flexible and competent]
- Keeping delivery integrity [To maintain quickness]
- Focusing on quality by initiating long term plans for quality such TQM [To improve competency]
- using CE or SE for [To Quicken activities and perform processes effectively]
- Relying on company's core competencies and trying to make the more powerful
- Concurrent performance of marketing and engineering (closing people in two sections and redefining processes)
- Reviewing and redefining company's strategy and initiating long term planning considering the new environment of competition
- Organising around process instead of products.
- Making organisation flexible and adaptable to change of marketplace and focusing on a specific goal in responding to a certain threat or opportunity
- Taking any efforts to reduce costs (cost-effectiveness or optimising cost/performance) including a rewarding system for encouraging people
- Focusing on customer
- Establishment of councils or teams for controlling the whole business including benchmarking the company, evaluating and ranking suppliers and vendors, ...
- Combining inspection in operators job.

Giving responsibility of all activities and problems to people in any section and asking to resolve their problems [Competency]

Table 4.3. Continued

4.7 THE CONCEPTUAL MODEL IN PRACTICE;

To achieve the third objective of the research, which is to develop a methodology for manufacturing organisations to approach the concept in practice, a frame needs to be established based on the conceptual model. In order to provide a provision of the methodology aimed at in the objective a brief discussion is provided here in this chapter. Objective two of the research is then pursued during chapters five and six. The results obtained will be used in conjunction with this basic proposal to develop the aimed methodology for achieving agility.

The proposed conceptual model of agile manufacturing provides an understanding of the concept of agility, which closely follows the real conditions, and experiences of the manufacturing industry while employing the necessary theoretical bases from the

existing literature in the field of manufacturing management. The model is derived so that it has the potential for being transformed to a practical approach towards agility in manufacturing organisations.

To provide this transformation and propose a practical tool for the implementation of agility, a methodology is needed through which the concept may be delivered with the implementation of practical steps, methods and tools.

A generic method for devising and defining such a methodology is followed after the work of Preiss et al. [1996], and also with reference to the work by Maul and Tranfield et al. [1992]. The proposed generic model of Preiss et al. is described in section 2.5.2. Maul and Tranfield et al.[1992] have reported the result of their research in methodological approaches to competitiveness in manufacturing. According to them a methodology that will assist manufacturing companies make strategic choices and identify the appropriate configuration consistent with the business strategy must have some features as follows :

1. It needs to take a systems perspective
2. It must address the strategic issues
3. It must include a stage which sets out a vision and then identify theme for change. This includes the criteria for choice of theme, the criteria for choice and priority of the regeneration technologies and activities and the way in which these can be integrated into an overall change strategy.
4. It must be able to specify appropriate tools, techniques and approaches which will fit both strategic need of the business and the regeneration theme
5. It needs to provide guidance on the available means for meeting the needs of the company.

The methodology shall contain basic items to serve the explained purposes in the previous parts. A general schematic diagram of a methodology, which is being proposed for the mentioned purpose, is depicted in Figure 4.3.

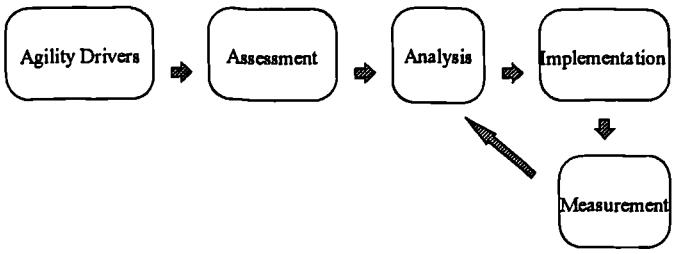

Figure 4.3. The Proposed Methodology To Achieve Agility

The business environment surrounding the organisation and the changes in it, which we already called agility drivers, are the entrance gate to the matter of agility. These factors define the boundaries of the subject of agility for an organisation. A major pre-step is evaluation and assessment of the business environment to determine the need of the organisation for agility. The analysis based on this assessment would lead the organisation to refine or redefine its strategy for agility, identify the required and missing capabilities and providers of agility, implement the practices determined as necessary requirements, and finally evaluate the outcomes to examine the agility position for the organisation and repeat the process in a recursive movement towards agility.

The research will be concentrated at introducing a preliminary methodology including the related tools.

4.7.1 Assessment of agility

The first step towards agility mentioned above is the assessment step. This process as a generic method is considered to include two main parts :

- Assessment of the level of needs of an organisation for agility
- Assessment of the current level of agility an organisation already has

The work by Pine [1993] in exploring the modern idea of mass customisation, which is partly an adjunct to the concept of agility, is being followed for this purpose. The proposed model by Pine is followed because he takes the similar theoretical base as taken by this research and suggests two steps to evaluate the level of need of an organisation for mass customisation and then assess the abilities of the organisation in

that relation. However the mentioned work is a stand-alone model, which does not serve any particular further purposes.

An appropriate model for the purpose of assessing agility basically can be described as follows. Agility as it was proposed in the conceptual model is partly defined as the ability to respond to unpredicted and unprecedented changes in the business environment. Therefore, agility is a direct function of the changes in the business environment. This means that the more the circumstances for doing business are changing, the more the organisation needs to be agile to respond to the changes positively.

Business environment is the atmosphere the company lives and breathes in. We have characterised the business environment with factors, which we called agility drivers. The extent to which the mentioned factors are perceived as changing and turbulent will be the indicator of the business environment the company competes in, and hence will represent the level of agility the company needs in order to stay in the business and maintain its competitive advantage, and make further progresses.

Agility as the ability of a company in responding appropriately to changes in the business environment is a characteristic that can be assessed and measured.

Agile manufacturing, as shown in the proposed definition, in essence concerns two main dimensions which are responding to changes that could be anticipated, or unexpected, and taking advantage of changes either unpredicted/unprecedented as opportunities.

To deliver this purpose, an agile company must show its ability in different areas such as;

1. Detecting, analysing and understanding the changes in the business environment
2. Responding to changes through ; neutralising the imposed changes from the business environment; or effecting necessary changes in the company's internal and external affairs to provide the right solution in the shortest possible time
3. Tackling opportunities and taking advantage of them

The assessment model shall be devised with a tool in order to study the position in which the company lives, and provide the preliminary mindset for moving towards agility. This is approached based upon the conceptual model of agility. An assessment model, which includes two practical tools, is suggested and graphically shown in Figure 4.4.

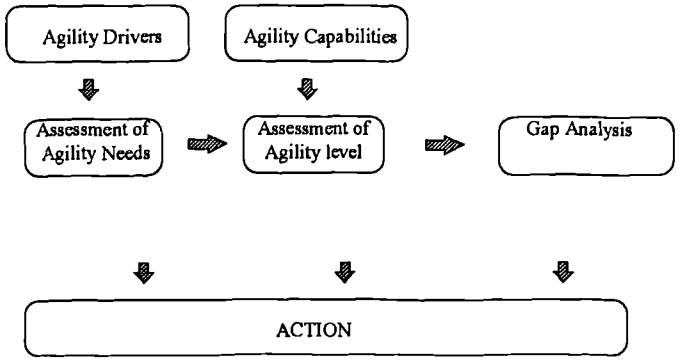

Figure 4.4. Assessment model for agility

The proposed model takes the ideas from the conceptual model and defines two analysis processes of the company, one for its level of need for agility and one for its current level of ability or agility. Agility drivers from the conceptual model are the inputs to the agility need level analysis. The tool for applying this part will be developed and introduced in the next steps of the research. The tool is supposed to asses the company's business environment to determine the degree of its turbulence and hence the level of the company's need for agility.

Based on the first assessment and considering another part of the conceptual model of agility, another assessment must be accomplished in order to determine the level of a company's agility. Measuring the level of an organisation's current agility, which in fact is the ability of the organisation in responding to the changes in its business environment, should be performed in relation with the degree of turbulence and changes in the company's business environment. This measurement is also related to the *capabilities* suggested in the conceptual model of agility. Responsiveness, competency, flexibility, and quickness, which are the main components of the agility capabilities considered in the conceptual model, are the references with which the company's abilities (current agility level) should be measured.

As depicted in Figure 4.4, output of the assessment tools could be analysed during which an speculative interpretation can be made to specify the point where the company is located and provide the information for entering action part of the methodology.

SUMMARY OF THE CHAPTER

Chapter four represented the formation and formulation of a conceptual model for agility and the perceived necessary steps based on the conceptual model to achieve the third objective of the research.

1. A quick review and summary of the literature on agile manufacturing is first provided. This summarisation is provided by the support of a table in which the major works in this area and the proposed attributes of agility are quoted.
2. The understandings from the literature were articulated into some building blocks to establish a basis for defining agility in manufacturing organisations. As a result three main blocks were identified and discussed.
3. The literature summary is then followed by extraction of facts from the preliminary empirical study phase reported in chapter three. As a result the building blocks of the agility conceptual model were redefined and extended
4. In concluding the understandings and perception from the literature and the conducted studies agility is defined to be the ability of an organisation to:

- Respond to changes (anticipated or unexpected) in proper ways and due time, and
- Exploit changes and take advantage of changes as opportunities.

The final elements of a conceptual model are then identified and composed to form a proposal for a conceptual model of agile manufacturing. Three main constituting parts are employed in proposing the conceptual model of agility. These are agility drivers, agility capabilities, and agility providers. Agility strategy is the joint where the business circumstances (from the agility drivers) are translated into a practical movement, which comprises determining capabilities and providers of agility. For each of the three main parts of the model a list of detailed items have been recognised which will form the background for further empirical studies. At this stage the first objective of the research is achieved, which included a definition for agility in manufacturing organisations.

5. The necessity of a methodology for the implementation of agile manufacturing in manufacturing organisations is discussed. The practical approach is determined to

be a methodology, which is aimed at, in the third objective of the research. The conceptual model is derived so that it can be transformed to a practical approach. A generic model is put forward to serve as a basis for further studies.

6. An important step of the methodology is determined to be an assessment model for assessing the level of need of an organisation for agility, and its current level of agility.

CHAPTER FIVE

THE QUESTIONNAIRE SURVEY

5.1 INTRODUCTION

This chapter provides the results from the questionnaire survey conducted as another phase of the research in order to study the developed conceptual model of agility discussed in chapter four in detail, investigate the research hypotheses further, and obtain data and information required to satisfy the second objective of the research which is to identify main factors constituting the concept and relationship between these factors. Design of the survey questionnaire, selection of manufacturing companies to be surveyed, and the tools and techniques used in data analysis are described first. Following this, some general results from the analysis of the surveyed sample including the responding companies' organisational characteristics, and various aspects of their business and related agendas such as business priorities are discussed. Analysis of the gathered data from the surveyed sample is presented which includes the various aspects considered in the conceptual model of agility such as pressures from the business environment (agility drivers) and the strategies that are pursued by manufacturing companies in responding to agility drivers. The conducted analysis also provides detailed results with regard to examination of agility practices (agility providers). Further statistical study using cross-tabulation method is performed to find the relationship between different factors studied, the results of which are reported.

An investigation is made to study the commonality and differences between sectors targeted during the survey. Comparisons are made between the statistics of three targeted sectors based on various approaches including application of a non-parametric statistical test for comparing means between different groups.

Limitations of the survey in obtaining more precise results are considered during the discussions.

5.2 THE SURVEY DESIGN

The developed conceptual model for agility contained material from the literature review and understandings from a preliminary empirical study. Validating the introduced conceptual model and finding answers to some of the research questions would be possible only through conducting further studies. Also information was needed in order to complete the development of a practical model or a methodology for achieving agility.

A postal questionnaire sent to a large number of the UK manufacturing industry was planned to fulfil the following aims:

- Introducing the concept of agility to manufacturing companies and analysing their responses in various aspects related to the conceptual model.
- Studying the changes in the business environment of manufacturing companies, and the ways the companies respond to the changes.
- Studying the strategic capabilities and practices, which may assist the organisations in recovering from changes and providing appropriate responses and solutions.
- Studying the relationship between agility capabilities and agility providers (practices).
- Studying the difference between three main investigated industrial sectors, i.e. Electronics and Electrical, Auto Parts, and Aerospace, in various aspects related to the agility conceptual model.

The mentioned goals, in fact, comprise the basis for analysis of data obtained from the survey.

5.2.1 The Questionnaire Design

In order to obtain the required information, the questionnaire was arranged in five sections following the structure of the proposed conceptual model:

Section 1; The Company's profile, which contained questions about:

- The company's organisational characteristics such as sector, size, turnover, marketshare, type of production, number of products.

- New product introduction and success rate, R&D expenditure, business priorities, suppliers, customers, etc.
- The level of familiarity of the company (respondents) with the subject.

Section 2; Agility drivers, in which questions with regard to changes in the business environment were asked.

Section 3; Strategies and strategic capabilities that was included to examine the strategies that are important in responding to changes.

Section 4; Agility practices (agility providers) that might have been impactful on the companies' abilities to respond to changes and the emphasis the companies place on these practices.

Section 5; Practices with regard to information system/technology including their levels of utilisation in the surveyed companies and their impact on the companies' agility. The purpose of this section is, in fact, the same as that of the last section. However, it was designed as a separate section solely because there is a broad and widespread vision in the manufacturing management sciences about the exceptional importance of these practices.

A copy of the questionnaire is included in appendix C.

5.2.2. Conducting the Questionnaire Survey

The preliminary survey, as a pilot size study, used a limited number of companies. To examine the concepts in a wider area, the new questionnaires were sent to 900 UK manufacturing companies. The companies were chosen from various sources and from different sectors. However, most of the surveyed companies belonged to three sectors. These sectors were Electronic and Electrical, Aerospace, and Auto-Parts. The questionnaires were accompanied with an explanatory sheet to describe the purpose of the survey and to give some basic ideas and definitions about the subject.

As the subject of agile manufacturing does not address a specific section of the manufacturing business and is mainly considered at a strategic level, it could be the

best if the questionnaires were answered by the companies' managing director. However, considering the time limitations of the people in this job and in order to lessen the risk of low response rate, the questionnaires were addressed to the manufacturing directors/managers.

79 responses were received from which 60 responses were valid. The response rate was less than 7%, which was lower than expected, but on a statistical basis and considering the newness of the subject, the number of responses may be considered satisfactory for the purposes of this research.

5.2.3 Data Analysis Tools and Methods

Considering the basic requirements needed for analysing the data, and number of responses from the survey, it was necessary to make use of an appropriate software tool. SPSS (for WINDOWS) was chosen for this purpose due to its popularity within academic circles as recommended by some authors such as Puri [1996]; its relative strength and convenience such as easy data entry, strong data handling, and easy operation of most common statistical tests; and its availability in the University's computing systems.

Basically, there are four different types of measurement scales associated with variables, which are nominal, ordinal, interval, and ratio [Puri, 1996]. The questions of the survey were in nature covered by two nominal and ordinal measures.

Statistical test techniques for data analysis are generally categorised in two types, which are parametric techniques and non-parametric techniques. To use the parametric techniques the variables should satisfy some assumptions including; the population must have a normal distribution; the dependent variables must be continuous; and variances of different samples, when they are compared with each other, should not differ significantly [Siegel and Castellan, 1988].

If the mentioned conditions are not met, non-parametric techniques should be used. One of the frequently used techniques, which is recommended by many authors including Neave and Worthington [1988], Miller [1984], and Siegel and Castellan

[1988], is the Mann-Whitney U test. This test is an alternative to the *t*-test for independent samples when studying difference between populations. The test could be used with data that measures on an ordinal scale while the test makes no assumptions with regard to the shape of population.

Another popular non-parametric technique for data analysis is the contingency table referred to as crosstabulation [Puri, 1996]. The crosstabulation is a table with a cell for every combination of values of two or more variables. The table shows the number of cases with each specific combination of values. The data and variables to be analysed using this technique must conform to some conditions such as; the data must be either nominal or ordinal; the variable should be independent and unrelated; and the parent population of samples compared do not have any particular distribution. The Chi-Square test is used to test the null hypothesis that the row and column variables of a crosstabulation are independent. The number of degree of freedom of a crosstabulation is identified by (number of rows - 1) x (number of columns - 1). The null hypothesis that two variables are independent should be tested using the Chi-Square test. If the significance identified by the test is less than the specified level of accuracy (confidence interval), then the null hypothesis is rejected.

5.3. OVERALL FINDINGS

In this section, findings from analysing the entire sample will be described.

5.3.1 Sample Description

5.3.1.1 Studied sectors

The surveyed companies were chosen from three major sectors. According to the reported works in the field of new product development, lean manufacturing, and agile manufacturing, companies in electrical and electronics, aerospace, and automotive and auto-parts are subject to much faster change in their business environment [see for example: Clark and Fujimoto, 1991; Wheelwright and Clark, 1992; Womack, 1990; Sanderson et al., 1994; Tracy, 1994].

These sectors were targeted mostly in the survey, while some other companies in different sectors were studied as well. Among other companies, white goods producers are of more importance, as they deal with fashion-oriented markets.

Table 5.1 shows the distribution of the surveyed companies in different sectors. The three major sectors named above form 88% of the total sample, of which electronics companies almost dominated the survey with an overall 41.4% of the total which is more than half of the population of the three major sectors.

Sectors	Percentage
Electrical and Electronics	41.4
Aerospace	20.7
Auto Parts	25.9
Others	12.0

Table 5.1. Distribution of surveyed companies in different sectors

5.3.1.2 Size of companies

Indicated by two measures, i.e. the number of employees and the average turnover in the past few years, size of the surveyed companies, are depicted in Tables 5.2 and 5.3.

Employee No.	Valid Percentage of companies	Cumulative Percentage of companies
1-50	8.6	8.6
51-200	34.5	43.1
201-500	36.2	79.3
501-1000	12.1	91.4
1001-2000	6.9	98.3
> 2000	1.7	100.0

Table 5.2. Size of surveyed companies - Employee number

Turnover in the past three years, M£	Valid Percentage of companies	Cumulative Percentage of companies
< 3	5.5	5.5
3-10	32.7	38.2
10-30	27.3	65.5
30-60	25.5	90.9
60-120	7.3	98.2
>120	1.8	100.0

Table 5.3. Size of surveyed companies - Turnover in the past three years

The figures show that a considerable number of respondents are small to medium size companies (43.1%), while 48.3% are bigger companies with 201-1000 employees.

Also 8.6% of companies have more than 1000 employees, which could be considered as big companies.

This is the same with the average annual turnover of the surveyed firms. The sample could positively be assessed as a suitable structure for the survey purposes as it consisted a relatively balanced combination of companies from different sectors with different sizes (SMEs and big companies).

5.3.1.3 Number of finished product types

To find an approximation to the number of finished product types, companies were asked to place them into a number of categories defined according to the number of finished types of products being produced. Table 5.4 shows the ranges of the categories and the percentages of companies belonging to each category. A major part of the firms manufacture less than thirty types of products (49%). Also 25.5% of them produce between 30 and 200 finished products (in three categories) and 25.5% produce more than 200 different products.

Number of finished Product Types	Valid Percentage of companies	Cumulative Percentage of companies
<10	21.8	21.8
10-30	27.3	49.1
31-60	9.1	58.2
61-100	7.3	65.5
100-200	9.1	74.5
> 200	25.5	100.0

Table 5.4. Number of finished products types

The results, however, could have been biased because of the difference in the perception of companies about the finished product types. Later in the interview sessions it was understood that some companies take every single part they produce as a finished product.

5.3.1.4 Production type

Table 5.5 indicates the production type of the surveyed companies according to the known categories. This was of specific concerns of the research, as a move from mass production towards customisation, or mass customisation is believed to be the future trend of manufacturing.

Production Type	Valid Percent
Engineering to order	6.9
Assemble to order	5.2
Manufacture to order	69.0
Mass Production	3.4
Manufacture to stock	15.5

Table 5.5. Type of production of surveyed companies

The result is quite promising, as 69% of companies manufacture based on order, which is close to what is meant by mass customisation. However, manufacturing to stock is still second in the descending order of the results. This will be discussed more lately when studying sectors.

5.3.1.5 Export of products

The percentage of export of products was examined to find to what extent the responding companies face the global competition and challenge. Table 5.6 represents the categories defined and the distribution of surveyed companies over the categories. A good deal of firms (39.6%) export more than 50% of their products, while 67.2% of them sell more than 20% of their products to foreign markets.

Percentage of Products Export	Valid Percentage of companies	Cumulative Percentage of companies
0	6.9	6.9
1-5	13.8	20.7
6-20	12.0	32.8
21-50	27.6	60.3
51-80	29.3	89.7
81-100	10.3	100.0

Table 5.6. Export of products among the surveyed sample

5.3.1.6 Position in the market

The surveyed companies were found to be relatively successful manufacturers according to the information they provided with regard to their marketshare at home and globally. On average the surveyed companies possess 39.2% of home markets and 24.9% of global markets. These figures could be considered as high in the scale of marketshare.

Also the respondents were asked to assess their company for the level of being world-class. In response an average of 2.8 out of 5 (Highly World-Class Company) was resulted, which shows a relatively good image and self-confidence of the companies.

5.3.1.7 Customers, Suppliers, Partners

Table 5.7 illustrates some figures about the average number of suppliers, customers, and partners that the surveyed companies are in relation with.

Although decreasing the number of suppliers has been considered as one recommended way of increasing productivity and efficiency, the average number found for the surveyed group of companies was high. This might cause difficulties in managing the supply chain and impose unreasonable costs.

Customer/Supplier related figures	Mean
No. of Main Suppliers	133.54
No. of Main Customers	22.93
No. of Suppliers as Partner	8.96
Criticality of Relationship with Suppliers	4.33 out of 5

Table 5.7. Figures with regard to suppliers, customers, and partners

Much emphasis was put by the respondents on the criticality of their companies' relationship with suppliers. The criticality of this relationship is set for 4.33 out of 5 (highly critical).

Also partnership, as an advanced way of cooperation, has not received much consideration by the surveyed companies. A less than 6% of customers and suppliers are taken as partners. However, the confusion with regard to exact definition for partnership can be thought of as one limitation of this analysis and the related conclusions.

5.3.2 Investment in Research and Development (R&D)

Research and development (R&D) has always been considered as one indicator of improvement in industry, though it cannot be equated to innovation or innovativeness. There has been resistance reported by managers from their shareholders who prefer the money not to be spent on R&D [Cohen, 1992]. Also the increasing uncertainty of markets does not encourage more spending on R&D. In such a condition, recovering the costs before being forced to substitute the product with new versions is not very likely.

However, the result from questioning the surveyed companies about their investment in R&D, which is shown in Table 5.8, indicates a relatively acceptable rate of spending on R&D. This, in comparison with the survey conducted in 1989 and 1992 [Poolton, 1994], shows a further shift in R&D spending. The previous surveys reported that 52% of companies spend under three percent of their turnover on R&D,

while our survey shows this to be less than 40%. Hence, companies with four to six, and more than six percent of turnover spent on R&D, have increased.

Percentage of Turnover Invested on R&D	Valid Percentage of companies	Cumulative Percentage of companies
0	3.8	5.7
[0.5-1)	18.9	24.5
[2-4)	20.8	45.3
[4-6)	28.3	73.6
> 6	26.4	100.0
Mean Percentage of turnover invested on R&D: = 5.82, Number of Cases = 52		

Table 5.8. Investment on R&D in surveyed companies

It was also found that the average of turnover invested in R&D is 5.82% among all surveyed companies.

5.3.3 New Products Introduction and Success of New Products

Introduction of new products in the shortest possible time has been considered a successful strategy in order to take competitive advantage. However for some reasons this trend is not strongly supported by data from the survey. Table 5.9 shows the six categories defined and the distribution of companies in these categories.

Number of New Products Introduced in the past 3 Years	Valid Percentage of Companies	Cumulative Percentage of Companies
< 3	16.1	16.1
3-10	39.3	55.4
11-30	21.4	76.8
31-60	5.4	82.1
61-100	3.6	85.7
> 100	14.3	100.0

Table 5.9. Number of new products introduced in the past three years

However, the results in comparison with the surveys conducted in 1987 and 1992 [Poolton, 1994] show a considerable change in the past few years. According to the

referred surveys, 75% of the surveyed samples introduced less than 10 new products, while this figure is as low as 55.4% for the survey of this research. In fact, 76.8% of the surveyed companies have introduced from less than three to thirty new products. This can be an indicator of new notions considered in the competition criteria of the new industrial age. In previous surveys the figures were justified with the complexity of the new technologies, which could not be confined by one single company. This seems to have been removed to a certain level considering the improvements in the area of technology application, technology and manufacturing management, and specially the wide spread application of information system/technology.

The same argument goes with the success rate of new products. An average of around 60% has been an acceptable rate of success of new products which was confirmed by two surveys in 1987 (64%) and in 1992 (60%) [Poolton, 1994]. Our survey shows a rate of about 73% of new products success. Details are shown in Table 5.10. This can be interpreted as a sign of achievements of a long history of emphasis on improving new product development (NPD) through new technologies and methods, which were being experienced in 1992 and prior to that.

Percentage of New Products Success in the Market in the past 3 Years	Valid Percentage of Companies	Cumulative Percentage of Companies
< 5	2.0	2.0
5-10	2.0	3.9
11-30	3.9	7.8
31-60	9.8	17.6
61-80	31.4	49.0
81-100	51.0	100.0

Table 5.10. Success of new products introduced by the surveyed companies

In another attempt to examine the subject of new products introduction, the respondents were asked about the newness of their new products. Results are shown

in Table 5.11. This shows a further support for customisation tendency among manufacturing companies, while the lowest rate belongs to complete innovation.

Products Newness	Mean	Std. Dev.
Custom Made	40.96	36.74
Improved Products	30.76	31.35
New Lines (Not to market)	16.22	25.60
Completely Innovation	11.16	21.38

Table 5.11. Newness of products introduced by surveyed companies

5.3.4 Business Priorities

Business priorities, which are also referred to as strategic objectives, or success criteria, are a set of factors that every company tries to excel in order to take the competitive advantage.

Among the diverse combinations, a more common set is cost, quality, flexibility, and time. In chapter two the importance of these priorities and the evolving trend in their rises and falls were elaborated. Also it was mentioned in section 2.3.3 that despite the recent emergence of new factors such as flexibility and time, the emphasis is still on older factors such as quality and cost. This has been shown by many surveys, which in a sense have contradicted the powerful belief of the emergence of new priorities.

Table 5.12 shows the mean degree of importance of the business priorities indicated by the respondents. As it is evident, quality and cost are still at the top of the list, and time is at the bottom.

Business Priorities' Degree of Importance	Mean
Quality	2.25
Cost	3.14
Flexibility	3.65
Time	3.68
1 = The Most Important, 5 = The Least Important	

Table 5.12. Business priorities among surveyed companies

For quality it can be explained by reciting notes of some respondents in the questionnaire that quality is a must and is unquestionable. Also for the position of time factor, although it has been justified by saying that new concepts take a good deal of time to be taken into practice [Lorenz, 1992], the elapsed time from the late 1980s to now must have been enough for the concept being trickled down into practice.

However, apart from the case of quality, the slight difference between the emphasis on other factors, most of which are scored close to very high importance, shows that the emphasis on strategic targets depends on different circumstances of manufacturing companies in which the uncertainty of the business environment plays a bold role. This also implies that the priorities are now considered as a whole package rather than emphasising on some particular ones. This was already discussed in chapter two as a consensus on the subject of business priorities among academics.

5.3.5 Awareness of Agility, Level of Need for Agility

The research initially was based on the perception that the subject as a new concept is new to UK manufacturing companies. This was put into examination by asking the respondents to what extent they are familiar with the subject. On a scale of 1 (Not heard of) to 5 (completely familiar) it was found that on average the respondents' awareness of agility concept is 2.37. This is less than the medium level (2.5 out of 5),

however, it does not necessarily mean that the companies are not alert, do not know their business environment and circumstances, or are not aware of the importance of responding to change. Besides, data from the pilot questionnaire survey which was conducted about 9 months before the main survey showed an even lower level. At that time this level was found to be 1.89 out of 5 which in comparison shows a shift in the expansion of concept due to some works and projects conducted recently with regard to agile manufacturing.

Also the level of need for agility was among the main concerns of the research. As elaborated in chapter two, and stressed in the research hypotheses, different companies need different levels of agility. This was simply examined by asking a direct question about the level of need for agility at each company on a scale of 1(No need) to 5 (Highly needed). The question was supported by the supplied explanatory sheet sent with the questionnaire in which the concept and some definitions were introduced to the respondents. The outcome was 3.96 out of 5, which supports the above reasoning for the degree of awareness of the companies with regard to agility.

The data from the questionnaire will be later applied to provide support for a preliminary method for determining the level of need for agility.

5.3.6 Agility Drivers

Agility drivers or the pressures from the business environment, which were categorised under 5 main titles, were examined to find out the extent to which they are perceived by the manufacturing companies as changing and turbulent. Table 5.13 represents the ranking given by the overall respondents. The numbers indicate the pressure each factor has on the company. Customer requirements received the highest degree while social factors were shown to have the lowest degree of change and turbulence. Also marketplace as a widely concerned factor for its increasing level of uncertainty is in the fourth place, though the differences in the calculated means are not too much.

Further investigations into this subject, and particularly the sub-factors, which could be entitled under each of these, sub-factors, were left to the interview stage of the research.

Agility Drivers	Rank for pressure on the manufacturing companies
Customer Requirements	3.75
Competition	3.62
Technology	3.35
Marketplace	3.32
Social Factors	2.53
1 = Stable with the Least Changes (No Threats) 5 = Highly Changing and Turbulent	

Table 5.13. Ranking of Agility Drivers among the surveyed companies

5.3.7 Strategic Capabilities

As another part of the conceptual model, capabilities or strategic capabilities, which are defined as required abilities to respond to changes and becoming agile, were investigated. An extended version of the four dimensions that are used in the model was the base of questions from the respondents to find out which strategies (strategic capabilities) have received more concern by manufacturing companies in responding to the changing environment.

Table 5.14 depicts the results, which show a rank order of the introduced factors. Focus on customer, which categorically belongs to "competency" item, is accounted as the most important factor. Proactivity, which is extracted from "responsiveness", stays at the second place. Competency, responsiveness, and flexibility with slight difference are put in the next three positions, and innovation that is a part of the more general category of "competency" lays in the next step. Quickness and relation with suppliers are the last two items and hence the least important items, while the lowest mean rank indicated for "relation with suppliers" is 3.75 out of 5 (Highly important and vital).

Strategic Capabilities	Rank for Importance to the manufacturing companies in Response to Changing Environment
Focus on Customer	4.55
Proactivity	4.24
Competency of the company	4.23
Responsiveness	4.22
Flexibility	4.07
Innovation	4.03
Quickness	3.84
Close Relations with suppliers	3.75
1 = No important 5 = Highly important	

Table 5.14. Strategic capabilities ranked by the surveyed companies

5.3.8 Methods, Tools, Practices in Support of Agile Manufacturing

Based on the conceptual model introduced during the research, the last stage in becoming agile is adopting practices, and deploying methods and tools, which can accommodate achievement of necessary capabilities, required to be change proficient and agile.

Four separate sets of practices, methods, and tools were considered in examining the concept and investigating the effects and importance of some distinguished practices on becoming agile. Major methods and tools of manufacturing control systems, some common and popular manufacturing system methods and tools, a number of practices that are recognised in the literature as supporting practices for agile manufacturing, and finally a list of practices in the field of information system/technology are constituting parts of this investigation.

Table 5.15, and Table 5.16 include information on the manufacturing control system tools, and manufacturing system methods and tools respectively. The average years

the methods have been in use, and the percentage of companies that have these tools and methods in practice are stated.

Manufacturing Control Systems Type	Average Years in use	Percentage of Companies Using the Method
MRP/MRPII	4.97	67.2
Manual	2.81	13.8
JIT/Kanban	1.70	41.3
OPT	0.1	7.0

Table 5.15. Manufacturing Control System used by the surveyed companies

Manufacturing System Methods/Tools	Average Years in use	% of Companies Using the Method
CAD/CAM	6.42	64.8
TQM methods	2.89	35.1
Robot Technology	1.67	16.2
Lean Manufacturing	1.54	35.1
Concurrent Engineering	1.20	24.3
Flexible Manufacturing System	1.10	21.6
Joint Venturing	0.81	16.2
CIM	0.45	8.9

Table 5.16. Manufacturing System Methods/Tools used by the surveyed companies

Fourteen general practices and nine practices related to information system/technology were studied to find out:

- Whether the practices have been completely or partially implemented, or not implemented at all

- To what degree the practices have been found effective in the way of responding to changes in the business environment, in case they are completely or partially implemented.
- To what degree the practices are perceived as important for the company to have in responding to changes, in case the surveyed companies do not implement them.

Table 5.17, and Table 5.18 show the results from data analysis.

In practice, establishing virtual organisation, which has recently received a wide range of interests, and is introduced as a revolutionised method of cooperation that can bring about solution to many problems of the new business challenges, is found to be accounted as the lowest practised method, with a low degree of effectiveness and importance as well. Mass customisation is the second least implemented practice, but with a good degree of effectiveness (3.37 out of 5). However those who have not adopted mass customisation did find it very important. Most of the rest of examined practices are being implemented partially in more than 70% of the companies. Among these, however, informal management, and concurrent and team working have been completely implemented in around 20% of the surveyed companies. "Partnership" with 91.2% , and "close relationship with customers/suppliers and involving them in company's planning" with 81% partial implementation are the most popular practices among the surveyed companies.

Agility Supporting Practices	Completely Implemented Percent	Partially Implemented Percent	Not Implemntd Percent	Mean Degree of Effectiveness where completely or partially Implemented	Mean Degree of Importance Where Not Implemented
Establishing Partnership with Suppliers and Customers	5.3	91.2	3.5	3.18	2.00
Establishing Virtual Organisation	0.0	19.2	80.8	2.2	2.05
Close relations with customers/suppliers and involving them in company's planning and PDP	5.2	81.0	13.8	3.06	2.88
Adoption of Advanced Technology	12.1	77.6	10.3	3.24	2.5
Mass-Customisation	8.8	52.6	38.6	3.37	2.09
Integration of Inter-organisational systems and modules	8.8	75.4	15.8	3.00	2.5
Total Integration of Manufacturing System	14.3	73.2	12.5	3.16	2.14
Flexible, Responsive, Flat, Learning, and Team and Focused Organisation	17.2	75.9	6.9	3.24	3.25
Continuous Re-engineering of the Organisation and Business Processes	8.6	70.7	20.7	3.09	3.09
Informal, Coaching, and Encouraging Management	19.0	74.1	6.9	3.22	3.75
Structured and flexible Manufacturing Processes	17.5	70.2	12.3	3.3	3.14
Concurrent and Team Working Methods	19.3	64.9	15.8	3.25	3.78
Empowerment of People	8.6	79.3	12.1	3.04	3.71
Continuous Training and Education of People	15.5	72.4	12.1	3.38	3.75

Table 5.17. Agility supporting practices implementation, effect on the company's ability to respond to changes (where used), and importance (where not used)

Agility Supporting Information System/Technology Practices	Completely Implemented Percent	Partially Implemented Percent	Not Implemntd Percent	Mean Degree of Effectiveness where completely or partially I mplemented (out of 5)	Mean Degree of Importance Where Not Implemented (out of 5)
Using Internet and Related Information Tools for Communication with Outside of the Company and Capturing Market	3.7	70.4	25.9	2.67	2.33
Computerised Manufacturing Information System compatible to STEP	7.4	51.9	40.7	2.71	2.55
Information System Interface with Suppliers to update them	1.8	55.4	42.9	2.78	3.00
Information System Interface with Customers to provide them Information	0.0	64.9	35.1	2.86	3.16
Computerised Manufacturing Information System	53.4	15.5	22.4	3.59	3.25
Information Management Plan or Model	8.8	47.4	43.9	3.41	3.05
Strategic Use of Information System Through the Company's Information Management Plan	3.5	54.4	42.1	3.39	3.59
Internal Information Network	18.2	63.6	18.2	3.43	3.2
Integrated Computer-based Product Development Process	10.9	63.6	25.5	2.95	3.00

Table 5.18. Agility supporting Information system/technology practices implementation, effectiveness on the company's ability to respond to changes (where used), and importance (where not used)

In information system practices, information management model or plan, and strategic use of information in the companies' business have been found to be the least implemented practices while their effectiveness and importance are reasonably high. The major tendency of the surveyed companies was found to be towards establishing computerised manufacturing information systems.

5.4 RELATIONSHIP BETWEEN THE STUDIED FACTORS OF AGILITY MODEL

The conceptual model introduced in this work for studying the concept and practices of agile manufacturing consists of some related and interactive parts which are employed to translate the core concept of change in the business environment to an appropriate action in responding to the change, and also to deliver a transitional movement from realisation of surrounding forces to appropriate responses through application of suitable practices.

The general analysis presented in previous sections would not be complete in providing support and validation for the presumed conceptual model without looking into the relationships between the factors using further statistical testing tools. This would also accommodate the required basis for the in-depth case studies, and provide more insight into the subject, which is crucial in establishing a practical model of agility.

To fulfil this purpose, the cross-tabulation method or contingency table method was employed. With crosstabulation method, as explained in section 5.2.3, the results from cross-tabulation would show the existence of relationship between factors that are expected not to be independent from each other. In fact the procedure aims at comparing independent unrelated categorical data, which will be formed in contingency tables.

For each cross-tabulation a null hypothesis, H_0, was defined as: "there is no relation between the two variables", which was tested by Chi-Square test.

For confidence interval a maximum 10 percent interval was considered as the measure for finding whether the difference is significant or not. Therefore a significant level of less than 0.1 is considered which will reject the null hypothesis if resulted, and in that case two variables are considered as dependent.

In the following sub-sections, where the results of crosstabulation are shown, the tables contain the Chi-Square value computed by the software (value), degrees of

freedom (DoF), significance computed by the software (Sign.), and the accuracy level or the upper limit of the confidence interval (Acc. %).

5.4.1 Agility Drivers VS Agility Strategies

Agility drivers are expected to be responded by appropriate strategies and hence by accommodating strategic capabilities. From 40 cross-tabulations of these factors, 8 were found to be significant in the assumed confidence interval, and hence the existence of a relationship considered as evident. Table 5.19 represents the significant cases.

As it is shown in Table 5.19, agility drivers are mostly found related to those strategic capabilities, which are introduced in the conceptual model. They are "responsiveness", "flexibility", and "quickness". Innovation and proactivity are in fact sub-items of the "competency" item, the fourth dimension of the introduced capabilities in the model.

However, for some reasons such as the novelty of the concept to the literature, the span of the results to conform to the basic assumptions of the research is limited.

5.4.2 Agility Drivers VS Implementation of Agility Supporting Practices, and Information System/Technology Practices

Although the introduced practices in the questionnaire were questioned for their roles in responding to changes, it was a matter to be clarified whether the practices can be related to specific forces from the business environment.

This was tried by cross-tabulating agility drivers with agility practices and information system/technology practices. Results are reported in Table 5.20, that includes 17 significant relationships between the defined factors, of which 9 are for agility practices, and 8 are for information system/technology practices. Value for Chi-Square, degrees of freedom and the significance level are shown as well.

Cross-tabulated factors	Value	DoF	Sign.	Acc. %
Agility Driver/Competition VS. Strategy/Increasing Responsiveness	17.06731	6	.00904	1
Agility Driver/Competition VS. Strategy/Increasing Flexibility	21.97778	9	.00895	1
Agility Driver/Competition VS. Strategy/Increasing Quickness(speed)	15.67517	9	.07398	8
Agility Driver/Customer Requirements VS. Strategy/Increasing Responsiveness	22.01608	8	.00489	1
Agility Driver/Customer Requirements VS. Strategy / Innovation	20.26823	12	.06218	7
Agility Driver/Social Factors VS. Agility Strategy / Innovation	20.26727	12	.06220	7
Agility Driver/ Technology VS. Agility Strategy/Proactivity	17.27820	9	.04453	5
Agility Driver/ Technology VS. Agility Strategy/Increasing Responsiveness	16.18531	6	.01279	2

Table 5.19. Cross-tabulation of Agility Drivers and Agility Strategic Capabilities - Significant cases

5.4.3 Agility Strategic Capabilities VS Implementation of Agility Supporting Practices and Information System/Technology Practices

One of the aims of the research is to establish a preliminary practical model, which can define some logical and perhaps mathematical relationship between agility drivers, agility capabilities, and agility practices. The relation between capabilities and practices as two adjacent parts of the model is mostly required. However, due to the limitations that the research suffered from, this was partly left to be investigated more in the next stage of the study, case studies, and also was expected to be handled intuitively and with support from literature.

To take the most out of the conducted survey, however, the capabilities were cross-tabulated with practices and information system/technology practices. The results are depicted in Table 5.21, which includes 18 agility practices and 12 information system/technology practices related to some of strategic capabilities. These results indicate that the assumed relationship between agility capabilities and agility practices in the conceptual model is valid in general.

Cross-tabulated factors	Value	DoF	Sign.	Acc. %
Agility Driver/ Marketplace VS. Agility Practice Implementation /Total integration	14.87424	8	.06164	7
Agility Driver/Competition VS. Agility Practices Implementation/ Mass Customisation	11.33514	6	.07855	8
Agility Driver/ Technology VS Agility Practices Implementation/ Mass Customisation	13.45013	6	.03642	4
Agility Driver/ Technology VS Agility Practices Implementation/ Flexible, flat, .. Organisation	12.94289	6	.04395	5
Agility Driver/ Technology VS Agility Practices Implementation/ Continuous Re-engineering of Organisation	21.87060	6	.00128	1
Agility Driver/ Technology VS Agility Practices Implementation/ Concurrent and team working	13.61478	6	.03425	4
Agility Driver/ Technology VS Agility Practices Implementation/ Continuous training, Education of people	19.27886	6	.00372	1
Agility Driver/ Technology VS Agility Practices Implementation/ Customer, suppliers Involvement in Planning & Product Development Process	16.65443	6	.01064	2
Agility Driver/ Technology VS. Agility Practice implementation/ Adopting Advanced Technology	18.53876	6	.00502	1

Table 5.20. Cross-tabulation of Agility Drivers and Agility Supporting practices Information System/Technology Practices Implementation-Significant cases

Cross-tabulated factors	Value	DoF	Sign.	Acc.%
Agility Driver/Competition VS. Information System Implementation/ Using Internet	12.52189	6	.05129	6
Agility Driver/Competition VS. Information System Implementation/ Information Management Plan	10.68968	6	.09845	10
Agility Driver/Customer Requirements VS Information System Implementation/ Computerised MIS Connected to STEP	17.27347	8	.02738	3
Agility Driver/Customer Requirements VS Information System Implementation/ Internal Information network	18.01653	8	.02110	3
Agility Driver/Social Factors VS. Information System Implementation/ Using Internet	14.75188	8	.06415	7
Agility Driver/Social Factors VS. Information System Implementation/ Information Connection to Suppliers	15.02688	8	.05862	6
Agility Driver/ Technology VS Information System Implementation/ Computerised MIS Connected to STEP	13.01657	6	.04277	5
Agility Drivers/ Marketplace VS. Information System Implementation Computerised Manufacturing Inf. System	18.66855	12	.09685	10

Table 5.20. Continued

Cross-tabulated factors	Value	DoF	Sign.	Acc. %
Strategy/Increasing Responsiveness VS Agility Practice Implementation / Continuous Re-Engineering of Organisation	8.71667	4	.06859	7
Strategy/Increasing Responsiveness VS Agility Practice Implementation / Concurrent team working	8.42160	4	.07730	8
Strategy/Increasing Responsiveness VS Agility Practice Implementation / Empowerment of people	10.20639	4	.03709	4
Strategy/Increasing Competency VS Agility Practice Implementation / Adopting Advanced Technology	15.19154	6	.01882	2
Strategy/Increasing Flexibility VS Agility Practice Implementation / Adopting Advanced Technology	12.12484	6	.05924	6
Strategy/Increasing Quickness VS Agility Practice Implementation / Structured and Flexible Manufacturing Process	21.26955	6	.00164	1
Strategy / Innovation VS Agility Practice Implementation / Continuous Re-engineering of Organisation	11.70119	6	.06898	7
Strategy / Innovation VS Agility Practice Implementation / Structured/Flexible Manufacturing Process	18.86974	6	.00439	1
Strategy / Innovation VS Agility Practice Implementation / Empowerment of People	16.22019	6	.01262	2

Table 5.21. Cross-tabulation of Agility Strategic Capabilities and Agility Supporting practices. (Information System/Technology Practices Implementation) -Significant cases

Cross-tabulated Factors	Value	DoF	Sign.	Acc. %
Strategy/Proactivity VS Agility Practice Implementation / Partnership with Suppliers/Customers	29.72060	6	.00004	0.05
Strategy/Proactivity VS Agility Practice Implementation / Establishing Virtual Organisation	8.33731	3	.03953	4
Strategy/Focus on Customer VS Agility Practice Implementation / Adopting Advanced Technology	13.12093	6	.04116	5
Strategy/Focus on Customer VS Agility Practice Implementation / Structured/Flexible Manufacturing process	14.91161	6	.02096	3
Strategy/Focus on Customer VS Agility Practice Implementation / Continuous Training/Education of People	16.02766	6	.01361	2
Strategy / Innovation VS Agility Practice Implementation / Partnership with Suppliers/Customers	13.50962	6	.03562	4
Strategy / Innovation VS Agility Practice Implementation / Mass Customisation	12.11081	6	.05954	6
Strategy / Innovation VS Agility Practice Implementation / Integration of Inter-Organisational Systems	11.56562	6	.07239	8
Strategy/ Close Relation with Suppliers VS Agility Practice Implementation / Continuous Training/Education of People	14.02619	6	.02935	3
Strategy/Increasing Flexibility VS Information System Implementation / Information Connection to Customers	6.63291	3	.08457	9
Strategy/Close Relation with Suppliers VS Information System Implementation / Using Internet	12.78494	6	.04658	5

Table 5.21. Continued

Cross-tabulated Factors	Value	DoF	Sign.	Acc. %
Strategy / Innovation VS Information System Implementation Using Internet	13.09693	6	.04152	5
Strategy / Innovation VS Information System Implementation Information Connection to Suppliers	16.51741	6	.01123	5
Strategy / Innovation VS Information System Implementation Information Connection to Customers	8.09320	3	.04412	5
Strategy / Innovation VS Information System Implementation Integrated Computer-Based Prod. Dev.	13.22086	6	.03966	5
Strategy/Increasing Quickness VS Information System Implementation / Integrated Computer Based Prod. Dev.	18.11868	6	.00594	1
Strategy/Increasing Responsiveness VS Information System Implementation / Computerised Manufacturing Inf. System	12.12753	6	.05918	6
Strategy/Increasing Responsiveness VS Information System Implementation / Information Management Plan	8.13481	4	.08676	9
Strategy/Increasing Quickness VS Information System Implementation / Information Connection to Customers	6.87536	3	.07598	8
Strategy/Increasing Quickness VS Information System Implementation / Internal Information Network	12.32618	6	.05508	6
Strategy/Close Relation with Suppliers VS Information System Implementation / Internal Information Network	12.01746	6	.06158	7

Table 5.21. Continued

5.5. BY-SECTOR ANALYSIS

Different companies in different sectors possess characteristics, which are specific or perhaps unique to them. This is the same for the circumstances they face in their competition for winning the game of succeeding in market. These particular circumstances would define the way that the company may be treated when it enters the field of competition, be threatened by rivals, face opportunities, be evaluated by markets and customers, and hence the way it has to respond to these environmental pressures. This uniqueness cannot be excluded from companies in a sector, though members of each sector are expected to share some characteristics, show similar behaviour, and maintain same competitive environment. This is also more evident with the increasing formation of niche markets, and also the sophistication and complication of technologies. Therefore, agility, as a way of responding to changes in the business environment, can be thought of as a characteristic, which ties to the specific situations, and circumstances a company is engaged in.

Some comparisons between the three studied sectors are being made to find out to what degree the sectors are different according to measures considered in the research and the conceptual model.

5.5.1 Sectors Characteristics

Production type, number of new products introduced, the success rate of new products, products newness, and investment on R&D are the factors used in making the comparisons.

Tables 5.22, 5.23, 5.24, and 5.25 depict the results of data analysis under mentioned subjects.

Aerospace sector tends to use manufacturing to order as the type of their manufacturing more widely. This may be due to the types of products they manufacture, and the market they serve. The two other sectors seem to follow a pattern same to each other and different from that of Aerospace sector. Aerospace sector again is different from two other sectors in the number of introduced new products. 100% of the companies in this sector have introduced between 1 to 30 new

products (less than 30 products), which can again be explained based on the nature of the products they produce and the market they serve. The pattern of new products introduction for electronics sector and auto-parts sector is also closely similar to each other.

Table 5.24 shows the (valid) percentage of companies in three sectors for the categorised percentages of successful new products introduced by the companies in the past three years (the left column). As it is evident all three sectors have shown a good pattern of success of their new products, while auto-parts sector has a better record than the two others, and electronics sector is in a lower position than aerospace sector.

Production Type	Valid Percentage of Companies in each Sector		
	Electronics	Aerospace	Auto Parts
Engineering to order	12.5	0.0	6.7
Assemble to order	4.2	8.3	0.0
Manufacture to order	62.5	91.7	66.7
Mass Production	4.2	0.0	6.7
Manufacture to stock	16.7	0.0	20.0

Table 5.22. Comparison sectors for production type

Number of New Products Introduced in the past 3 Years	Valid Percentage of Companies in each Sector		
	Electronics	Aerospace	Auto Parts
< 3	13.0	16.7	26.7
3-10	43.5	58.3	13.3
11-30	13.0	25.0	33.3
31-60	8.7	0.0	0.0
61-100	4.3	0.0	6.7
> 100	17.4	0.0	20.0

Table 5.23. Comparison of sectors for introduction of new products

Percentage of Successful New Products introduced in the past 3 Years	Valid Percentage of companies in each sector		
	Electronics	Aerospace	Auto Parts
< 5	0.0	9.1	0.0
5-10	0.0	0.0	7.7
11-30	4.3	9.1	0.0
31-60	17.4	9.1	0.0
61-80	39.1	18.2	23.1
81-100	39.1	54.5	69.2

Table 5.24. Comparison of sectors for new products success

Products Newness	Average Percentage of Products		
	Electronics	Aerospace	Auto-parts
Custom Made	44.38	46.5	41.15
Improved Products	31.17	14.42	39.23
New Lines (Not to market)	18.33	11.18	13.2
Completely Innovation	5.92	20.50	7.64

Table 5.25. Comparison of sectors for newness of their products

The three sectors tend to adopt customisation as the form of their new products introduction, but aerospace sector is considerably higher in introduction of innovative new products. This accounts for 20.5% of their new products, which is as much as three to four times that of the two other sectors.

Also as shown in Table 5.26, aerospace sector with an average 7.91% of turnover investment on R&D leads in this issue, followed by electronics and auto-parts sectors with respectively 6.39% and 4.27% of their turnover invested.

	Electronics	Aerospace	Auto-parts
Percentage of Turnover Invested on R&D (%)	6.39	7.91	4.27
Level of need to Agility (out of 5)	4.33	4.00	3.86
Awareness of Agility (out of 5)	2.33	2.83	2.00
World Class Degree (out of 5)	3.67	3.11	2.50

Table 5.26. Comparison of sectors for investment on R&D, level of need to agility, awareness of agility, and world-class degree

Aerospace sector seems to be more aware about agility than the two other sectors. This can be reasoned to be related to a few research projects conducted with regard to agile manufacturing involving UK aerospace companies. Electronics sector and auto-parts sector follow aerospace sector in the matter of awareness respectively, though the difference between these two sectors is not very significant.

Electronics sector has indicated a higher level of need for agility with 4.33 out of 5, which is followed by aerospace sector with 4.0 out of 5, and auto-parts sector with 3.86 out of 5.

On average electronics sector has assessed them to be more world class than the two other sectors. 3.6, 3.1, and 2.5 out of 5 are the mean degrees appointed by the respondents in electronics, aerospace, and auto-parts sectors respectively for this question. This might be due to the fact that electronics companies present in a globally wider market, while for example, most of auto-parts sector companies serve local auto manufacturers.

5.5.2 Agility Drivers, Agility Capabilities

Except for "social factors" which are scored on average under 3 out of 5 other factors are found to be very changing and turbulent to all three sectors. As stated in Table 5.27, electronics and aerospace sectors have seen customer requirements to be more turbulent while competition is the more important factor to auto-parts sector.

Technology changes seem to be more important to electronics sector than to others, while it is found to be the third important factor for aerospace sector, and the fourth one for auto-parts sector.

However, as shown in the table, the differences between sectors are not highly significant. This can be used in forming some understandings about the business and competition criteria in different sectors.

Agility Drivers	Rank for pressure on the manufacturing companies		
	Electronics	Aerospace	Auto-Parts
Customer Requirements	3.64	3.94	3.73
Competition	3.40	3.74	3.86
Technology	3.42	3.17	3.33
Marketplace	3.18	3.07	3.80
Social Factors	2.47	2.08	2.96
1 = Stable with the Least Changes (No Threats) 5 = Highly Changing and Turbulent			

Table 5.27. Comparison of sectors for agility drivers

Table 5.28 represents the specified importance of the proposed set of strategies or strategic capabilities by the three sectors. A ranking number indicates the degree of importance of each item for each sector. As it is shown, "focus on customer" is the first priority for all three sectors. However other factors are quite different in terms of their rank given by different sectors. In the meantime it can be argued that according to the results most of the strategies are evaluated to be very to highly important. This can be interpreted as due to the diversity and turbulence of the circumstances that manufacturing companies are facing in the new world of business. In other words, manufacturers have to adopt a wide range of strategies and strategic capabilities in order to be able to cope with changes and stay in business.

Strategic Capabilities companies	Rank for Importance to the manufacturing in Response to Changing Environment		
	Electronics	Aerospace	Auto-Parts
Focus on Customer	4.46	4.75	4.47
Proactivity	4.21	4.00	4.33
Competency of the company	4.04	4.50	4.4
Responsiveness	3.96	4.42	4.40
Flexibility	4.00	4.00	4.07
Innovation	4.08	3.17	3.93
Quickness	3.75	3.50	4.20
Close Relations with suppliers	3.82	3.75	3.67
1 = Stable with the Least Changes (No Threats)			
5 = Highly Changing and Turbulent			

Table 5.28. Comparison of sectors for agility strategic capabilities

5.5.3 Agility Supporting Practices, Information System/Technology Practices

Comparisons are made between the three sectors in terms of the extent of implementation of practices in support of agility, their perceived effects, and their importance in case they are not implemented. Tables 5.29 and 5.30 show the results of this analysis.

Electronics sector is found to be more concerned about most practices, with a higher percentage of implementation than other sectors. This is more evident in the matter of "establishment of virtual organisation" in which auto-parts sector has a record of 100% not implemented, and "mass customisation" in which aerospace sector has not practised it at all. These differences exactly refer to the nature of the products each sector manufacture and the market they serve. This reasoning is also more evident from the degree of importance given by three sectors to these items.

Practices that have been considered more seriously by electronics sector are "informal management", and "empowerment of people". For aerospace "concurrent and team working ", "continuous education of people", and "total integration of manufacturing system" have been found to be more concerned practices. "Structured and flexible manufacturing system" has been found to be the practice, which receives more attention from the aerospace sector.

With regard to information system practices it can be observed that on average the electronics sector has more concerns over different methods and tools. However, aerospace sector showed a higher record of complete implementation of the methods. For example 60% of companies in this sector have completely implemented computerised "manufacturing information system", while this percentage for electronics and auto-parts are 15 % and 9.7% respectively. This factor is also found to be the most effective one for aerospace sectors, but companies in electronic sector who have not implemented it (33.7%) have given a degree of importance of 1.0 out of 5, which means it is not important for them.

"Information management plan or model", and "strategic use of information" are comparatively considered higher in aerospace sector with both high degree of effectiveness and high degree of importance. These items are also found very effective by the two other sectors, but for auto-parts sector companies who have not implemented the items, the practices were not perceived as important factors.

Agility Supporting Practices	Electrical & Electronics					Aerospace					Auto Parts				
	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. Where comp. or or part. Impl.	Mean Deg. of Imprt Where Not Impl.
Establishing Partnership with Suppliers and Customers	12.	7 9.2	8.3	3.00	2.00	0.00	100.0	0.0	3.50	------	0.0	100.0	0.0	3.14	------
Establishing Virtual Organisation	0.0	31.8	68.2	2.29	1.93	0.00	9.1	90.9	2.00	1.89	0.0	0.0	100.0	-------	2.42
Close relations with customers/suppliers and involving them in company's planning and PDP	4.2	79.2	16.7	2.80	2.50	8.3	83.3	8.3	3.30	4.00	6.7	80.0	13.3	3.46	3.50
Adoption of Advanced Technology	16.7	79.2	4.2	3.17	4.00	16.7	75.0	8.3	3.50	3.00	6.7	66.7	26.7	3.64	2.00
Mass-Customisation	16.7	58.3	25.0	3.39	1.17	0.0	0.0	100	-----	2.09	0.0	73.3	26.7	3.55	3.25
Integration of Inter-organisational systems and modules	13.0	82.6	4.3	2.77	1.00	8.3	58.3	33.3	3.63	2.00	0.0	73.3	26.7	3.27	3.25
Total Integration of Manufacturing System	13.0	87.0	0.0	2.91	----	18.2	63.6	18.2	3.89	2.00	13.3	66.7	20.0	3.25	2.00
Flexible, Responsive, Flat, Learning, and Team and Focused Organisation	16.7	7 9.2	4.2	3.04	1.00	16.7	75.0	8.3	3.45	4.00	13.3	80.0	6.7	3.64	3.00

Table 5.29. Comparison of sectors for implementation of agility supporting practices, their effect on agility, and their importance for agility

Agility Supporting Practices	Electrical & Electronics					Aerospace					Auto Parts				
	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. Where comp. or or part. Impl.	Mean Deg. of Imprt Where Not Impl.
Continuous Re-engineering of the Organisation and Business Processes	12.5	79.2	8.3	2.86	2.00	0.0	58.3	41.7	3.443	3.00	13.3	60.0	26.7	3.64	3.5
Informal, Coaching, and Encouraging Management	20.8	75.0	4.2	3.04	5.00	33.3	58.3	8.3	3.36	4.00	13.3	80.0	6.7	3.64	2.00
Structured and flexible Manufacturing Processes	8.3	79.2	12.5	3.00	3.67	27.3	63.6	9.1	3.90	4.00	20.0	60.0	20.0	3.50	2.33
Concurrent and Team Working Methods	8.7	78.3	13.0	2.90	4.33	41.7	50.0	8.3	3.64	4.00	13.3	60.0	26.7	3.64	3.00
Empowerment of People	20.8	75.0	4.2	3.04	3.00	0.0	83.3	16.7	3.00	4.00	0.0	80.0	20.0	3.17	3.33
Continuous Training and Education of People	12.5	75.0	12.5	3.15	3.75	25.0	66.7	8.3	3.45	5.00	20.0	60.0	20.0	4.08	3.33

Table 5.29. Continued

Information System/Technology	Electrical & Electronics					Aerospace					Auto Parts				
	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. Where comp. or or part. Impl.	Mean Deg. of Imprt Where Not Impl.
Using Internet and Related Information Tools for Communication with Outside of the Company and Capturing Market	9.5	71.4	19.0	2.75	1.75	0.0	58.3	41.7	2.80	2.86	0.00	66.7	33.3	2.4	2.33
Computerised Manufacturing Information System compatible to STEP	4.5	63.6	31.8	2.29	2.14	25.0	33.3	41.7	2.83	3.67	0.00	40.0	60.0	3.25	2.5
Information System Interface with Suppliers to update them	4.3	60.9	34.8	2.6	2.88	0.0	25.0	75.0	2.88	3.67	0.0	53.3	46.7	3.13	4.0
Information System Interface with Customers to provide them Information	0.0	75.0	25.0	2.72	3.17	0.0	50.0	50.0	3.00	3.67	0.0	53.3	46.7	3.00	3.17

Table 5.30. Comparison of sectors for implementation of agility supporting Information System/Technology practices, their effect on agility, and their importance for agility

Information System/Technology	Electrical & Electronics					Aerospace					Auto Parts				
	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. where comp. or or part. Impl.	Mean Deg. of Imprt. Where Not Impl	Comp. Impl. %	Part. Impl. %	Not Impl. %	Mean Deg. of Effect. Where comp. or or part. Impl.	Mean Deg. of Imprt Where Not Impl.
Computerised Manufacturing Information System	15	52.3	33.7	4.5	1.00	60.0	30.0	10.0	4.00	3.89	9.7	69.7	20.7	3.18	4.00
Information Management Plan or Model	8.7	43.5	47.5	3.42	3.18	16.7	50.0	33.3	3.75	3.75	0.0	53.3	46.7	3.13	2.2
Strategic Use of Information System Through the Company's Information Management Plan	4.3	47.8	47.8	3.17	4.13	8.3	41.7	50.0	4.00	3.9	0.0	73.3	26.7	3.27	2.00
Internal Information Network	22.7	50.0	27.3	3.31	3.00	33.3	50.0	16.7	4.00	3.9	6.7	86.7	6.7	3.38	3.00
Integrated Computer-based Product Development Process	4.5	72.7	22.7	2.53	2.80	25.0	41.7	33.3	3.5	3.5	6.7	60.0	33.3	3.33	2.75

Table 5.30. Continued

The least effective method as pointed out by all three sectors is "using Internet as a means for communication and marketing ". This method is also found almost the least important for those who have not applied it in auto-parts sector.

5.5.4 Mean Comparison Statistical Test

Based on the data from the survey, a statistical test was carried out to investigate whether different sectors are different with regard to factors mentioned in previous sections. Pressures from the business environment or agility drivers, agility strategic capabilities, effectiveness of practices implemented including information system/technology practices, and importance of these practices has been considered in conducting the test.

For this purpose the Mann-Whitney U test for test of independent samples as a non-parametric test was used to establish whether any differences exist between the three sectors. The choice of the test tool as an alternative to the t-test for independent samples was based on the fact that due to the relatively low number of respondents the data was not very likely to be of a normal distribution, and that the data was ordinal as the respondents had been asked to rate their responses on a scale of 1 to 5. The mentioned conditions are in conformance with the definition and application of the Mann-Whitney U test as described in section 5.2.3.

A confidence interval of 10 percent was considered as the base for recognition of significance of the result. Any comparison test with a significance level of less than 0.1 was considered to present existence of difference between two populations. Table 5.31 and Table 5.32 show respectively 4 and 5 significant cases that have been extracted from 39 comparisons with regard to agility drivers and agility strategic capabilities.

The same procedure was carried out for agility practices including information system/technology practices with regard to their effectiveness and importance. Tables 5.33-5.36 represent 27 significant cases from 138 comparisons, which accounts for about 20% of the items. From the 27 significant cases:

- 10 are related to the effectiveness of agility practices

- 4 are related to the importance of agility practices
- 11 are related to the effectiveness of information system/technology practices
- 2 are related to the importance of information system/technology practices

These results imply that from a sector-wise point of view, companies can not be sharply distinguished or differentiated based on their business circumstances (agility drivers), strategies and strategic capabilities, and practices related to agility. In other words, agility as a particular characteristic should be studied according to the specific circumstances and situations of each company regardless of the sector it belongs to. This is in conformance with the hypothesis considered in the research stating that different companies need different levels of agility regardless of the sector they belong to. The result also support the proposal made in the introduction of the preliminary methodology for implementation of agility where an assessment model is considered as necessary for investigating the level of need of a company for agility.

Mean Comparison, Sector-wise **Agility Drivers, and Agility Strategy**	Sectors	Significance
Agility Driver/ Marketplace		
Mean Rank Sum of Ranks		
16.23 389.5	Electronics	
26.03 390.5	Auto-parts	2-Tailed P = .0081
Agility Driver/Competition		
Mean Rank Sum of Ranks		
17.54 421.0	Electronics	
23.93 359.0	Auto-parts	2-Tailed P = .0857
Agility Drivers/ Marketplace		
Mean Rank Sum of Ranks		
10.75 129.0	Aerospace	
16.60 249.0	Auto-parts	2-Tailed P = .0394
Agility Driver/Social Factors		
Mean Rank Sum of Ranks		
10.50 126.0	Aerospace	
16.80 252.0	Auto-parts	2-Tailed P = .0326

Table 5.31. Mean Comparison of Agility Drivers for sectors. Significant cases.

Mean Comparison, Sector-wise **Agility Drivers, and Agility Strategy**	Sectors	Significance
Strategy/Increasing Responsiveness		
Mean Rank Sum of Ranks		
16.40 393.5	Electronics	
22.71 272.5	Aerospace	2-Tailed P = .0644
Strategy/Increasing Competency		
Mean Rank Sum of Ranks		
15.91 366.0	Electronics	
22.00 264.0	Aerospace	2-Tailed P = .0546
Strategy/Increasing Responsiveness		
Mean Rank Sum of Ranks		
17.46 419.0	Electronics	
24.07 361.0	Auto-parts	2-Tailed P = .0534
Strategy/Increasing Quickness (speed)		
Mean Rank Sum of Ranks		
17.54 421.0	Electronics	
23.93 359.0	Auto-parts	2-Tailed P = .0714
Strategy/Increasing Quickness (Speed)		
Mean Rank Sum of Ranks		
10.63 127.5	Aerospace	
16.70 250.5	Auto-parts	2-Tailed P = .0379

Table 5.32. Mean Comparison of Agility Capabilities for sectors. Significant cases.

Mean Comparison, Sector-Wise **Agility Practices** **Effect**	Sectors	Significance
Agility Practice Effect/ Customer, Supplier Involvement in Planning		
Mean Rank Sum of Ranks		
14.18 283.5	Electronics	
21.35 277.5	Auto-parts	2-Tailed P = .0280
Agility Practice Effect/ Flexible, Flat,...Organisation		
Mean Rank Sum of Ranks		
16.76 385.5	Electronics	
22.68 317.5	Auto-parts	2-Tailed P = .0896
Agility Practice Effect/ Continuous Re-engineering of Organisation		
Mean Rank Sum of Ranks		
14.34 315.5	Electronics	
22.32 245.5	Auto-parts	2-Tailed P = .0164
Agility Practice Effect/ Informal & coaching management		
Mean Rank Sum of Ranks		
16.52 380.0	Electronics	
23.07 323.0	Auto-parts	2-Tailed P = .0601
Agility Practice Effect/ Concurrent & Team working		
Mean Rank Sum of Ranks		
13.82 276.5	Electronics	
19.95 219.5	Auto-parts	2-Tailed P = .0612
Agility Practice Effect/ Continuous Training, Education of People		
Mean Rank Sum of Ranks		
13.73 274.5	Electronics	
21.13 253.5	Auto-parts	2-Tailed P = .0245
Agility Practice Effect/ Integration of Inter-Organisation Systems		
Mean Rank Sum of Ranks		
13.27 292.0	Electronics	
21.63 173.0	Aerospace	2-Tailed P = .0153

Table 5.33. Mean Comparison of Agility Supporting Practices effects for sectors. Significant cases.

Mean Comparison, Sector-Wise **Agility Practices** **Effect and Importance**	Sectors	Significance
Agility Practice Effect/ Total Integration of Manufacturing Systems Mean Rank Sum of Ranks		
13.93 320.5	Electronics	
23.06 207.5	Aerospace	2-Tailed P = .0097
Agility Practice Effect/ Structured/Flexible Manufacturing Process Mean Rank Sum of Ranks		
13.40 281.5	Electronics	
21.45 214.5	Aerospace	2-Tailed P = .0165
Agility Practice Effect/ Concurrent & Team working Mean Rank Sum of Ranks		
13.43 268.5	Electronics	
20.68 227.5	Aerospace	2-Tailed P = .0247

Table 5.33. Continued

Mean Comparison, Sector-Wise **Agility Practices** **Effect and Importance**	Sectors	Significance
Agility Practice Importance/ Adopting Advanced Technology Mean Rank Sum of Ranks		
5.00 5.00	Electronics	
2.50 10.00	Auto-parts	2-Tailed P = .0455
Agility Practice Importance/ Mass Customisation Mean Rank Sum of Ranks		
4.17 25.00	Electronics	
7.50 30.00	Auto-parts	2-Tailed P = .0537
Agility Practice Importance/ Concurrent & Team Working Mean Rank Sum of Ranks		
5.67 17.00	Electronics	
2.75 11.00	Auto-parts	2-Tailed P = .0640
Agility Practice Importance/ Adopting Advanced Technology Mean Rank Sum of Ranks		
5.00 5.00	Aerospace	
2.50 10.00	Autoparts	2-Tailed P = .0455

Table 5.34. Mean Comparison of Agility Supporting Practices Importance for sectors. Significant cases.

Mean Comparison, Sector-Wise **Information System Practices Effect**	Sectors	Significance
Information System Practice Effect/ Information Connection to Suppliers		
Mean Rank Sum of Ranks		
8.47 127.0	Electronics	
14.67 44.00	Aerospace	2-Tailed P = .0466
Information System Practice Effect/ Information Connection to Customers		
Mean Rank Sum of Ranks		
11.08 199.5	Electronics	
16.75 100.5	Aerospace	2-Tailed P = .0632
Information System Practice Effect/ Strategic Use of Information		
Mean Rank Sum of Ranks		
7.58 91.00	Electronics	
13.33 80.00	Aerospace	2-Tailed P = .0218
Information System Practice Effect/ Integrated Computer-Based Prod. Dev.		
Mean Rank Sum of Ranks		
11.35 193.0	Electronics	
16.50 132.0	Aerospace	2-Tailed P = .0639
Information System Practice Effect/ Computerised MIS Connected to STEP		
Mean Rank Sum of Ranks		
8.32 116.5	Electronics	
13.63 54.50	Auto-parts	2-Tailed P = .0358
Information System Practice Effect/ Computerised Manufacturing Inf. System		
Mean Rank Sum of Ranks		
11.25 22.50	Electronics	
6.23 68.50	Auto-parts	2-Tailed P = .0749
Information System Practice Effect/ Integrated Computer-Based Prod. Dev.		
Mean Rank Sum of Ranks		
11.06 188.0	Electronics	
18.11 163.0	Auto-parts	2-Tailed P = .0154

Table 5.35. Mean Comparison of Agility Supporting Information System/technology Practices effects on agility for sectors. Significant cases.

Mean Comparison, Sector-Wise **Information System Practices Effect and Importance**	Sectors	Significance
Information System Practice Effect/ Computerised Manufacturing Inf. System		
Mean Rank Sum of Ranks		
13.00 117.0	Aerospace	
8.45 93.00	Auto-parts	2-Tailed P = .0684
Information System Practice Effect/ Information Management Plan		
Mean Rank Sum of Ranks		
10.25 82.00	Aerospace	
6.75 54.00	Auto-parts	2-Tailed P = .0986
Information System Practice Effect/ Strategic Use of Information		
Mean Rank Sum of Ranks		
12.33 74.00	Aerospace	
7.18 79.00	Auto-parts	2-Tailed P = .0303
Information System Practice Effect/ Computerised MIS Connected to STEP		
Mean Rank Sum of Ranks		
8.43 118.0	Electronics	
15.33 92.00	Aerospace	2-Tailed P = .0066

Table 5.35. Continued

Mean Comparison, Sector-Wise **Information System Practices Effect and Importance**	Sectors	Significance
Information System Practice Importance/ Information Management Plan		
Mean Rank Sum of Ranks		
6.75 27.00	Aerospace	
3.60 18.00	Auto-parts	2-Tailed P = .0785
Information System Practice Importance/ Strategic Use of Information		
Mean Rank Sum of Ranks		
6.50 52.00	Electronics	

Table 5.36. Mean Comparison of Agility Supporting Practices Importance for sectors. Significant cases.

SUMMARY OF THE CHAPTER

This chapter reported results form the survey phase of the research. The survey which was conducted to study the research hypotheses and to pursue the second objective of the research i.e. to identify the main factors of the conceptual model and relationship between these factors provided a large amount of information and data.

In summary:

1. A postal questionnaire was designed in five sections to fulfil some specified objectives including studying the research hypotheses, verifying the validity of the proposed conceptual model, and identifying the main factors of the conceptual model.
2. Questionnaires were posted to 900 UK manufacturing companies from various sectors, most of which were chosen from three sectors i.e., electronics, aerospace, and auto-parts. Around 8% of the corresponded companies replied to the questionnaire of which 60 responses were valid.
3. The resulting data were analysed using SPSS for Windows based on various statistical tests to examine different aspects of the conceptual model, and to identify important factors and relationship between them. Based on the nature of the gathered data and the required analysis, two major methods were used in the analysis of data which are Mann-Whitney U test, and Crosstabulation. The domain of findings of this survey, however, were subject to limitations such as newness of the subject to the surveyed organisations, extent of the investigated factors and issues, and the shallow nature of questionnaire survey. These limitations could partly be removed through a further phase of in-depth case studies, which will be discussed in the next chapter.
4. Various aspects of the surveyed sample were examined in accordance with the concept of agility and the proposed conceptual model. For instance:
    - 4.1. While the awareness of manufacturing companies with regard to agility concept is low, the indicated level of need for agility, based on the definition provided in the survey, is very high. This supports the validity of first hypothesis of the research i.e. agility is an ability that manufacturing companies need to have to be able to survive and prosper in the new order of the global business environment.

4.2. Business environment has been turning turbulent and very changing for most of the companies. This again supports the validity of first hypothesis of the research.

5. The relationships between the factors proposed in the conceptual model were studied using the crosstabulation method. Some strong correlation between the studied drivers of agility and the strategic capabilities, and also the capabilities and practices (agility providers) have been identified. This is in conformance with the employed concept in the conceptual model, or in another word the structure of the proposed model is validated.

6. Companies in three main sectors of the surveyed sample i.e., electronics, aerospace, and auto-parts are compared statistically to find out to what degree the sectors are different according to measures considered in the research and the conceptual model. As a result, there is not much significant difference between different aspects of agility among three studied sectors. This means that in studying the agility issue for different organisations, each organisation must be studied independently regardless of the sector it belongs to. This finding partly supports the second hypothesis of the research, i.e., different organisations are different in the way they should respond to changing business environment, and their level of agility is a direct function of changes in their business environment, the business environment itself and the company's situation.

7. The questionnaire survey resulted in a validation of the research hypotheses and the conceptual model, the identification of the major drivers of agility, the identification of important agility strategic capabilities and some effective practices in acquisition of agility capabilities, and the establishment of a preliminary relationship between the factors of the conceptual model.

CHAPTER SIX

IN-DEPTH STUDY OF AGILITY IN PRACTICE; RESULTS FROM THE CASE STUDY STAGE

6.1 INTRODUCTION

Based upon the conceptual model developed in chapter 4, an industrial survey was carried out and results were presented in the last chapter. The reasons behind the survey included studying the proposed conceptual model, grasping factual ideas about agile manufacturing from a practical point of view, and identifying main factors defining the model and relationships, which is required to achieve the second objective of the research. The obtained information from the survey is also expected to provide support for the formulation of the methodology, which is the third objective of the research. However, as explained in chapter five, constraints such as newness of the subject, the vast domain of involved factors in the research subject which could not be covered completely by the survey, and natural shortcomings of questionnaire surveys in close observation of the subject in practice have placed limitations on what we could expect from the survey.

To this end, a case study phase was carried out in order to :

- Obtain a larger set of data required for the second and third objectives of the research
- Reassess and validate the understandings from the survey
- Extend and widen the borders of understanding of agile manufacturing in practice.

This chapter will report the results from this phase. Following a brief introduction of the studied companies, each case and the related data and conclusions will be discussed. This will be followed by a cross-case analysis aimed to provide a detailed verification of the studied aspects, and to introduce the extracted data necessary for the purposes of the research.

6.2 DESIGN OF CASE STUDY

The constraints pertaining to questionnaire survey method, despite its considerable advantages, could be removed using the case study method. Case study method, mainly referred to as interview method, is recommended by Yin [1988] for the degree of detailed investigation attainable with this method. The interview method enables the researcher to visit the respondent's premise and operations, and even get access to documents of the studied firm. Yin [1988] suggests that the interview method is able to provide answers to "why" and "how" questions, while the postal questionnaire could be a fast and cheap tool for answering "what" questions.

To obtain more in-depth information about the subject and complement the questionnaire survey phase, a case study phase in the form of structured interviews was carried out. In the structured (or scheduled-structured) interview, the questions, their wording, and their sequence are already set and are the same for all interviewees [Nachmias and Nachmias, 1992].

A summary report of findings from the survey and the developed conceptual model were sent to the case companies attached to a questionnaire designed for the case study purpose. A copy of the questionnaire is provided in appendix D.

Taking the core meaning of agility as being change proficient, and responding to unprecedented and unpredicted changes in the business environment, the case studies were undertaken to obtain data in the following areas:

- Some important aspects around the concept of agility such as products life cycle time, products and services customisation, innovation, integration, strategies and strategy making, and virtual organisation
- Detailed change items
- Degrees of effects of change items on manufacturing companies' business
- Strategies (capabilities), and practices adopted in response to changes
- Relationship between change items and agility capabilities
- Assessing need for agility and agility level
- Definition of agile manufacturing according to manufacturing companies

The interview questionnaire consisted of 4 sections as follows:

Section 1: Information on the company including the profile of the company and general aspect around the concept of agility.

Section 2: The agility drivers, where the detailed list of changes in the business environment were examined to find their relevance to the company's business and the effect of changes on the company's business. This section also included space for adding other agility driving factors rather than the proposed ones, and an area for specifying the particular actions including strategies (capabilities) and practices, which had been taken by the company in response to each change item.

Section 3: Agility drivers and agility capabilities, which was aimed at finding a preliminary logical/arithmetic relationship between these two sets of factors.

Section 4: Agility circumstances in the company to study the exact perception of the respondent about agility, the company's level of need for agility, and its current level of agility.

6.3 THE STUDIED COMPANIES IN FOCUS

Twelve manufacturing companies from the survey population were chosen to conduct case studies in order to provide the required data, and take more in-depth steps for understanding and modelling agility in the real world of business.

A relatively high percentage of the surveyed companies had accepted to take part in this phase of the research (50%). In order to use this opportunity in the best way, some criteria were considered in picking the case study companies. These included:
(a) covering the three major sectors considered in the survey. However as two companies one in white goods and one in consumer goods sector were spotted as valuable sources of information with regard to the subject of the study, they were also included,

(b) possession of relatively successful record in the business of the company. This was provided from the record of the companies' new products success, marketshare of the company, and innovativeness of the company, as stated in the questionnaire response,
(c) living in a turbulent competitive environment and facing uncertainty and change,
(d) with various sizes. The minimum size considered was 200 employees,
(e) a medium to high level of familiarity of the contact person with the concept and the boundaries of the study subject.

Table 6.1 provides a brief description of the companies involved. Sector, size (turnover and employees number), success in new product, average market share, level of being a world class manufacturing company, and their production type are the constituting items of the Table.

Case Number	UK/Non-UK Owned	Sector	Employee Number	Turn Over £m/yr	No of New products intrdcd in the past 3 yrs	Avrg success rate of NP(%)	% of sale from NP in the past 3 years	Trend of NP Intrdction	% of T/Over invstd in R&D	Avrg Market-share Home	Avrg Market-share Global	% of product exprtd	World Class Level (out of 5)	Produc-tion Type
1	UK	Electronics	400	25	6	50	N/A	Increasing	20	N/A	N/A	50	-	Mfg to Order
2	UK	Aerospace	590	38	6	98	N/A	"	10	100	25	70	3	"
3	UK	White Goods	1054	50	1000	98	70+	"	5	40	N/A	3	4	"
4	Non-UK	White Goods	500	50	40	95	100	"	2-3	15	N/A	60	3	Mfg to Stock
5	UK	Electronics	800	60	10	90	15	No Change	15	8	3	80	4	Mfg to Order
6	Non-UK	Auto Parts	350	25	25	100	75	Increasing	1	45	15	15	4	Eng/Mfg to Order
7	UK	Aerospace	1320	60	5	100	50+	"	N/A	N/A	N/A	70	3	Mfg to Order
8	Non-UK	Auto Parts	500	45	150	N/A	50	"	N/A	N/A	N/A	50	3	"
9	UK	Electronics	500	32	4	50	10	"	3	15	N/A	80	3	"
10	UK	Aerospace	5200	300	5	80	20	Decreasing	20	40	30	80	3	"
11	UK	Atuo Parts	260	19	75	85	40	Increasing	N/A	10	30	60	3	Mfg to Ordr/Stock
12	Non-UK	Outdoor	650	25	25	90	70	"	7	30	3	25	4	"

Table 6.1. Case study companies in focus

6.4 STUDIED CASES

Case study number one is discussed in detail in the following section. The rest of cases are summarised in Tables 6.2, 6.3, 6.4 and 6.5 to shorten the discussions. Table 6.2 provides a general introduction of the cases number two to twelve. Table 6.3 summarises the circumstances in the case study companies' business environment, and table 6.4 gives information about various aspects and responses of the companies to the changes in their environment. Table 6.5 provides the perception of the case companies about agility, the degree of their need for agility and their current level of agility.

6.4.1 Case Study Company Number 1

6.4.1.1 Introduction

The case study number one is a manufacturer of high-tech electronics components and devices. As a subsidiary of a giant electronic group the company supplies the mother company. The company was originally established for providing the mother company with devices, which are used in high-tech. multi-million pounds special radar systems. But extensive changes in the business environment in recent years have resulted in contraction of this market to only 20% of the company's capacity. 80% of the remaining capacity is now being directed to serve other markets.

The company produces complex products in a very high complex and somehow unique product line using a jobbing and mostly batch production system. The products are highly customised, but generally based on a generic and basic design. The high technology used in the company only provides flexibility in specifications not in volume.

The company due to the specific markets and customers it serves follows the marketing strategy of "first to market and high technology". Staying in forefront of the technology and competing based on the technological reputation is the power point of the company while very small marketing activities is its weak point. This is happening while the market for 80% of the company's capacity is totally competitive. The company cascades down the general guidelines and strategies of the mother company, but draws its own strategies annually in the company.

6.4.1.2 Agility drivers; Circumstances in the company's business environment

The business environment for the company has turned different very significantly in the past few years. It seems that a totally different environment has appeared in which the company must seek its way towards success in a different way.

The major change faced by the company has been the downturn of military market as the major traditional customer of the company. The military market used to form 50% of the company's market and this was decreased to 20% as a result of the change. This also led to a downsloping trend in the profit for the company. The commercial market before the mentioned change was not attractive in that time and the company was taking its benefit out of the other half. This, however, is changed because of recent exploding progresses in the electronics and communication technologies such as wireless communication between computers, personal communication, and radar on cars. The emergence of these aspects of change have started to open a new horizon to the company in which stepping towards success is not as easy as it used to be, and the traditional ways of doing business have started to fade away.

Competition and marketplace have been changing more than ever for the company and changes in these areas have had the most significant impact on the company. Change in technology stands in the next level of impact followed by change in "customer requirements" and "social factors".

6.4.1.3 Strategies, capabilities and practices adopted in response to change;

A first reaction of the company to what occurred in the market structure was downsizing. The company at first followed the previous trend by only reducing the size of departments and hence the company's size. However it was then shifted to realising other sides of the problem, and considering some new concerns in the way of taking the competitive advantage. These responses include the following items:

Strategy ;

The company changed its strategy with regard to marketing to recover from the increasing losses in the profit. However, the extent of the implemented strategic changes is not wide enough. The company is now facing a growing niche market,

which can harm the business grounds for the company. No serious actions have been taken in practice yet with regard to this, although the company is still relying on their technical and technological reputation and competency. Opening new markets is being considered as a new strategy.

Improving response time to customer, and reducing time-to-market, continuous investment in new plants and facilities for remaining in the forefront of the technology are also among the new visions of the company.

Exploiting new commercial ideas for the company's products considering their short life cycle is now an important concern of the company and perhaps lies among the very limited options of further development for the company.

Strategic aspects of agility (capabilities); The case company's position

Core Competency;

The company possesses a great technical capability and performance. This is seen by the company as leverage to use in taking the competitive advantage. To do this the company has arranged a study of the major processes in trying to reorganise itself around these processes considering its core competencies. This is expected to accommodate a future movement towards opening new markets of massive demands for devices, which are in easy reach of the company.

Innovation;

Maintaining and progressing the level of technical competency is a main weapon for the company, which could not be provided unless innovation is valued, encouraged, and supported in the company. This, though has always been a major part of the company's characteristics, is receiving more attention now in the company.

Integration;

The importance of this factor is recently considered and a new programme is being managed to integrate different parts of the company. This is in line with the new tendency towards commercial markets. However, it is still in preliminary stages and tangible results are not achieved yet.

Cooperation;

The company is now considering an attempt for a joint-venture programme to extend the business into Asia by investing and establishing two new sites in South Korea and Malaysia. This needs to be conducted jointly with other cooperating companies, as the company itself cannot easily handle it.

This plans, if get accomplished successfully, will provide a solid base for transferring the company to the next millennium.

6.4.1.4 Agility; Perceptions, needs

Agile manufacturing as defined during the case study received the attention of the contact person in the following way: " *It will be beneficial and a positive thing. Change in the business environment more often and very likely happen to manufacturers and so they must face it perhaps by being agile as defined.*"

However, as the rate of changes for the company, considering its reliance on the mother company, is not very frequently, the concept is being seen in their special way: "*Agility in general can be equalled to things such as responsiveness and flexibility, but in our case I believe it is coming up with technical solutions to customer requirements in an efficient way rather than providing technical products. Also being fast in responding to them, and being cost effective to provide the expected price are important agendas.*"

The company indicated its level of need for agility to be 4 out of 5 (= Highly Necessary). Also on a scale of 1 to 5 (= Highly Agile), the company gave level 3 for its current level of agility. These figures, as stated by the respondent, are his speculation and could not be interpreted as bearing the real position of the company. However, for the level of need for agility it is more or less the figure, which could be expected from any other study over the company, considering the specific understanding and perceptions declared for agile manufacturing.

6.5 CROSS CASE ANALYSIS

In this section further analysis has been carried out to look at key themes across the case study companies. References are made to important factors such as turbulence of business environment as the main driver of agile manufacturing, and responses of companies to the changes in terms of strategy and integration. This is based on views, experiences and actions of the companies, which will be presented in tables showing the results.

The analysis of change factors in the business environment of the case study companies is presented which reveals the mean level of impact of each factor on the case study companies' business. This is followed by an established relationship between change factors and agility capabilities in detail. These two aspects will provide the required data for the establishment of a practical methodology for achieving agility in manufacturing organisations.

Information obtained from the case study session will be introduced including the list of practices adopted by case study companies in response to change factors. The information from this part, in combination with other relevant analysis will be used in the establishment of a practical methodology.

Case Co. No.	INTRODUCTION
2	The company is a manufacturer of high-tech electronics devices for aerospace applications. High technology automated facilities are in use to provide the reliability in products. The manufacturing process is complex. Flexibility in product specification and volume is not high and in fact not seen as crucial for the company. Products are typically "one-off" and hence highly customised. Marketing strategy of the company is "market penetration in a growing market" through "being first to market".
3	The company is a leading manufacturer of domestic cookers with a high rank among European manufacturers. Working with big retailers, managing a long chain of suppliers (about 80), and producing an average output of 1250 cookers per week in almost unlimited customised and fashionable varieties define a complicated business run by the company. A moderate level of technology is in use. One strategy followed by the company is "Exceeding the norms by originating changes." This is complemented by three major business strategies of the company which are : "innovation", "flexibility", and "continuous improvement".
4	This case is a subsidiary of a large Japanese manufacturing company that makes microwave ovens. A batch production system and a low to medium level of technology are in use. The market for products is totally competitive. The products are less technology push so the manufacturers try to escape from being bounded to niche markets and act in a mass-production/mass-customisation way. Very high flexibility in volume and high flexibility in specification are among considerable abilities of the company.
5	The company is a manufacturer of high-tech electronic measurement instruments. Products are manufactured in small batches of one to ten. Products are highly complex, and produced in a highly complex process using high-tech manufacturing facilities. A medium flexibility in volume and very high flexibility in specification are provided by the manufacturing system. In a moderately competitive market the company has the general policy of "following the leader and beating it", and "following others (Me Too)".
6	This company is a manufacturer of steering wheels for vehicles. It is a member of an international large group that is active in air bag and steering wheel markets and has the biggest world market share. Manufacturing is based on a batch system in large lots which can be equalled to mass production. A moderate technology is in use to produce medium complex products in a low complex process. The manufacturing system's flexibility is low to medium in volume, and low in specification.
7	This company is a manufacturer of aeroplane body parts. It is a part of a large manufacturing group now, and used to be in a military connected industrial group. The main market for the company is USA (Boeing Group) and then UK and Europe. The market is growing and technological development in aerospace industry has caused an increasing rate of new product introduction. A moderate level technology is being utilised to manufacture low complex products in a low to medium complex process. The business of the company does not face unprecedented changes very often.
8	This company is a manufacturer of vehicle parts (axles) for auto industry. In a batch manufacturing system low complex products are manufactured in a medium complex process using a moderate level of technology. The typical production of the company does not need much flexibility. The products are made to order and in another view are customised. The company's strategy for marketing and presenting in marketplace is generally based on pulling customers behind it.
9	The company is a branch of a large electrical machines manufacturer with 4000 employees in total. The manufacturing method is mainly jobbing. In a totally competitive market, the company's policy for entering the market is "following the leader, and beating it". Products are highly customised, so the manufacturing is very flexible in specification, but very low flexibility can be traced in volume which in fact is not a need for the company.
10	This case is a major player in the UK, Europe, and USA aerospace markets. The market is moderately competitive and is mainly a contractual based one. Most of the products are standard based while they are highly complex with many subassemblies. High technology is in use and considering the applications of the products and the level of reliability involved, the manufacturing process is highly complex.
11	The company is a medium size manufacture of auto parts and a member of some auto manufacturers' supply chain. Batch production is the manufacturing system in use, by which low to medium complex products are produced in a medium complex process. Products are manufactured to customer specifications (special design) in large lots (sometime millions of each). Low flexibility in volume and specifications are characteristics of the manufacturing system of the company.
12	The company is a non-UK owned manufacturer of outdoor and consumer products. The market is totally competitive market which is run by big retailers, but the company has established a position for itself ahead of many other manufacturers. Medium complex products are manufactured using moderate technology in a batch system. Rate of introduction of new products has been increasing in the past few years and continues to increase The manufacturing system has medium to high flexibility.

Table 6.2 General Information of the Case Study

Case Co. No.	Agility drivers; Circumstances in the company's business environment
2	Business environment for the company has been changing to some extent in the last 5-10 years. The stable, guaranteed and less competitive business has turned to a relatively fragile and unstable condition. In a ranking order, competition, marketplace, customer requirements, technology, and social factors have been found as effective changing areas on the company's business.
3	The circumstances of the business for the company is now totally different from few years ago. Market demands have decreased by 26% since 1989, people turn to fashion, and retailers have switched to requiring just in time , highly differentiated products and services. Customer requirements, marketplace, competition, social factors, and technology have been the important changing areas for the company in a ranking order.
4	Shortening of product life cycle time, shortening of lead time, increasing pressure for introduction of new products, increasing pressure for customisation up to "one off" scale, turning of the competition to a cost-based position, and growth of the niche markets are significant change factors which have been experienced in recent years. Marketplace, competition, customer requirements, technology, and social factors are ranked changing areas for the company.
5	In terms of product, market, technology evolution, time (lead time and delivery time), and customer requirements the business environment has changed in the past few years. The competition for taking the leadership is getting more fierce. Niche markets are shrinking due to new strategies pursued by large groups. Emergence of newly organised rivals in the form of powerful groups is an increasing pressure on manufacturing companies in this sector.
6	Uncertainties in the auto industry and markets affects the company's business. The experience of introduction of airbags in cars had a universal impact on manufacturers in this sector. Also aggressive move to models, pressure on cost and time, and tendency in market for fashionability are among the major changes in recent years. Competition, customers requirements, marketplace, social factors and technology are ranked areas of change for the company.
7	A structural change in the industrial sector which was indicated by demise of many military connected organisations, changed the business direction of the company. It was taken over by another group and restructured to serve both the commercial and military markets. This was then turned to a more complicated situation by increasing the pressure for cost reduction which is still going on.
8	Specific changes in the business environment returns to competition on time, cost and introduction of new innovative products. Globalisation of the business and fast changes in the marketplace have brought about opportunities. Now competition with other rivals is turning to be based on being more responsive to what happens around the company, and an important factor is being responsible for changes to take the lead.
9	Traditional markets that the company has been presenting are now going to disappear. The competition is getting so fierce. An aggressive position is now faced by the company which is caused by acquisition of customers by competitors. Marketplace, competition, customer requirements, technology, and social factors are ranked areas of change and pressure for the company.
10	Past few years have been very challenging for the company. A rapid structural change happened four years ago which is slowing down. Aside from the changes in the market which forced the company to reconsider its strategies, most traditional measures of competition and business priorities have changed. Competition, technology, marketplace, customer requirements, and social factors are the ranked change areas for the company.
11	The recent rapid and substantial change in the car manufacturing industries have affected the company's business. One major change has been reduction in number of suppliers by car manufacturers. This is a consistent trend and only "globally-able-to-do-business" companies can fit in this trend. Competition and customer requirements are two most important areas of change followed by marketplace, technology, and social factors.
12	The recent years have been found as the toughest times the company ever had. Many small companies have gone out of business or purchased by larger companies. Globalisation of the business, new competitive rivals from newly industrialised countries, pressure on cost and time, quality and excellence as standard, tendency of consumers to fashionable, more comfortable and fully featured products, etc. have been among new risen agendas. For the case study company competition, marketplace, customer requirements, social factors, and technology have been important areas of change in a ranking order.

Table 6.3 Circumstances in the case companies business environment

Table 6.4 Strategies, capabilities and practices adopted in response to change

Case Co. No.	**Strategies, capabilities and practices adopted in response to change**
2	Becoming more alert, monitoring the business, restructuring the organisation, and shifting to automation are the main parts of the company's response to the changes in the business environment. Strategy; The biggest strategic change the company has made is moving from manual production system to automation due to the increasing requirements of customers for more reliability. Reducing time (delivery), and remaining cost effective have also been among the newly concerned priorities considered in the company in responding to the changes in customers requirements. Core Competency; Considering manufacturing and technical competence and high level of customer services as core competencies of the company, a number of centrally planned schemes have been initiated to handle projects which are targeted at better establishment of core competencies. Innovation; The company is based on technological innovation, and recently the issue has been extended to organisational and managerial dimensions. Cooperation; Taking the risk of getting closer to other parties involved in the business, and particularly competitors is a new agenda for the company. In a new experience parts of a big order that the company was not able to accomplish on its own, were handled by referring them to a competitor.
3	The major responses of the company to changes in the business environment lies in two areas. These are adopting strategies that makes the company ready for any changes, and being proactive by creating and originating changes. Strategy; • Standing and persisting on the basic strategies of the company. • Providing a high level of flexibility in manufacturing systems, organisation, and relations with the business environment particularly suppliers. • Reducing time and cost by investing in sufficient technology, adopting relevant methods, and restructuring systems. • Strategising the life cycle of products by introducing fashion into the products using colour as the means. • Emphasising on innovation, taking some new innovations as uniquely possessed weapons, and manoeuvring on them as a leverage for keeping the leadership. • Defining a reasonable gap between the company and competitors, and pulling customers behind the company by leading and directing their requirements. • Introduction of customisation to customers and the company as a main differentiator. Core Competency; The company's core competency includes: cooking, gas, and enamelling technology. The capabilities of the company are arranged around these expertise and utilised so that it is the only manufacturer of cookers that benefits from this market. Innovation; This factor is among the major priorities and strategies of the company. The company strongly relies on innovative technology and processes it has in hand. The company is ways ahead of its competitors and this gap is 2-3 years for the closest competitor. Integration; Restructuring the organisation in line with the strategies of the company has been pursued by considering integration all over the system. Customisation; Establishment of a fully flexible manufacturing system coupled with the new structure of the organisation have led to the new ability of the company for customising products.
4	Strategy; Although strategy making is generally an adhoc action in the company, in response to the changing environment the company has considered following movements which categorically are strategic: • Increasing responsiveness of the company to customer requirements through faster interface with customers, a more flexible manufacturing system, and a more efficient organisation. • Enlarging design department to handle the complexity and severeness of changes in design. • Introduction of colour proliferation to market as the first manufacturer that did it in high volumes. • Efficient management of suppliers and switching to cheaper ones for the purpose of cutting costs.

Table 6.4 Continued

	• Continuous monitoring of technical design, operations, and management issues to keep the level of the company's competency, flexibility, and hence responsiveness in the desirable position. • Investment in new technology for flexibility and quickness purposes. • Tracing the development of new and innovative ideas and products. In particular a new heater is being introduced to market which is expected to make the differentiation the company needs. In response to the new pressures for "one-off" products, the company has accommodated customisation by increasing its flexibility and the current position is seen not far short from "on-off" supply. Innovation; Innovation for the company, due to the nature of products, does not mean technologically. What is taken as innovation is a general view which is acting in an innovative way to respond to customer requirements and translate their requirements into products (which is not innovation *per say*) Integration; Integration is found to be a critical issue by the company and efforts have been put to integrate engineering, sales, and purchasing. These are managed to work virtually as one department. This whole in another way is integrated with other sections of the company, and the results have been highly satisfactory in increasing responsiveness of the company.
5	Strategy; • Realising the business circumstances and reducing the entire manufacturing options in response to a downfall of company's position in the market due to technological changes. • Organising around core competencies of the company. • Shrinking down the product lead time to respond to the pressure from market and customers. • Merging into a larger company to form a stronger body and move to the second layer of the leading manufacturers. • Considering shift to new products interfaced with new technologies such as wireless communication and personal computers. • Establishing future platform of products. • Increasing internal efficiency using information system/technology in order to reduce time and cost. • Considering strategy of "one stop purchase" option as a long term goal. Core Competency; The company in a stage (in 1994) used to develop and produce many parts and materials internally. They included cables, metalwork, printing, plastics, etc. A reorganisation was arranged and core competencies of the company (PCB and microwave, and final configuration for customers) are now considered as pillars of the company's structure. This was later reviewed and promoted by creating new changes as circumstances of the business environment was changing. Customisation; The company's products are naturally manufactured based on orders and customised to customers requirements. This is not sufficient in responding to the changing market. The idea of "one stop purchase" is what the company is pursuing in the frame of customisation. Integration; The company already had a strong vertical integration. Realignment of the business and the experiences the company has had since then have led it to extend the integration to involve all the company. Now multifunctional teamworking is being used in this way and set goals are close to be achieved.
6	Strategy; • Taking a new look at customers to value them and realise whom the company should keep • Making adjustment and essential changes in response to environmental (including legislation), cost, and modularisation pressures, and global expansion of airbags. • Becoming an active member of the group to work in association with others and promote the business boundaries by relying on others. • Strengthening the company's internal capabilities and developing a productive organisational structure to keep up with the increasing changes in customers requirements, and pressures on cost and time.

Table 6.4 Continued

	Cooperation; • Very close relationship with customers which the company serve in their supply chain, and continuous monitoring of customer requirements. • Linking on a global basis with world-wide spread chain of the group and cooperating virtually in capturing the market and promoting the business. • A close relationship with suppliers and better management of the supply chain. Suppliers are highly involved in defining new products and in product development process. Integration; External integration with group members is pursued to make the globalisation of the business successful. This is done through utilisation of information system/technology including ISDN, video conferencing, technology information network, etc. Internally integration is considered and meant to increase the company's flexibility, ease communication, and provide more productivity.
7	Strategy; • Switching to commercial markets • Moving to North America markets • Reorganising to respond to the needs of the new markets • Increasing company's capabilities through technology uptake, people progress, etc., to reduce cost and deliver on time. Core Competency; Reorganisation was involved with investment in technologies for improving production of the major and core products. This has brought about a confidence to the company and a level of capability that is recognised and welcomed by customers so that it could not be easily beaten by competitors. Integration; In the line of cutting costs as much as possible, having a well organised and structured organisation is seen as a crucial factor to the company. Virtual integration of different departments which are now working more with more authority and responsibility is a way that company has tried to augment the extent of its efforts and investments for reduction of cost.
8	Strategy; A major change in strategy has occurred in the company. The change was generally based on take-over/acquisition activities. Later after the new structure was adopted by the company some essential moves were arranged to take the competitive advantage of the company back. They include : • Introduction of a new product range based on a new technology • Change to systematic approach in activities • Reorganisation of marketing and its interface with other parts of the organisation • Investment in new technology to reduce time and cost • Investment in people to enhance competency in the company's activities Customisation; Although historically the products are custom made, the new approach included the old concept, vast customisation, increasing in introduction of new products, and enhancing new techniques in products. Integration; Vertical integration has always been a power point of the company. This is now complemented with a total integration of the whole company internally and externally in the frame of the new group. Internal communication infrastructure is being developed and a reorganisation of marketing and new methods, tools and techniques are being deployed to provide a company-wide integration. A structural external integration is also targeted with other parts of the group, and is expected to provide a great deal of opportunities in the near future. Cooperation; Realisation of the new order that is being formed in the company's business environment, the company's strategy of creating change, and the organisational frame which the company has adopted, have caused the company to take cooperation in various ways as an important strategic issue for success. Virtual organisation is now being considered in cooperation with other members of the group and also with some Asian manufacturers to establish markets in a wider area.

Table 6.4 Continued

9	Strategy; • Take over by a larger group • Reorganisation of the factory and especially engineering design • Utilisation of information system/technology • Development of an international marketing liaison • Initiation of off-line development • Focusing on cost cut as a main goal Integration; In the line with the specified strategies and with focusing on cost reduction, integration of the internal activities is aimed which is being pursued by utilisation of information system/technology. Interaction between staff is supposed to improve and lead to a more productive work environment. This initiative has proven to be highly effective towards the set goals. Also a strengthened marketing is coupled with a reorganised engineering design to deliver the requirements of customers in the frame of cost control and cut. Innovation; Innovation, though not technically, is considered as crucial in revitalising the company's position. The process of product development is now fed with an ongoing concern on innovative programmes which are mainly aimed at cost efficiency and productivity. Inclusion of information technology in products is also being considered which would provide a leverage for compensation of the recent losses.
10	Strategy ; A vast series of changes in the company's strategy from marketing to internal competency was considered in the company including the following programmes : • Change leadership • Process re-engineering • Reorganisation of the whole company including delayering • New product introduction system revitalisation • Communication and information system/technology • Employees development including innovation in people • New financial system • Six-Sigma quality programme in the frame of the new quality system • Design-Build team formation • Flexible and lean manufacturing • Focus on core competencies • Significant capital investment Core competency; The pressures over the past few years particularly from the global business have made the company to reconsider the whole business strategically. One major tendency has been concentrating on the company's core competencies and removing resource wasting activities. Considering the specialities of the company including aerospace design, composites, flights, and a few more capabilities which are somehow unique among the manufacturers, further investment were focused on these areas. Also reorganisation was managed which aimed at redefining the company's direction to strengthen core competencies. Integration; Old vertical integration of the company has been reviewed and promoted to provide a company-wide integration which is partly implemented. The [illegible] the integration are time and cost reduction as factors that had started to put the company under intense pressure. This is supported by the new [illegible] ystem in the company, reorganisation of the system, and teamworking methods.
11	Strategy;

Table 6.4 Continued

	• Take over by the large group the company is now in • Restructuring the company in the frame of the new mother group • Enlarging the engineering department • Time and cost reduction initiatives • Investment in modern computer-aided technology • Internal performance improvement by reorganising and improving people • Developing and strengthening an engineering base in Germany to foster technological innovation. Innovation; Technological innovation is now generally neutralised as a competitive factor in the company's business, but the incremental changes in line of more security and environmental health are live agendas. The company handles these issues in cooperation with other members of the group and specifically with help of the engineering base in Germany. Integration; Restructuring of the company included a view for integration as a substantial means of increasing productivity, quick response to customer requirements, and reducing time and cost. Now most of the departments are interrelated and people from different sections move into other departments for specific purposes such as solving problems, promoting projects, and coordinating activities.
12	Strategy; • Proliferation of products in a wide range • Time and cost reduction • Spreading the overseas markets • Increasing responsiveness to changes • Better management of suppliers • Increasing internal productivity of manufacturing system and people • Enlarging engineering department and interrelate them with suppliers, marketing, and manufacturing Core Competency; Design to customer requirements, providing quality finished products and life time services are found as main abilities of the company. Efforts were made to reduce many other activities that distracted the concentration of the company. Many unnecessary tasks were removed and left to be handled by suppliers. Managing suppliers then became an important issue which is now being performed satisfactorily. Customisation; This is found by the company as one recently emerging need of the market. Previous strategies and abilities of the company only would allow to customise the products to a primitive level. A new initiative including capital investment is launched to accommodate platform products with customisable features according to the requirements of the single consumers. It is expected to bring about a leverage for the company which will differentiate the company's products and services in the market. Innovation; Simple ideas coupled with the possibilities provided by the modern technology provide a solid ground for innovative presence in the market. This is encouraged over the company in coordination with marketing to make innovation as a characteristics of the company. The same goes towards other aspects of the organisation including cost cut, time reduction, waste management, etc. The initiatives are quite promising and are expected to augment the total ability of the company.

Table 6.5 Case companies' perception of agility concept and their level of need and current level of agility

Case Co. No.	Perception	Level of need for agility 1=Very low, 5=very high	Current level of agility 1=Very low, 5=very high
2	Agility as propounded by the research was perceived as understandable for the company, however, the company does not fit completely in that frame. This is because as mentioned by the contact person :"*we are a customer-driven company and our agility is mostly with regard to responding to customer requirements.*" To the company agility can be defined as :"*responding appropriately to changes in the customer requirements.*"	~ 4	3
3	According to the company : "*The philosophy adopted here is in a sense agile manufacturing, however, it does not mean that the journey is ended. We do business in a proactive way that not only puts us on the top of the market, but also makes us flexible and responsive to changes. This can go much farther in practice, but our philosophy is already designed.*" Also as was stated by the contact person : " *We see agility as an ability of a succeeding company to protect its position and remove the barriers that inhibit its success.*"	5	4
4	Agility, though not in the exact words offered by the research, is perceived as important to the company in order to survive and by putting it in the company's own way of need, it is seen as an unavoidable move for future. The contact person perceives agility as : "*responding to customer requirements, being flexible while cost effective and quick*".	5	3
5	According to the contact person, the frame proposed by the research fits the company's situation and needs to a high level (about 80 percent out of 100 percent). The following statements include the definition the company put forward for agility: • *Tuning with the changes in business - not a single focus business* • *Being flexible enough to respond to changes in customer and market requirements* • *Having the required ability to capture the future and maintain it* • *Being aware of the circumstances and business environment and accommodating the abilities to prosper.* "	4	3
6	As the company is basically customer-driven, the extent of the company's needs to agility might not go as far as the research proposes. However, as declared by the managing director of the company : " *in terms of responsiveness and speed, we are held by the technological barriers, which is homoligation for reducing cycle time. Agility is definitely needed for enhancement of colours changes, excitement of core product, but as an urgent, and overwhelming process is not what the company needs at the moment*". The definition of agility in manufacturing to this company is :" *responding to the fashion which has started to appear in car styles and moving innovatively towards satisfying customer requirements in this way*".	4	3
7	Agility in the way that was presented by the research was commented by the contact person in this way : " *It is a prerequisite now in order to take part in the marketplace, though not at the moment for our company. In future as market shrinks and new rivals arrive we need to be more agile* ". Also the following statement represents the definition of agility according to the company : " *the ability to quickly meet the customers' needs, and take on board their philosophies. In another word being responsive to customers.*"	4	3
8	In the current position of the company radical changes do not seem to be necessary. However, considering what is happening		

	around the company, how competitors are struggling to take the lead, and increasing pressures from customers are enough reasons for rethinking the company's position and moving to become agile. This was commented by the contact person in the case study company while providing the following definition for agility : " *managing effectively in an environment of incremental change, step change, and increased created change*".	5	3
9	Agility in the frame of the research work does not seem to be the first priority for this company. As the competition basis still remains to be cost, and considering the increasing pressures from competition, and customer requirements, it is perceived by the company to be a "*greater responsiveness*". This, in particular, can be accommodated by utilising a company-wide information system/technology.	--	--
10	Agility is found necessary for the company to consider as an ability, but considering the size of the business the company is involved in, it is viewed as "only part of the solution". This comment refers to the understanding of the company about agile manufacturing, and the definition provided by the vice president and managing director of the company which is as follows : "*Improved responsiveness to market and schedule, and being performance driven*".	4	3
11	In this way a clear definition of agility is needed by the company to match its specific circumstances. The following is given as the perception of the company of agility : " *The ability to change and respond to customer requirements*".	3	<2
12	The contact person perceived the concept of agility as a necessary prerequisite for competing in today's business world. The company expressed itself as having some features of agile manufacturing, but much more efforts are needed to keep the position acquired by the company, and take the leadership of the market. A fundamental definition presented by the manufacturing director of the company was as follows :" *Responding quick to market and customer requirements and changes in them while staying in a low level of cost and efficient delivery.*"	--	--

Table 6.5 Continued

6.5.1 Business Environment

Case study companies were questioned about the circumstances of their business environment, whether there have been changes in the past 10-15 years, and about the specific changes experienced by them. Results are shown in Table 6.6. All companies have strongly confirmed the changing nature of their business environment most of which have led to substantial problems, disturbances, and eventually damages to the position of the case companies.

Almost all of the specified changes in the Table are in the frame of the change areas and factors defined in the conceptual model, which can be considered as a further support for the validity of the model and also for the results obtained from the questionnaire survey.

Case Number	Has the company's business Environment been changing in the past few years	Specific Changes in the company's business environment
1	YES	Downturn in military market that led to major changes in customer profile
2	YES	Time factor alongside cost, quality and reliability, and customer services became very important; Market is getting fragile and unstable
3	YES	Demise of British Gas Co. as the major customer of the company and structural change in market (privatisation); People's fashion tendency; Just-in-Time and highly differentiated market
4	YES	Shortening of life cycle time in terms of design/product life; More fierce competition; Lead time shrinkage
5	YES	Globalisation of business; Pressure on time-to-market; pressure of "One Stop Purchase" strategy of market leaders
6	YES	New technological improvements in car industry (airbag); Pressure on delivery time and cost; Aggressive move to modules; Fashion tendency in products
7	YES	Downturn of military market; Commercialisation of aerospace products; More pressures on cost and time
8	YES	More fierce competition; Business becoming more clever; Pressure on cost, time, and quality as standard; Emergence of capable, fast, and cost effective international rivals
9	YES	Emergence of large, organised, cost-effective and powerful manufacturers who put unbearable pressure on cost, delivery time, and services, and hence acquire the company's customers
10	YES	Rapid rise in the market demand for new products and services; Pressure on cost, reaction of cycle time including delivery; Increasing unexpected changes in the customers' requirements
11	YES	Reduction in number of competitors due to policies of car industries; More fierce competition; More pressure on time, cost, and quality including security regulations
12	YES	Proliferation of products; Pressure on time; Extensive requirements for services; Emergence of new powerful overseas competitors

Table 6.6. Change in the business environment of the case study companies

6.5.1.1 Change areas/factors as agility drivers

Determining the typical changes in the business environment, studying the way the changes have been faced by manufacturing companies, the level of impact changes have had on the manufacturing organisations' business have been among the aims of the case studies.

Studying the five general areas and detailed sub-factors, which in total were counted to be 23, were left to the case study phase, as it was not practical in the questionnaire survey. Investigation of the change items' relevance to case study companies and the level of impact they have had on their business was the aim of this study. The company was asked to indicate the relevance of the proposed change factors; the degree of their impact on the company's business on a three choices basis (Low, Medium, High), and to add any further factors companies might have faced with.

Table 6.7 is the result of the study showing the change factors, number of companies indicated the item as relevant to their business, and the average degree of impact of each factor on the case study company's business. The average is shown in the way it was asked and also is converted to numerical scale of 1 to 5 [1 = Low, 3 = Medium, 5 = High].

The results in each change area (like marketplace) are sorted in descending order, but its rank in the total is indicated separately in the next column.

Results from this study in a way show the importance of change factors to average manufacturing organisation, although it is limited to the number of case study companies.

6.5.2 Responses To Change In The Business Environment

In line with the apprehended model for the concept of agility in manufacturing during the research, responses of the case study companies to change in their business environment were examined. This is presented under two main issues, i.e. strategy as a starting point for the initiation of agility and agile behaviour, and integration as one

Change Areas/Factors	No of co.s the item is relevant to	Average impact (Low, Med., High)	Converted level of impact	Rank in the Total
MARKETPLACE				
Increasing rate of change in product models	11	Med. to High	3.73	3
Growth of the niche market	10	Medium	3.00	8
Product lifetime shrinkage	10	Med. to High	2.64	11
National and international political changes	9	Low to Med.	2.27	13
COMPETITION				
Increasing pressure on cost	12	High	4.6	1
Decreasing new products time-to-market	11	High to Med.	4.1	2
Increasing pressure of global market competition	10	Med. to High	3.45	4
Rapidly changing market	11	Med. to High	3.1	7
Increasing rate of innovation	10	Med. to Low	2.73	10
Responsiveness of competitors to changes	9	Low to Med.	2.4	12
CUSTOMER REQUIREMENTS				
Quicker delivery time and time-to-market	11	Med. to High	3.73	3
Quality expectation increasing	10	Med. to High	3.45	4
Demand for individualised products and services	9	Med. to Low	2.82	9
Sudden changes in order quantity and spec.	9	Med. to Low	2.73	10
TECHNOLOGY				
Introduction of new soft technologies (Software and methods)	10	Med. to High	3.18	6
Inclusion of information technology in (new) hard and soft technology	9	Med. to Low	2.64	11
Introduction of new materials	9	Low to Med.	1.91	15
Introduction of more efficient, faster, and economic production facilities	8	Low to Med.	1.82	16
SOCIAL FACTORS				
Environmental pressures	11	Med. to High	3.28	5
Workforce/workplace expectations	10	Med. to Low	2	14
Legal/political pressures	9	Low to Med.	1.5	17
Cultural problems	7	Low	1.1	18
Social Contract changes	6	Low	1	19

Table 6.7. Change areas and change factors according to the case study companies major means of delivering the agile behaviour in response to changes in the business environment.

6.5.2.1 Strategy

Strategies of company, being managed in a structured or in an adhoc way, were examined to find whether they have been reconsidered, changed or restructured in response to some major unpredicted changes in the business environment. Table 6.8 represents the provided information in this regard. Only one company out of the twelve case study companies did not have such an experience. The company, in fact, considered this, as a positive side as they were so confident about their performance that despite the extensive changes in their business environment their strategies were remained unchanged. However, in practice the company has been adopting and streamlining the strategies with the changing trend of the business environment.

The strategies specified by the case study companies are generally in the line of strengthening capabilities concerned by the research. However, the studies show that manufacturing companies still need to get more aware of the concept of agility as an ability in responding to change, and guidelines are necessary to translate the changes in their business environment into the company's strategy. These guidelines can then be delivered to form a practical approach for identifying the appropriate actions.

6.5.2.2 Integration

As it is already stressed in chapters two and four, integration of the whole system is now a widely recommended approach to achieving greater performance in most aspects of manufacturing business. To some workers agile manufacturing is a totally integrated organisation that can utilise its resources in the best way including responding to changes [Yusuf, 1996].

This, as considered in the conceptual model introduced in chapter four, was examined in the case study companies. Four aspects were considered in this regard including:

1. Whether the concept is being considered in the company as an important issue, especially with regard to changes in the business environment.
2. Whether there have been any initiatives with regard to integration of the organisation.
3. Major goals of the initiatives, if any.

4. Achievement of the initiatives. This was asked to be indicated on a scale of 1 to 5 (5= very high achievements).

Results of this verification is shown in Table 6.9. Almost all companies have had the issue as one of their major considerations, and have introduced some planned or adhoc initiatives into their organisations. Many of the case companies have referred to responsiveness to business or customer, or something close in meaning to this as one of the main goals behind the initiatives. Other important strategic priorities such as cost, time, and performance have also been identified as main goals of the initiatives.

Table 6.8. Strategies of the case study companies against change in their business environment

Case Number	Has the company had to change its strategy Because of change ?	Major Changes in the company's strategy
1	YES	Marketing Strategy is Changed to better and organised marketing; New commercial products with application in new technologies are considered in the company's strategy
2	YES	Moving to automation from manual production; Taking in new manufacturing philosophies for excellence [Cellular Manufacturing, Lean Manufacturing]
3	NO	Company's basic strategies only have been adapted with the changes in the business environment. The general direction is already set
4	YES	Aimed at becoming more cost-effective, more flexible and hence responsive to the business environment; Introduced colour proliferation as the inventor in mass production
5	YES	Downsizing the company; Reorganising around core competencies; Merging into a larger group to form a solid body; "Future Platform Production " policy to respond to "One Stop Purchase" strategy of competitors
6	YES	Take a new vision of customer in the business; Virtual cooperation with group's members; Fashion tendency in products design
7	YES	Moving to a new market (North America); Reorganising to stay competitive in price and services
8	YES	Take over and acquisition; Working in association with other partners
9	YES	Reorganising of factory and engineering Design to cut costs using information technology; Approaching international marketing, and initiate off line development
10	YES	Restructuring of the whole business around core competencies an reengineering of most of systems based on the new strategy; Redefining the way for presenting in market and marketing activities
11	YES	Restructuring in the frame of the new group
12	YES	Proliferation of products mode; Capital investment to increase flexibility and responsiveness

Case Number	Is integration considered in the company as a strategic issue	Initiatives for integration , if any	Major goals of the initiatives	Achievem-ents of goals (On a 1 to 5 *scale.* 5=very High)
1	YES	Project and cross-functional teams using information technology	Faster delivery of ideas to products; More productive organisation	Started recently. Not measured yet
2	YES	Programme management structure based on a matrix org. model	One point of customer contact; Faster delivery of customer requirements and changes in them	3
3	YES	Matrix organisation, virtual integration , Teamworking	48 hours delivery time for customised products	4
4	YES	Integration of engineering, sales, purchasing to work as one department	Satisfying customers (responsiveness to customer demands)	5
5	YES	Multifunctional team working	Responsiveness to customer demands; Cost/time effectiveness	3-4
6	YES	Internal vertical integration; External integration with group's members	Responsiveness and flexibility in satisfying customer requirements	5
7	Partly	More responsibility and authority for departments	Faster operations and delivery	4
8	YES	Vertical Integration; Teamworking (CE)	Improve company's performance	Not measured
9	YES	Adhoc approach	Shortened line of communication and improved interaction between staff	4
10	YES	Reorganising around core competencies, teamworking methods	Time and cost reduction	4
11	YES	Interrelation of different departments; teamworking; vertical integration	faster, cost-effective operations; More responsiveness to changes in customer requirements	Half the way 3 (so far)
12	YES	Project and multifunctional teamworking	New product development time reduction,; Responsiveness and flexibility against changes in the customer requirements	3-4

Table 6.9. Integration in case study companies

6.5.3 Agility Capabilities

Analysis of the case studies with regard to the overall set of capabilities, which could be adopted in order to provide appropriate abilities in the organisation and to use them in responding to changes, did not bring about considerable changes to the original list provided in chapter 4 when the conceptual model was introduced. However, the capabilities, as were already introduced, found more support and made a sufficiently concrete basis for the establishment of further details of the methodology and its tools. The list of twenty agility capabilities under four main titles is depicted in Table 6.10.

6.5.4 Practices Adopted in Response to Changes Factors

Responses of the case study companies in the form of strategies and practices to the medium to high impacting change items were identified during this phase. Some of the results are shown in Tables 6.11 and the rest of the results are provided in appendix E. Many practices are common in different changes items and some may be found contradicting.

The resulting practices will be classified to provide a basis for the completion of the methodology for implementing agility in conjunction with the studies conducted with regard to general practices during the survey phase.

6.5.5 Relationship Between Change Factors And Agility Capabilities

In pursuing the assumptions of the conceptual model about the inter-relationship between agility drivers and agility capabilities as immediate means of responding to changes in the business environment, initial supports have been found through the industrial survey in chapter 5. To find further support to the assumptions, extensive study was carried out in the case study phase.

Case study companies were asked to indicate the degree of importance of specified capabilities, which included detailed items of capabilities under the four main titles, in responding to change items.

Responsiveness: The ability to identify changes, respond rapidly to changes either reactively or proactively, and recover from changes. This is itemised as:

(1) Sensing, perceiving and anticipating changes.

(2) Immediate reaction to changes.

(3) Recovering from changes.

Competency: The abilities that provide a company with productivity, efficiency, and effectiveness in achieving its aims and goals. Following items form the major part of the list:

(1) Strategic vision.

(2) Appropriate technology, or sufficient technological capability.

(3) Products/service quality.

(4) Cost effectiveness.

(5) High rate of new products introduction.

(6) Change management.

(7) Knowledgeable, competent, and empowered people.

(8) Operations efficiency and effectiveness (leanness).

(9) Cooperation (internal and external).

(10) Integration.

Flexibility: The ability to process different works and achieve different objectives with the same facilities. It consists of items such as:

(1) Product volume flexibility.

(2) Product model/configuration flexibility.

(3) Organisation and organisational issues flexibility.

(4) People flexibility.

Speed: The ability to carry out tasks and operations in the shortest possible time. Items include:

(1) Quickness in new products time-to-market.

(2) Quickness and timeliness in products and services delivery.

(3) Quickness in operations (short operational lead-times).

Table 6.10 List of agility capabilities

Tables 6.12 shows two change items and associated capabilities extracted from the case study analysis in a descending order which represents a weight allocated to them by the case study companies. This table is presented only as a sample of the results from the study, and the rest are shown in Appendix E. The numbers will later be used in defining the logical relationship between the two main factors of the practical methodology to be used as a tool for determining the appropriate respond to changes.

Growth of the niche markets	Case number
• Investing in automation to expand the capacity and process reliability	2
• Increasing flexibility of manufacturing in both volume and configuration	3
• Providing a wide range of choices for customers in every sections of the market	3
• introduction of unlimited choice of colours and configurations	3
• Enlargement of design department and purchasing department	4
• Developing more standard products to reduce dependence on niche markets [Pressure was low]	9
• Developing focused organisation and niche skills	10
National and international Changes	
• Opening additional international sales channels and restructuring or closing others	5
• Realigning the company's order procedure with the new regulations imposed, and embracing the new changes	
• Setting operations to be ready for such instant changes	7
• Short term : cost reduction; Long term : Review of strategy	7
• Contracting the site and introducing an integrated computer system to address costs	8 9
• Moving the business within a large group to reduce the impacts	11
Increasing rate of change in product models	
• Improving response time (to customer in manufacturing, etc.), continuous improvement, developing JIT, Cellular Mfg., problem solving techniques	1
• Investment in modern technology	2
• Increasing the capability and capacity of the company to produce more than the present demand of the market in terms of models and configuration	3
• Introducing colour proliferation (choice) to customer, reducing cost by switching to new suppliers	4
• Reducing product engineering timescales (time-to-market) by adopting core technologies and modular design	5
• Introducing DFMA; Late configuration of relatively standard models; Reducing time from concept to design and from design to manufacturing	6
• Introduction of more new products for new applications	8
• Initiating a development programme	9
• Adopting flexible manufacturing system and lean manufacturing	10
• Enlarging engineering department to cope with the demands through employing new design technology and recruiting more engineers.	12
Product life time shrinkage	
• Design improvement and DFMA	6
• Introducing a new range of products	8
• Deleting obsolete products	9
Rapidly changing markets	
• Consolidation of different companies in the group and vertical integration of them	6
• Product rationalisation; Profitability drive; Introducing new markets	8
• Increasing market awareness with a group marketing approach	9
• New and modified new product introduction process	10
• Moving the business into a larger group	11

Table 6.11. Responses of the case study companies to change items

INCREASING PRESSURE ON COST		DECREASING NEW PRODUCT TIME-TO-MARKET	
Capabilities	Wts	Capabilities	Wts
• Cost effectiveness (competency)	4.1	• Quick new products time-to-market (speed)	4.3
• Appropriate technology/Sufficient technological ability (competency)	3.9	• High rate of new products introduction (competency)	3.7
• Strategic vision (competency)	3.4	• Knowledgeable, competent, and empowered people (competency)	3.7
• Products/services quality (competency)	3.4	• Co-operation (internal/external, competency)	3.7
• Operations efficiency and Effectiveness-leanness (competency)	3.4	• Strategic vision (responsiveness)	3.6
• Sensing, perceiving and anticipating changes (responsiveness)	3.4	• People flexibility (flexibility)	3.6
• Change management (competency)	3.3	• Integration (competency)	3.6
• People flexibility (flexibility)	3.3	• Appropriate technology/sufficient technological ability (competency)	3.4
• Immediate reaction to change by effecting them into system (responsiveness)	3.1	• Products and services delivery quickness and timeliness (speed)	3.4
· Co-operation(Internal/external, competency)	3.1	• Fast operations time (speed)	3.4
• Organisation and organisational issues flexibility (flexibility)	3.1	• Sensing, perceiving and anticipating changes (responsiveness)	3.3
· Fast operations time (speed)	3.0	• Immediate reaction to change by effecting them into system (responsiveness)	3.3
• Recovery from change (responsiveness)	2.9	• Products/services quality (competency)	3.3
• Product volume flexibility (flexibility)	2.9	• Change management (competency)	3.3
• Products and services delivery quickness and timeliness (Speed)	2.9	• Operations efficiency and effectiveness-leanness (competency)	3.3
• High rate of new products introduction (competency)	2.7	• Product model/configuration flexibility (flexibility)	3.3
• Integration (competency)	2.7	• Cost effectiveness	3.0
• Product model/configuration flexibility (flexibility)	2.7	• Product volume flexibility	3.0
• Knowledgeable, competent, and empowered people (competency)	2.6	• Organisation and organisational issues flexibility	3.0
• Quick new products time-to-market (speed)	2.4	• Recovery from change	2.9

Table 6.12. Relationship between agility drivers and capabilities

SUMMARY OF THE CHAPTER

Chapter six provided the results from conducting and analysing twelve case studies of manufacturing companies.

In summary:

1. The study was carried out to take more in-depth steps in studying the developed conceptual model, validating the understandings from the questionnaire survey, and to provide additional data and information for the achievement of the third objective of the research, i.e. the development/formulation of a methodology for implementation of agility in manufacturing organisations (the third objective of the research).
2. A structured interview method was adopted in carrying out this phase of the research. A summary report of findings from the survey and a questionnaire designed in four sections for the case study purpose were first sent to twelve companies. High-ranking managers of the companies were interviewed based on the prepared questionnaire and the results were studied and analysed later. The case study was designed to examine aspects such as important issues related to the agility concept, detailed change items and the effect of them on the companies' business, relationship between changes and capabilities, etc.
3. The twelve case study companies were chosen from the survey population. These companies were chosen considering some specific criteria such as success of he company, their business environment, and familiarity of the interviewee with the concept.
4. Agility drivers, circumstances in the companies' business environment, strategies, capabilities and practices adopted in response to changes, and perception and need of the companies for agility were studied in particular. A case company is reported in detail, and the rest are summarised in some tables.
5. Further analysis has been carried out to study the key themes across the case study companies. Views, experiences and actions of the case companies are studied and some results are extracted. Analysis of change factors in the business environment of the case companies, practice adopted by the companies in response to changes, and relationship between change factors and agility capabilities are presented as the result.

6. A preliminary relationship is established between the agility drivers and the agility capabilities, which represents the importance of each of the items of agility capabilities for every change item of agility drivers. The established relationship, which is based on the facts and figures obtained from the conducted case studies, provides support for the existence and validity of this relationship. Also it can be used to conclude that a more accurate and extensive pattern of relationship between the mentioned factors could be provided.
7. The results from this phase included final identification of agility drivers and their impact on the companies' business (to complement the results from the survey in chapter five), relationships between agility drivers and agility capabilities (which were not efficiently available from the survey results), factors for assessing the need for agility and current level of agility of an organisation (to introduce the assessment model for agility), and identification of a large number of practices related to agility. The mentioned results have accomplished the second objective of the research, i.e. to identify main factors constituting the concept and relationship between these factors.

The results from this chapter and chapter five will be combined to develop the methodology for achieving agility which will be discussed in chapter seven.

CHAPTER SEVEN

DISCUSSION OF RESULTS AND DEVELOPMENT OF A METHODOLOGY FOR ACHIEVING AGILITY IN MANUFACTURING ORGANISATIONS

7.1. INTRODUCTION

In this chapter the results of the research programme will be presented. Based on the results a methodology will be developed to achieve the third objective of the research. The methodology which was originally introduced briefly and in a general way in chapter four, is developed and discussed here considering further complementary work pursued during the research and reported in chapters five and six.

A review of the conceptual model described in chapter four will be followed by discussion of a methodological approach developed during various stages of the research, and a brief discussion of the results obtained from empirical studies conducted during the research. The final proposal of the developed methodology for achieving agility in manufacturing organisations including its structure, the relationship between different parts, and the practical mechanisms will be discussed succinctly. Two particularly significant parts of the methodology will be elaborated which are the assessment model for the examination of a manufacturing company's need for agility and its current level of agility, and the practical tool for enhancing agility characteristics in organisations.

7.2. AN OVERVIEW OF THE RESEARCH

As it was elaborated in chapter four, exploration of the literature pertaining to the latest philosophies and theories of manufacturing management and in particular agile manufacturing led to some general ideas which incorporated a preliminary empirical work resulting in a conceptual model for agile manufacturing. The conceptual model needed to be transformed to a practical approach to implement agile manufacturing in industry, which is clearly missing in the recent research literature in this area. A preliminary idea of a methodology was introduced to serve this purpose. The proposed idea was then put into examination through practical investigations

including an industrial survey and a series of case studies in the form of structured interviews. The results from the latter stages provided the data and hence the information required for the promotion of the ideas and the development of the final model which is a methodology for achieving agility in manufacturing organisations. The whole idea of the research as described above is depicted in Figure 7.1.

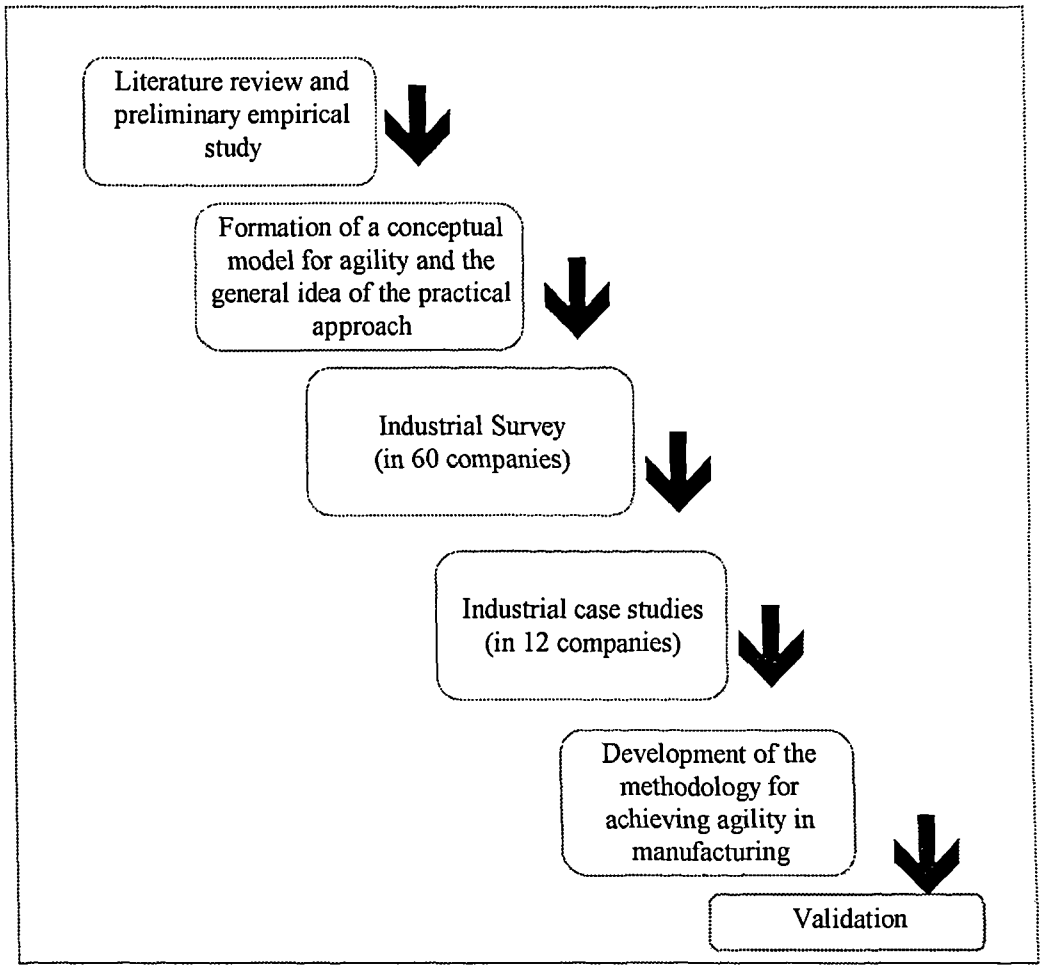

Figure 7.1. The process followed during the research

7.3 DISCUSSION OF RESULTS FROM THE CONDUCTED EMPIRICAL STUDIES

The methodology targeted by this research will be derived based on the theoretical and empirical work carried out so far. The methodology will basically follow two major lines. One is the generic structure of methodologies in manufacturing management introduced in chapter four, and the other one is the conceptual model of agility developed earlier in this research. To satisfy the purpose of this chapter a brief discussion of the results from the two phases of studies, i.e. questionnaire survey and case study, seems necessary. The discussion will summarise and highlight the important and relevant issues investigated, and the results achieved during the two phases of study to provide the ground for development and introduction of the methodology. More discussion of the results will be provided in chapter nine.

Pilot Survey

The conclusions from the literature survey were put into examination through a preliminary and pilot survey, which was complemented with six case studies. The results and conclusions are discussed in chapter three and chapter four.

The questionnaire survey was mainly aimed at achieving a realistic understanding of the new circumstances of the business environment in the manufacturing industry, and examining the stressed concepts, factors and elements in the literature within the real world of manufacturing business.

The results from the questionnaire survey were supportive to the extracts from the literature.

However, the results from the pilot survey were found to be in need of refinement. Conducting six mini case studies, which were reported in chapter three, pursued this. The case studies were carried out by introducing the conclusions with regard to agility achieved during the previous steps of the research to the companies. The aim of this stage was to study the recognised elements within the frame of manufacturing companies' experience, and search for more details to complete the model.

The results from the case studies provided the required details needed for the construction of the conceptual model. These results were used in conjunction with the understandings from the literature survey to construct a conceptual model for agility, which is introduced in chapter four.

Questionnaire Survey

The research hypotheses and the proposed conceptual model were put into examination through a questionnaire survey and case studies. The reasons behind the questionnaire survey included: investigating the validity of the research hypotheses on which the conceptual model were based; studying the proposed conceptual model for the validity of its structure; grasping factual ideas about agile manufacturing from a practical point of view, and identifying main factors defining the model and relationships which is required to achieve the second objective of the research, i.e. identifying main factors constituting the concept and relationships between these factors. The obtained information from the survey was also expected to provide support for the formulation of the methodology, the third objective of the research.

The results from this phase of study were helpful in partial validation of the hypotheses, and providing support and more information (identification of main factors) with regard to the conceptual model. These results are discussed briefly later in this section.

Case Studies

Constraints and limitation of the survey method, as expected, led the research to carry out a case study phase in order to obtain a larger set of data required for the second and third objectives of the research, reassess and validate the understandings from the survey, and extend and widen the borders of understanding of agile manufacturing in practice.

Agility drivers, circumstances in the companies' business environment, strategies, capabilities and practices adopted in response to changes, and perception and need of the companies for agility were studied in particular during the case study phase. Key themes of the concept were studied across the case study companies. Views,

experiences and actions of the case companies were studied the results of which will be used in the final construction of the methodology for implementation of agility in manufacturing organisations. For instance, analysis of change factors in the business environment of the case companies, practices adopted by the companies in response to changes, and relationships between change factors and agility capabilities were among the results.

Validation of the Research Hypotheses (Results from the Questionnaire Survey)

Various aspects of the surveyed sample were examined in accordance with the concept of agility and the proposed conceptual model. As an outcome, the research hypotheses received sufficient though partial support from analysis of the results. For instance, agility was widely considered as an ability necessary for surviving and prospering in the new world of business. This was in support of the first hypothesis, i.e. agility is an ability that manufacturing companies need to have to be able to survive and prosper in the new order of the global business environment. Different organisations and sectors were found to be different in the way they define, need or may approach agility in their organisation. This finding was in partial conformance with the second hypothesis of the research which is: organisations are different in the way they should respond to changing business environment, and their level of agility is a direct function of changes in their business environment, the business environment itself and the company's situation. Achieving the capability of being agile was observed to be through strategic identification and carefully implementation of business practices. This last finding supports the research hypothesis number three, i.e. in practice, agility could be achieved through strategic utilisation of business methods, manufacturing and management processes, practices and tools. The validation of the research hypotheses justified the grounds on which the conceptual model were established.

Validation of the Conceptual Model (Results from the Questionnaire Survey)

The structure of the conceptual model received support from the survey as the defined factors and relationships were positively answered by the respondents in conformance with the proposed structure. Agility drivers or the pressures in the business environment of manufacturing companies were considered by the respondents as

realistic and important as it was suggested by the research; the expected responses for ranking the change items were mainly in conformance with the original understandings of the research while some factors were suggested by the results to be different from the previous perceptions of the research; strategies were considered necessary and vital in responding to the changes and pressures in the business environment; and the suggested strategies and strategic movements were mostly in the defined range of the factors proposed by the research. The relationships between the factors proposed in the conceptual model were studied using the crosstabulation method to verify the existence and strength of these relationships. Some strong correlations between the studied drivers of agility and the strategic capabilities have been identified. These results supported the employed concept in the conceptual model in which the right response to the changes in the business environment (agility drivers) were considered to be uptaking of strategic capabilities which could provide the ability for responding appropriately to the changes. In another words the structure of the proposed model was validated, and hence the path to achieving agility, which will be introduced in the form of a methodology, can follow the same structure.

Identification of the major drivers of agility, identification of important agility strategic capabilities and some effective practices in acquisition of agility capabilities were also resulted from the survey. A preliminary relationship between the factors of the conceptual model including the relationship between agility drivers and agility capabilities were also established. These results were, in fact, in support of the achievement of objectives two and three of the research.

Further Findings and Validation of the Model (Results from the Case Studies)

A preliminary relationship is established between the agility drivers and the agility capabilities, which represents the importance of each of the items of agility capabilities for every change item of agility drivers. The established relationship, which is based on the facts and figures obtained from the conducted case studies, provides support for the existence and validity of this relationship. Also it can be used to conclude that a more accurate and extensive pattern of relationship between the mentioned factors could be provided.

The results from this phase included the final identification of agility drivers and their impact on the companies' business (to complement the results from the survey in chapter five as explained above), relationships between agility drivers and agility capabilities (which were not sufficiently available from the survey results), factors for assessing the need for agility and current level of agility of an organisation (to introduce the assessment model for agility), and identification of a large number of practices related to agility.

Summary

In summary, the empirical studies provided the research with:

- Relative validation of all three hypotheses of the research on which the proposed model were relying,
- The required support for the model proposed by the research, and that the suggested methodology could be developed on the basis of the conceptual model,
- Main factors of the model in details,
- The relationship between factors of the model which could be used in developing the methodology aimed by the research,
- Proof of necessity of an assessment model for agility, and the main factors to be assessed.

At this stage it can be concluded from the discussed results that a methodology for achieving agility to be applicable to most of manufacturing organisations could be derived in the line of the conceptual model of agility introduced in chapter four. The methodology should consider the assessment of need for agility and current level of agility of an organisation, identify the requirement of the organisation for agility, define the strategic lines for acquisition of agility, and propose the capabilities and consequently the practices which could support the achievement of agility. The measures and tools of the methodology will be based on the basic concept employed by the conceptual model that agility drivers should be considered and verified first for an organisation and the responses to the agility drivers in the form of agility capabilities and agility practices should then be identified and put into practice.

The summary of the results from the empirical studies is illustrated in Figure 7.2.

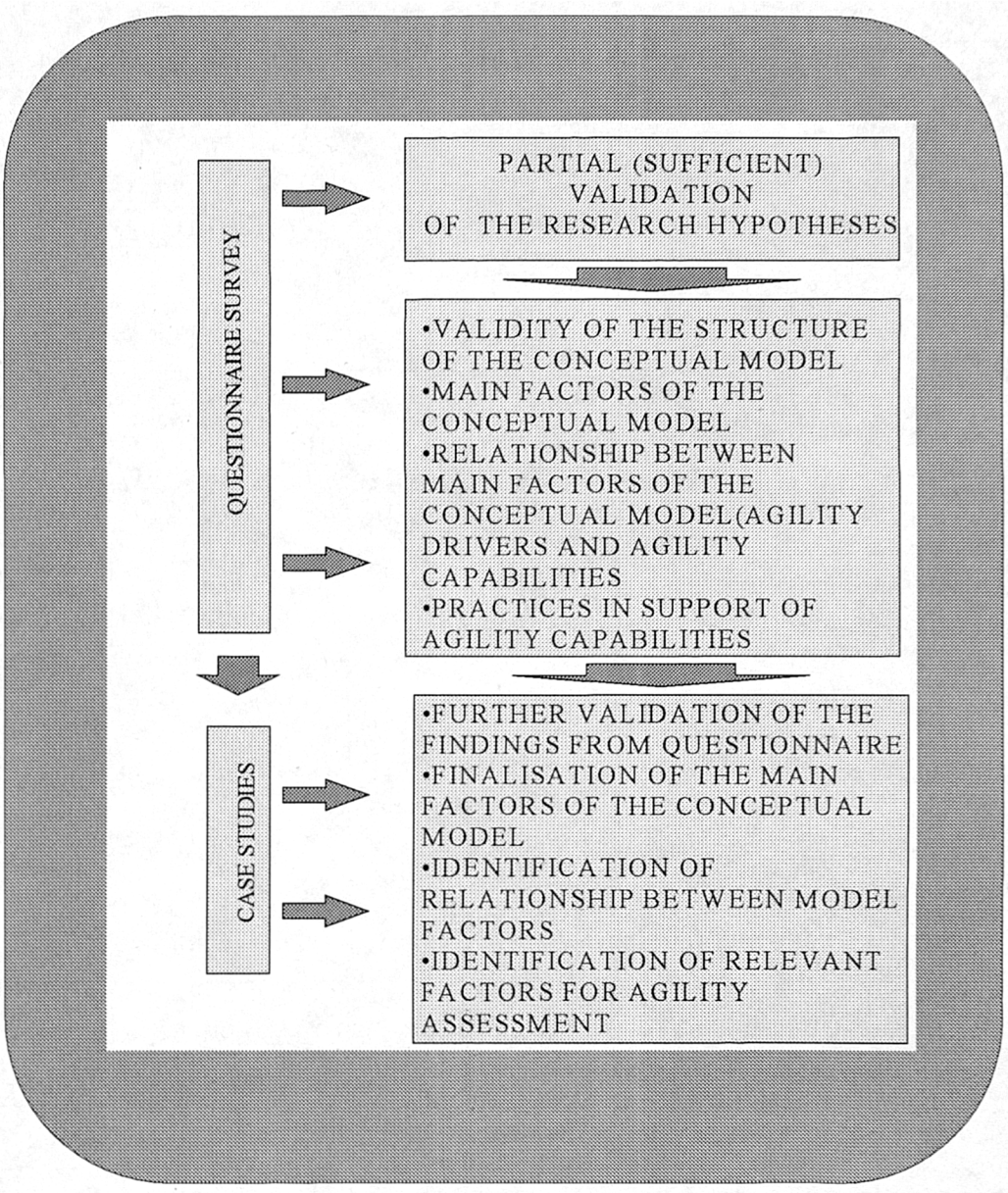

FIGURE 7.2 Summary of the findings from the research empirical studies resulting in development of the targeted methodology by the research

7.4 THE DEVELOPMENT OF THE RESEARCH TARGETED METHODOLOGY

The methodology is basically developed based on the conceptual model for agile manufacturing, introduced in chapter four, in which the basic building blocks of the

agility concept are articulated to form a structured view of agile manufacturing. The proposed structure for the methodology, in fact, was the result of employing a generic approach in manufacturing management and applying the generic approach to the conceptual model of agility. Consideration was taken to ensure that the methodology satisfies some generic requirements expected from such an approach to an acceptable level. These criteria include:

- Taking a systems perspective and addressing strategic issues
- Setting out a vision and also themes for changes and change strategy
- Identifying and specifying tools, and approaches that fit strategic needs of users and also the regeneration themes
- Providing guidance on the available means.

The methodology adopts some basic definitions for agility as its backbone, which in essence has one major common theme. This core theme is "responding appropriately to changes in the business environment and taking advantage of changes". This theme resulted in the definition of a starting point in the methodology, which relate to agility drivers. Agility drivers, in fact, are the pressures from the companies' business environment that force manufacturing organisations to act in a way, different from the conventional ways, that suits the changing circumstances in the world of business. The idea of starting from the agility drivers was derived from the conceptual model and the adopted definition for agility mentioned above, which basically relate the concept of agility to the changes in the business environment of manufacturing organisations. The idea was strongly supported during the research and so it is taken as the area from which the movement towards agility should be started.

These forces and their impacts on the company's business should be identified to understand the position of the company in its business environment. To achieve this purpose it is necessary to conduct an assessment of the company's business and business environment. The necessity of this action was identified during the case study phase as reported in chapter six. The assessment should be conducted in order to obtain a preview of the position in which the company does business, recognise the extent to which the company is under various pressures, and hence identify the

company's level of need for agility. This must also be complemented with evaluating the level of ability that the company already has in responding to agility drivers. The assessment phase during which the organisation and its circumstances are studied at a strategic level will lead to a strategic vision about the company's business and could be used in deriving, defining or reviewing the company's strategy through an analysis stage. The analysis stage takes the results from the assessment of the organisation and provides a strategic decision about the position of the organisation with regard to agility. This decision will be made in conjunction with the overall strategy of the organisation.

In case the strategy of the organisation recommended a practical movement towards agility, the implementation of agility should be considered as the next stage. Practical tips and themes, which are expected as a result of the analysis stage, can be used as input into a change plan or implementation stage. This can also be called deployment or policy deployment stage during which goals are conveyed to the organisation and then turned into actions for change and improvement. The definition presented by Coleman [1992] is a suitable and useful reference to this subject which states: "Policy deployment is the process whereby the whole company, based on an understanding of the company's strategic direction and the critical areas where improvement is needed are involved through an iterative and participative process in identifying the actions necessary to achieve that direction and in tracking processes against them (identified actions)."

According to the conceptual model and the supports it received from the empirical studies the means with which the agility characteristics would be provided are agility capabilities, which in turn could be provided by adoption of appropriate providers (agility practices). The integration of best practices in support of acquisition of agility capabilities are highly supported during the research as a practical way for achieving agility in organisations. These understandings lead to this point that the next stage in the methodology should be identification of agility capabilities and agility practices relevant to the specific circumstances and needs of an organisation.

The identified practices for achieving agility then should be implemented to provide the required capabilities in the organisation for responding appropriately to changes.

Measurement of the results and feedback to strategy level for the revision of company's policy and actions is another important part of the methodology, which can bridge the gap between strategy and practice.

In summary, the methodology is designed so that the comprising concepts of the conceptual model of agility may be transformed to a practical tool for approaching agility in manufacturing organisations based on their real need and requirements.

7.5. STRUCTURE OF THE METHODOLOGY FOR ACHIEVING AGILITY IN MANUFACTURING ORGANISATIONS

The preliminary methodology proposed in section 4.6 (Figure 7.3) was put into study along with other backgrounds related to it. Additional and more detailed information were obtained as the result of the empirical studies, which in turn resulted in further development, and change of the model. An improved version of the methodology is shown in Figure 7.4.

As it is precisely shown in Figure 7.4, the methodology is proposed as an extended form of the preliminary idea propounded before, and comprises the following parts;

- Agility drivers
- Assessment model which includes two elements;
    - Assessment of the organisation's need for agility
    - Assessment of the organisation's current level of agility
- Analysis or gap analysis
- Strategy formulation and identification of strategic capabilities required for the company to become agile and those missing in the organisation
- Identification of agility providers or agility practices
- Implementation
- Performance measurement and feedback

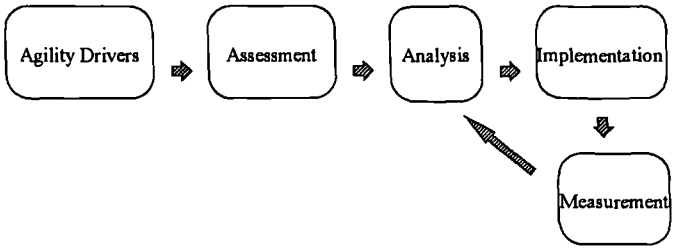

Figure 7.3. The Original Proposed Methodology To Achieve Agility

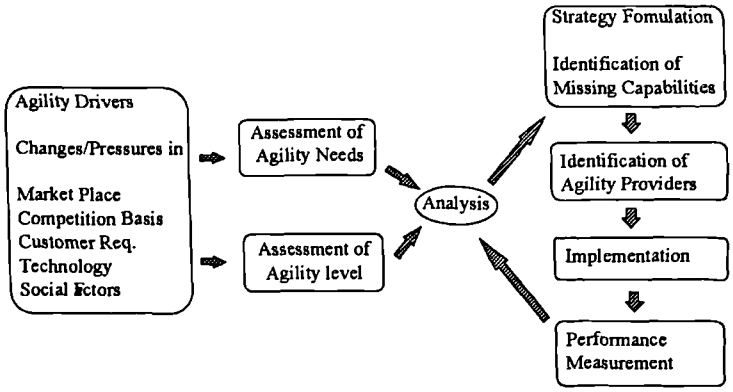

Figure 7.4. The Final Proposed Methodology To Achieve Agility

Uncertainties, changes, and pressures, i.e., the so-called agility drivers, urge a company to search for appropriate ways to maintain its competitive advantages.

As changes and pressures faced by companies may be different, the degree of agility required by individual companies will be different [James-Moore, 1996]. This degree is defined as the "agility need level", which is a function of various factors such as turbulence of the business environment, the environment that the company competes in, and the characteristics of the company itself. Once the agility need level is determined for a company, the next step is to assess the current agility level of the company, i.e., how agile the company is now. The difference between the level of agility required and that the company already has may then be analysed to provide a basis for further decision-making.

The next stage following the analysis of agility needs is to determine the required agility capabilities in order to become agile. This would require the detection, recognition and classification of changes faced by the company, as well as the analysis of the impact individual changes would bring to the company. The agility capabilities required may then be determined from the changes.

The final stage in the methodology involves identifying agility providers that could bring about the required capabilities, implementing the identified providers, determining the level of agility achieved (through performance measurement), and formulating corrective measures to further improve the performance. A number of tools are being developed to assist manufacturing enterprises to carry out the above process. The tools will be discussed later in this chapter.

7.5.1. Agility Drivers

The changing nature of the business environment and the increasing rate of change experienced in the past 10 to 15 years is turning the circumstances for doing business more and more turbulent. It is widely argued that almost all of the factors related to the business environment are subject to relentless, unpredicted and ever increasing change. The realisation of this provocative new era has resulted in the introduction of new approaches to managing business especially in manufacturing area such as agile manufacturing. The driving forces that cause the new waves in the world of business and push organisations to become agile and act agile are called agility drivers.
The research has resulted in the identification and classification of these drivers as recited in Table 7.1.

Each topic and item of the specified set of forces in the business environment can have different meanings for different organisations and even for the same organisation in different circumstances. However, the research for achieving a preliminary understanding of average importance and impact of each factor has resulted in some figures, which are shown in Table 7.1. The figures indicate the average level of importance of these items in the companies targeted in the empirical studies, which are limited to only three sectors as described in chapters five and six.

CHANGES	IMPACT	CHANGES	IMPACT
1. Changes in MARKET		4. Changes in TECHNOLOGY	
Growth of the niche market	M	Introduction of faster and more efficient/economic production facility	L/M
National and international political changes	L/M		
Increasing rate of change in product models	M/H		
Product lifetime shrinkage	L/M	Introduction of new soft technologies (Software and methods)	M/H
2. Changes in COMPETITION criteria			
Rapidly changing market	M	Inclusion of information technology in (new) hard technologies	L/M
Increasing pressure on cost	H		
Increasing rate of innovation	L/M		
Increasing pressure of global competition	M/H	5. Changes in SOCIAL FACTORS	
Decreasing new products time-to-market	M/H		
Responsiveness of competitors to changes	L/M	Environmental pressures	M/H
		Workforce/workplace expectations	L/M
3. Changes in CUSTOMER REQUIREMENTS		Legal/political pressures	L/M
		Cultural problems	L
Demand for individualised products/services	L/M		
Quicker delivery time and time-to-market	M/H		
Quality expectation increasing	M/H		
Sudden changes in order quantity specification	L/M		

Table 7.1. Changes As Agility Drivers. L = Low, M = Medium, H = High

The degree of impact of each factor will be the input for the practical tool which will be discussed later.

7.5.2. Assessment Model

As described earlier in this chapter and mentioned in chapter four, it is essential to conduct an assessment prior to taking any action towards becoming agile. The assessment model is introduced in this chapter to study the position in which the company lives and to provide the preliminary mindset for moving towards agility.

Figure 7.6 represents another view of the proposed assessment model, which is an improved version of Figure 7.5 (originally introduced in chapter four, Figure 4.4)

resulting from the conducted empirical studies. In this frame the model assesses the level of the organisation's need for agility and its current level of agility or its overall abilities required for responding to change factors. The results can be divided into two parts including a gap analysis to provide a general view of the company's position and urgency of becoming agile, and also some facts about the strengths and weak points of the company. This will help to cater strategy making and action planning which is the next stage as shown in the model's schematic figure.

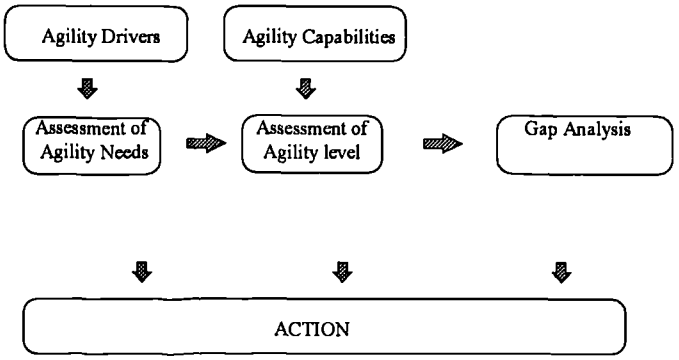

Figure 7.5. The original assessment model for agility

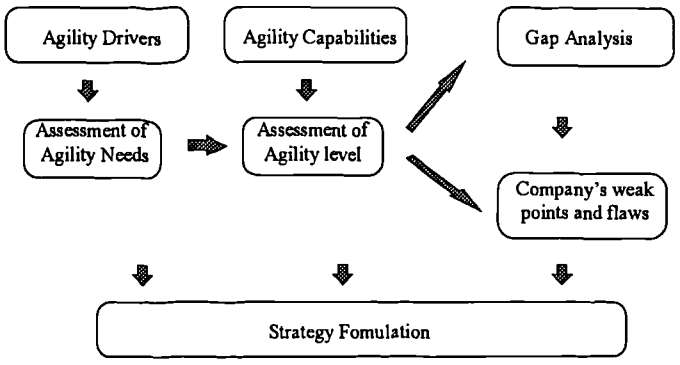

Figure 7.6. The final Assessment model for agility

7.5.3. Analysis

The assessment model should be followed with an analysis to obtain some fact-based ideas about the company's business position and the alternatives it may have.

The analysis as mentioned earlier can have two faces. One is a gap analysis from which a general speculation of the company's position can be extracted and a rough

estimation of the level of the company's need for agility may be produced. The other is determining the weak and strong points of the company in areas that are important for responding to changes.

7.5.4 Strategy Formulation

Results from a preliminary assessment will provide a basis for the company to review and define/design its strategy. As argued before in chapter four, strategy of an organisation with regard to agility can involve two major steps [Kidd, 1995], which are:

- A strategy to become agile
- A strategy to exploit agility throughout the organisation

The model has followed the same presumption with regard to the strategy. In practice, the first step relates to deciding upon the direction the company can take with regard to becoming agile and approaching agile manufacturing. This will incorporate the specific circumstances the company is faced with including time, external business circumstances and internal position of the company.

Results from the analysis of the assessment phase are the guidelines for determining the agility strategy for the organisation. As mentioned already, some alternative directions and detailed information can be extracted from the analysis. In other words results from assessing agility in the company can be used to decide on the appropriate agility strategy for the company. The strategy could encompass whether the company needs to become agile, and the extent of its need for agility.

Exploiting agility again needs another strategic intent and can be achieved only through designing a strategic movement, which includes realising the required necessities at a strategic level and defining the ways to achieve them. This process can be imagined as a broad and wide approach, which may require unlimited time, effort and money considering the broadness of the agility concept and involvement of almost all aspects of a manufacturing organisation.

The proposed methodology accomplishes the approach towards agility by adopting a practical tool, which is based on the strategic level components defined in the conceptual model including agility capabilities and agility providers. The graphical representation of the methodology, as shown in Figure 7.4, classifies the strategy formulation with identification of missing (strategic) capabilities. This will be described later when introducing the tools of the methodology.

7.5.5. Implementation

Outputs from the practical tools will be the capabilities that the company needs and is missing in order to become agile and the corresponding practices, which are likely to be supportive in achieving and enhancing the missing capabilities.

The strategy of the company for exploiting agility will determine the practices to be adopted. The timing, schedule, action plan and the implementation process then will be worked out to bring the practices into action and gain the required results.

7.5.6. Performance Measure

In this part the strategic goals set in the previous stages will be sought against the implemented practices. A system for measuring the performance of the organisation, and in specific terms the practices adopted with the aim of becoming agile is needed in a company.

The output from the performance measurement will help evaluate the effectiveness of the adopted practices in achievement of the agility capabilities and hence assist in resetting and revising the objectives already set for agility purpose.

7.6 TOOLS FOR IMPLEMENTATION OF AGILITY

As mentioned before a number of tools are developed to assist the application of the methodology in manufacturing organisations. These tools are explained in the following sub-sections.

7.6.1 Tool For Assessment of Agility

The tool consists of two parts. Part one assesses the need level of an organisation for agility and part two evaluates the current level of an organisation's agility. Foundation of the tool is graphically shown in Figure 7.7, which is based on the concept shown in Figure 7.4. Agility drivers from the conceptual model are the input to the agility needs level analysis. The basic measure for determining the level of agility need for an organisation is considered to be equivalent to the degree of turbulence of the business environment of the organisation. The business environment is then broken down into factors, which are in fact agility drivers, and for each a number of sub-factors are introduced. Assessing an organisation's position with regard to these factors will be the means for indicating the total turbulence of the organisation's business environment.

This assessment is performed by answering a questionnaire during which different aspects of the company's business environment are examined. This part will result in a total average score, which is designed to be between 1 and 10. The closer the score is to 10, the more turbulent the business environment of the company is and hence the more agile the company needs to be. The idea is shown in Figure 7.8. The questionnaire designed for this purpose can be found in appendix F.

The second part of the assessment model, as mentioned before, relates to assessing the abilities the company has in responding to the changes and turbulent environment. This part of the tool, which receives input from the first tool and also considers the set of agility capabilities in the conceptual model, will operate using another series of questions. The results would provide an image of the company's ability in responding to the changes in the business environment and hence its agility. In scoring the question items of this tool, the corresponding item(s) from agility need level tool, if exists should be controlled to see whether that item is reasonably changing and hence is important to the company. We suggest that only those items of this tool whose corresponding item(s) from the agility need level tool is scored 5 or more be considered in evaluating the current level of agility of the company.

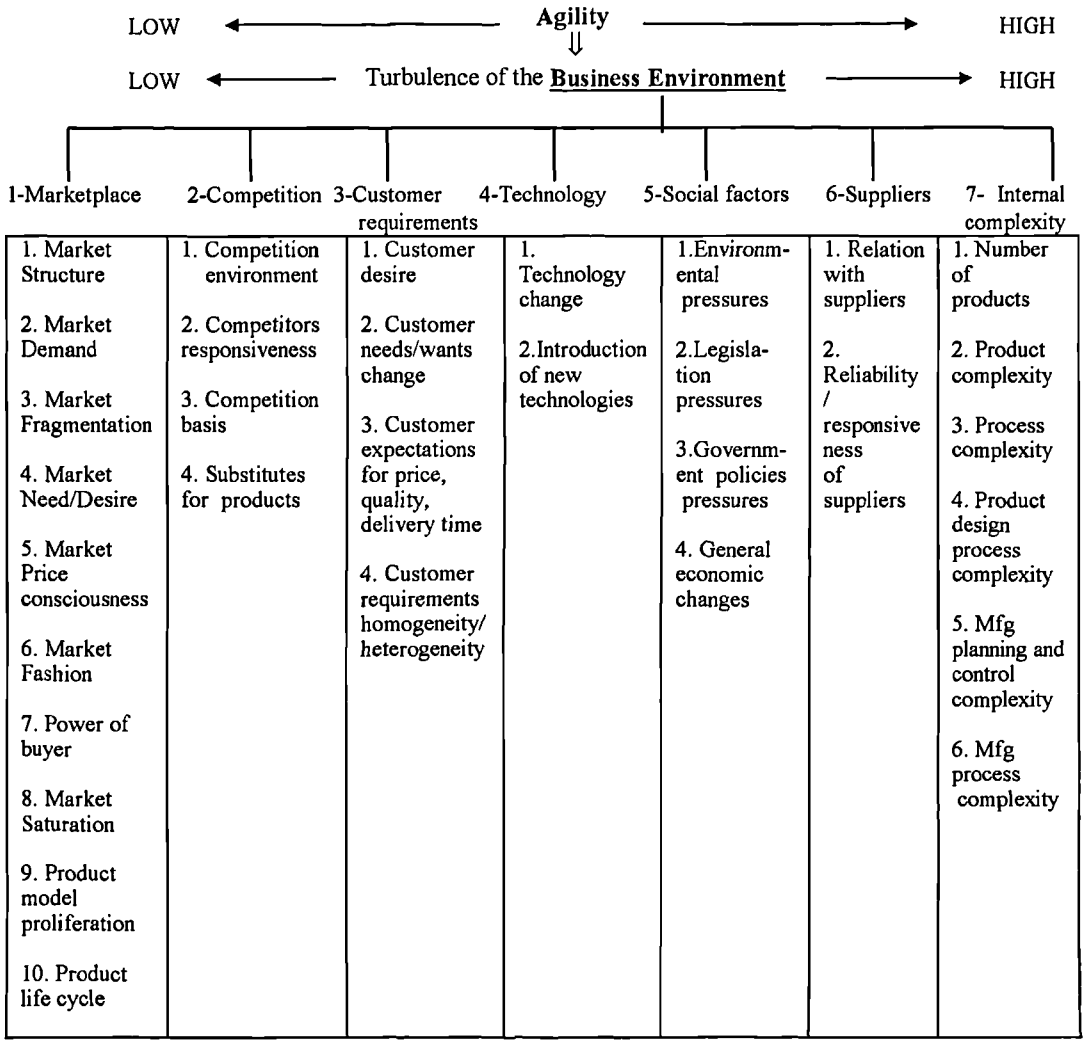

Figure 7.7. Analysing the need of the company to agility

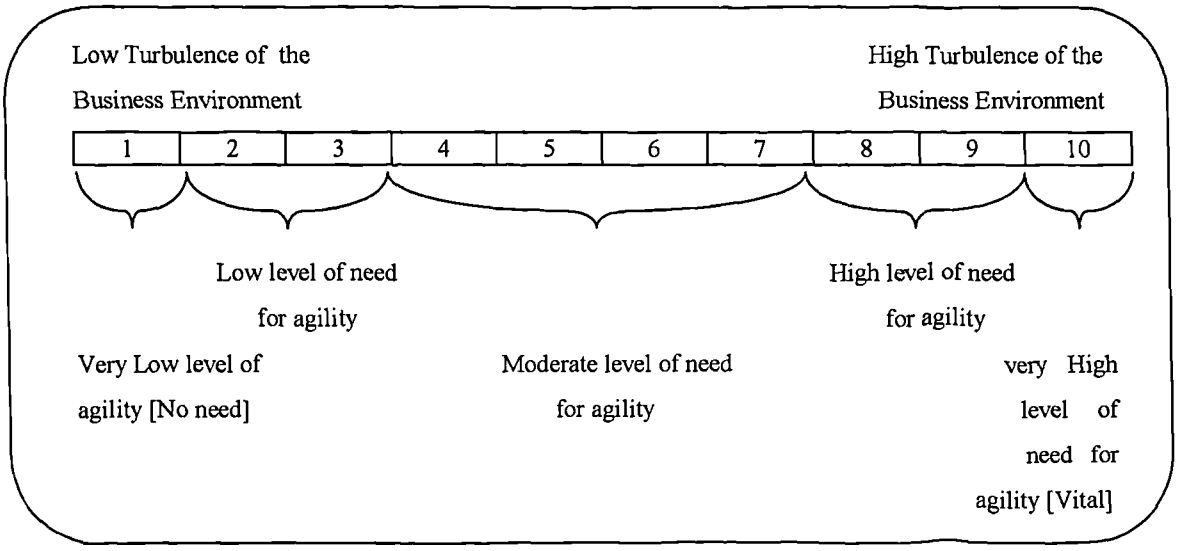

Figure 7.8. Indicating the level of agility needed by a company after applying the tool for assessing agility.

The questionnaire for this assessment is presented in appendix F. The assessment model is put into examination in order to study its validity. The results will be explained briefly later in this chapter.

7.6.2 Tool for Analysis of agility position of an organisation

As explained before, the results form the assessment stage must be analysed to determine the strategic position of the company with regard to approaching agility. A preliminary tool in the form of a list of options is developed. Table 7.2 represents some possible strategic options as outcomes of the gap analysis. More options can be considered which may be targeted for exploitation in further research in this area.

• The company does not need to be highly agile or it is not an urgent issue for the company.
• The company is agile enough to respond to changes it might face in future.
• The company needs to take actions to become agile but not as an urgent agenda.
• The company needs to be agile strongly and urgently.

Table 7.2. Some general strategic alternatives with regard to becoming agile as the output of analysis phase

The analysis is applied in two case studies conducted with the purpose of validating the methodology. The results will be reported later in this chapter. In practice, the change areas and factors that can cause problems for the company are first identified and then the abilities of the company considering those areas are determined. The results will be some practical guides for considering strategies at the company's management level.

7.6.3 Tool for Strategic Enhancement of Agility in the Organisation

Once the company's strategy for becoming agile was decided upon based on the study and assessment of the company with regard to agility, the company shall seek practical ways towards adopting the agile characteristics in its entire organisation. A practical tool is provided to assist conducting this stage of the methodology. The tool takes its main elements from the conceptual model of agility and follows the following logic which is based on the concepts exploited and enriched through the research:

1. Determining the degree of impact or importance of different change items of agility drivers.
2. Determining the agility capabilities required for responding appropriately to changes based on the output of statement 1.
3. Determining the agility providers or agility practices required for achieving the identified capabilities stated in statement 2.

The tool, therefore, includes three parts of the methodology, which as mentioned are agility drivers, agility capabilities, and agility providers or practices. Details of the mentioned tool are explained as follows:

7.6.3.1 Determination of agility capabilities

The determination of agility capabilities to be acquired/enhanced in a company in order to respond to the perceived changes/pressures is carried out with the assistance of a network model shown in Figure 7.9. With this model, external and internal changes/pressures (agility drivers) that have impacts on manufacturing organisations are classified and represented as inputs to a network. The agility capabilities required to challenge and overcome the changes/pressures are represented as the outputs of the network. The network connections between various changes/pressures and

capabilities, as well as between different capabilities, are established to a preliminary level through the industrial questionnaire survey and case studies as reported in chapters five and six, specifically represented by Table 6.12 in chapter six. A connection weight between a capability and a change/pressure reflects the importance of the capability to the change/pressure. The lateral connections between different capabilities represent the impacts of each capability on other capabilities. For practical applications, each change/pressure is represented by a value between 1 and 5, which corresponds to the impact the change may have for a given company (or the significance of the pressure to the company). These values are then used as inputs to the network. At the output layer, the item corresponding to each capability calculates an weighted sum of inputs to the item (including those from the changes/pressures as well as those from other capabilities), processes the resulting sum, and produces an output value representing the level of importance of the capability to the company. Due to the lateral connections between different capabilities, the calculation will experience an iterative process before stabilised results are produced.

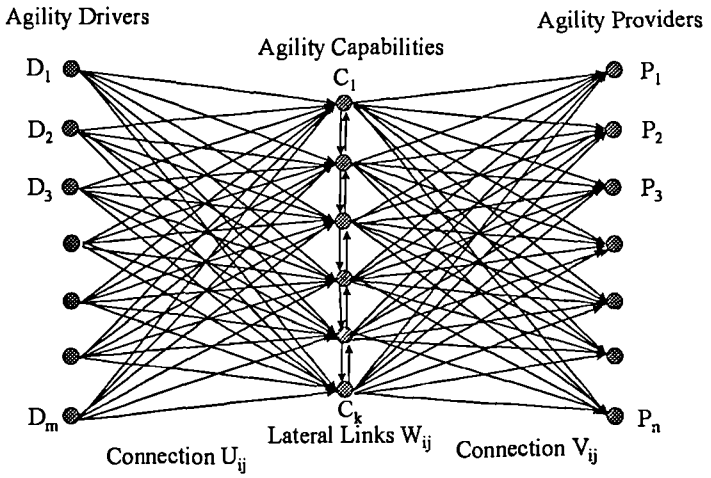

Figure. 7.9 Network to Determine the Required Agility Capabilities and Providers

7.6.3.2 Identification of agility providers

A list of business practices, methods, tools, and techniques, generally referred to as agility providers that could bring about agility capabilities for manufacturing companies is provided during the research. These providers or practices include both proven tools and practices that are already available to manufacturing organisations as well as those which are still being developed by the research community. Some

general practices have been studied during the questionnaire survey to determine their effects on the manufacturing companies' responsiveness and their abilities in responding to unpredicted changes. The results are reported in chapter five. Also the case study phase provided a long list of practices or providers, which had been approached by the case study companies in responding to different change items. The list which exceeds 120 practices and was presented in section 6.5.6 of chapter six can be used as a guide for those who might seek experienced ways of acting in specific situations and confronting change.

The importance of these agility providers (or the perceived importance of those providers still under development) to various capabilities are represented by another network relationship shown in Figure 7.9, where the connection weight between a capability and a provider corresponds to the importance of the provider to the capability. The network takes as inputs the results from the "capability network" described before and produces a set of outputs representing the importance of individual agility providers to a company.

The original list of practices identified in different stages of the research including the literature survey, the pilot study, the questionnaire survey and the case studies are then analysed with regard to their relationship with the capabilities and the impact they could have upon acquisition of these capabilities. The results are shown in Tables 7.3, 7.4, 7.5 and 7.6. The relevance of the capabilities to the practices is concluded from different sources, which have been explored during the research. They include the emphasis put by the literature, the significance of statistical relationship recognised in the questionnaire survey, and the positive and fruitful experience of the case study companies in implementing them. The source or sources of the identified dependence of the capabilities on the specified practices are shown in Tables mentioned above.

Agility Capabilities and Corresponding Practices Recommended for Achieving them	Source from Literature	Source from Survey	Source from Case Studies
RESPONSIVENESS			
1. SENSING, PERCEIVING AND ANTICIPATING CHANGES			
PRACTICES :			
• Strategic use of information system	*	*	
• Using Internet and other information tools for communication with outside of the company	*		
• Information interface with suppliers/customers	*	*	*
• Internal information network	*	*	
• Empowerment of people		*	*
• Information management plan or model	*		
2. IMMEDIATE REACTION TO CHANGES			
PRACTICES :			
• Computerised manufacturing information system	*	*	
• Internal information network		*	*
• Concurrent teamworking	*	*	
• Increasing market awareness with group marketing approach			*
• Time-Compact-Technology methods adoption	*		*
• Virtual organisation		*	
3. RECOVERY FROM CHANGE			
PRACTICES :			
• Continuous re-engineering of the organisation		*	*
• Concurrent team working		*	
• Adoption of advanced technology	*		*
• Empowering people	*		
• Virtual organisation		*	

Table 7.3. Agility practices supporting the achievement of agility capabilities (Responsiveness)

Agility Capabilities and Corresponding Practices Recommended for Achieving them	Source from Literature	Source from Survey	Source from Case Studies
COMPETENCY			
1. STRATEGIC VISION			
PRACTICES :			
• Establishment of high rank teams for dealing with the business			*
• Strategic use of information systems		*	
• Continuous improvement as the company's strategy			*
• Merging into/joining more powerful manufacturing group			*
• Strategic planning techniques	*		
• Information management plan or model		*	*
2. APPROPRIATE TECHNOLOGY			
PRACTICES :			
• Adopting advanced technology	*	*	*
• Automation	*		
• Strategic investment	*		*
• Information management plan or model		*	
3. PRODUCT/SERVICES QUALITY			
PRACTICES :			
• Information Technology adoption	*	*	
• Cellular manufacturing	*		*
• Just-In-Time methods	*		*
• Automation	*		
• Quality programmes	*		*
• TQM (Total Quality Management)	*	*	*
• Streamlining the company's processes			*
• Investment in technology			*
4. COST EFFECTIVENESS			
PRACTICES :			
• Quality programmes	*		
• DFMA (Design For Manufacturing and Assembly) methods	*		*
• Outsourcing	*		
• Virtual organisation		*	
• FMS (Flexible Manufacturing System)	*		*
• Streamlining the company's processes			*
• Lean Manufacturing techniques	*		*
• Continuous education and training of people			*
• Adopting new/advanced technology	*		*
• More system approach			*
• Cost reduction initiatives			*
• Continuous re-engineering of the organisation		*	

Table 7.4. Agility practices supporting achievement of agility capabilities (Competency)

5. HIGH RATE OF NEW PRODUCT INTRODUCTION	Source from Literature	Source from Survey	Source from Case Studies
PRACTICES :			
• Mass customisation	*	*	
• Concurrent Engineering	*	*	
• TCT (Time-Compact-Technology) methods	*		
• DFMA methods	*		*
• Virtual organisation	*	*	
• Strategic investment in technology	*		*
• Structured and flexible manufacturing process		*	
• Integrated computer-based product development process		*	
• Computerised manufacturing information system		*	
• Enlarging the engineering department			*
• Partnership with suppliers		*	*
6. CHANGE MANAGEMENT			
PRACTICES :			
• Employees involvement	*		
• Informal, coaching and encouraging management		*	
• Streamlining processes			*
• More systematic approach to problem solving			*
• Continuous re-engineering of the company's systems with changes			*
• Strategy review			*
• Integration of inter-organisational systems and modules		*	*
7. KNOWLEDGEABLE, COMPETENT, EMPOWERED PEOPLE			
PRACTICES :			
• Empowering people	*	*	*
• Continuous training of people	*	*	*
• Informal, coaching and encouraging management	*	*	
• Involvement of employees	*		*

Table 7.4. Continued

8. OPERATIONS EFFICIENCY AND EFFECTIVENESS (LEANNESS)	Source from Literature	Source from Survey	Source from Case Studies
PRACTICES :			
• Information system/technology adoption	*		
• Internal information network		*	
• Computerised manufacturing information system		*	
• MRP/MRPII	*		
• JIT	*		
• Lean Manufacturing techniques	*		
• Automation	*	*	*
• Quality enhancement programmes	*		
• Cellular Manufacturing	*		
• Streamlining processes			*
• Continuous education of people			*
• Integration of inter-organisational systems and modules		*	*
• Total integration of manufacturing system		*	
9. COOPERATION(INTERNAL/EXTERNAL)			
PRACTICES :			
• Information system interface with suppliers/customers		*	
• Introduction of fast communication infrastructure (such as Video Conferencing, Internet connection)			*
• Close relation with customers/suppliers and involving in the company's programmes		*	
• Virtual organisation	*	*	
• Establishing team working and concurrent methods inside the organisation	*		*
• Establishing partnership with suppliers/customers/competitors	*	*	
10.INTEGRATION			
PRACTICES :			
• Integration of inter-organisational systems and modules	*	*	
• Total integration of manufacturing system	*	*	
• Integrated computer-based product development process	*	*	
• Vertical integration globally			*
• Integration of all products' components and parts			*
• Automation	*		

Table 7.4. Continued

Agility Capabilities and Corresponding Practices Recommended for Achieving them	Source from Literature	Source from Survey	Source from Case Studies
FLEXIBILITY			
1. PRODUCT VOLUME FLEXIBILITY			
PRACTICES :			
• FMS (Flexible Manufacturing System)	*		*
• Long term contract (partnership) with customers/suppliers	*	*	
• Adoption of advanced technology		*	
• Information connection with customers/suppliers	*	*	
• Mass Customisation methods	*	*	
• Automation			*
2. PRODUCT MODEL/CONFIGURATION FLEXIBILITY			
PRACTICES :			
• FMS (Flexible Manufacturing System)	*		
• Information system/technology utilisation	*	*	
• Information connection with customers/suppliers	*	*	
• Mass Customisation methods	*		
• Integrated computer-based product development process		*	
• Colour proliferation of products			*
• Basic design with flexibility in specification (design modularity)			*
3. ORGANISATIONAL FLEXIBILITY			
PRACTICES :			
• Establishing flexible, flat, learning and team-focused organisation	*	*	
• Informal, coaching and encouraging management	*	*	
• Concurrent and team working methods	*	*	*
• Continuous education of people			*
• Developing focused organisation			*
4. PEOPLE FLEXIBILITY			
PRACTICES :			
• JIT	*		
• Continuous education and training of people	*	*	
• Empowerment of people		*	*
• Developing niche skills			*

Table 7.5. Agility practices supporting achievement of agility capabilities (Flexibility)

Agility Capabilities and Corresponding Practices Recommended for Achieving them	Source from Literature	Source from Survey	Source from Case Studies
QUICKNESS			
1. QUICK NEW PRODUCTS TIME-TO-MARKET			
PRACTICES :			
• DFMA	*		
• QFD	*		*
• CAD/CAM integration in the system	*		*
• Kanban			*
• Outsourcing (delegation of functions)	*		
• JIT	*		*
• MRP/MRPII	*		
• Quality programmes	*		
• Set-up time reduction	*		
• Tightening communication between design, engineering and manufacturing	*		
• Reduction of suppliers	*	*	
• Re-engineering processes		*	*
• Re-structuring manufacturing process			*
• Reducing time from design point			*
• Joint venture/virtual organisation			
• Developing an effective communication infrastructure for the company		*	*
2. PRODUCTS AND SERVICES DELIVERY QUICKNESS			
PRACTICES :			
• JIT	*		*
• Long term contract with customers/suppliers (partnership)	*		
• Cellular manufacturing	*		
• Reduction of suppliers	*		*
• Information technology/system connection with market/customers/suppliers	*		
• MRP/MRPII	*		*
• Concurrent Engineering	*		*
• Establishing a structured and flexible manufacturing process		*	
• Internal information network		*	

Table 7.6. Agility practices supporting achievement of agility capabilities (Quickness)

3. FAST OPERATION TIME	Source from Literature	Source from Survey	Source from Case Studies
PRACTICES :			
• JIT	*		*
• Concurrent Engineering	*		*
• Continuous training and education of people		*	*
• Establishing a structured and flexible manufacturing process		*	
• Cellular manufacturing	*		*
• Automation	*		
• Adoption of advanced technology	*	*	*

Table 7.6. Continued

However, it is important to consider the following points:

- The recommended practices are a general guide list, which cannot be extended as applicable to all and every organisations. In fact they can only be used as a reference in the process of defining the practical actions for providing the required capabilities.
- It has been understood from the research that adopting practical actions and employing tools and techniques is a totally adaptive process which can depend on many factors in an organisation including the business of the company (the sector it belongs to and the products it manufactures), the market it serves and competes in, the characteristics of the company (size, history, politics, etc.), the time and the corresponding circumstances, and so on. The process is also directly dependent on the company's strategies. So any reference to the recommended practices should be made with the above points taken into consideration.
- The list of practices lacks the required information for establishment of the weights for relationship between the capabilities and providers. In other words, the weighting system between the agility capabilities and agility providers or practices, which forms a part of the methodology, is not provided by the recommended list of practices. In fact it is still in early stages of development, the completion of which is left to further research in the future.

The results from this stage must be examined with the strategy of the company for becoming agile, and strategic plans for adopting the identified practices should be developed considering the following two factors:

1. Results of the assessment model where the practical capabilities of the company are assessed.
2. The cost of this approach and strategic targets of the company in this regard.

7.7 A GUIDE LIST FOR THE IMPLEMENTATION OF AGILITY

A general list of guidelines for adopting the methodology is depicted in Figure 7.10. It comprises the steps a company should take in moving from the position it is located in towards a revision in strategy for changing in answer to the ever-changing business environment.

STEP ONE

Study the business environment of the company using the reference model and score the change areas for the company

STEP TWO

Assess the level of the company's need for agility using the assessment model; The Assessment Tool for agility.

STEP THREE

Assess the company's abilities in responding to changes, using the assessment model; The assessment Tool for agility.

STEP FOUR

Define the company's strategy with regard to becoming agile, using the analysis of steps two and three above.

STEP FIVE

If recommended by the company's strategy for agility, apply first part of the practical tool (network model) to the company using the results from step one to determine the required capabilities for the company in response to the change areas and threatening factors.

STEP SIX

Apply second part of the practical tool to determine the practices needed to acquire and provide the specified capabilities, using the results of steps two, three, four, five, and the specific experiences of the company on different practices

STEP SEVEN

Measure the results and feed them back to the previous steps for correction and revision.

Figure 7.10. A glossary of the methodology as a stepwise approach to its application

SUMMARY OF THE CHAPTER

This chapter provided the final achievements of this research, objective number three, which was a methodology for implementation of agility in manufacturing organisations. In this chapter:

1. The research, its objectives, and the process applied in fulfilling it was briefly reviewed. The necessity of the research agenda, the identified gap in the existing body of research in this area, the basic assumptions of the research, and the adopted methodology to conduct the research was restated.
2. The results from two empirical studies were discussed. Validation of the research hypotheses, validation of the proposed conceptual model, and achievement of the factors of the conceptual model and their relationship that were later used in the development of the targeted methodology were briefly discussed.
3. The methodology targeted by the research was reviewed quickly, during which the skeleton of the methodology, its theoretical background and support, and the logic implemented in defining the methodology are discussed.
4. The methodology and its structure is discussed in details. The improved version of the proposed methodology for implementation of agility in manufacturing organisations is introduced, and each part of the methodology is discussed in detail. The relationships between the building blocks of the methodology are also described to provide a practical approach for the purpose of becoming agile. The proposed methodology is based on the conceptual model developed in early stages of the research and the empirical studies in UK manufacturing industry.
5. Some tools have been developed to support the implementation of the methodology, which are presented conclusively. In particular the assessment tool for agility, the tool for analysis of agility position of an organisation, and the tool for strategic enhancement of agility are discussed.
6. A general list of guidelines for adopting the methodology is derived to comprise the steps a company should take in moving from the position it is located in towards a revision in strategy for changing in response to the ever-changing business environment.

The proposed methodology and its associated tools will be introduced to the industry by applying it in two case companies. This will satisfy the last objective of the

research. i.e. to introduce the methodology to assist manufacturing organisations to adopt agility as a characteristic.

CHAPTER EIGHT

INTRODUCTION OF THE METHODOLOGY TO MANUFACTURING INDUSTRY

8.1 INTRODUCTION

A methodology for assisting manufacturing organisations to achieve agility is developed now. The novelty of the developed methodology and its generality induced the research to conduct an introduction effort as the fourth and last objective of the research. Results of this phase are briefly discussed in this chapter. The introduction stage while providing considerable supports to the proposed methodology and its practicability, clarified the areas, which are in need of further research and investigation. This will provide a broad view for further research ideas, which will be described in chapter ten.

The proposed methodology and its associated tools were introduced and examined through two case studies. The results from the cases studies comply satisfactorily with the specified aims and expected outcomes of the methodology.

8.2. INTRODUCTION OF THE METHODOLOGY TO INDUSTRY

Although the methodology developed in chapter seven was a result of the vast review of the literature pertaining to the subject and two empirical study stages, it was seen as necessary to put the methodology into examination by introducing it to manufacturing industries and study the results.

However, the introduction of the methodology is not a trivial task due to the following limitations:

- It was not practical to thoroughly examine the methodology considering the time frame involved in implementing the proposed tools and practices with the available resources for the research.
- It was difficult to find collaborators for participating in this stage even in a superficial way.

Therefore, it was decided that a preliminary study involving three main parts of the methodology is carried out to provide the objective of the research. The three parts investigated are:

1. The assessment model
2. Determination of agility capabilities
3. Determination of agility providers

For simplification, items two and three listed above are referred to as "the practical tool".

8.2.1 The Assessment Model

The electrical and electronics sector was chosen to examine the assessment model in companies from that sector. This was due to the relatively higher uncertainty in the business environment of this sector. 22 companies from this sector were in the list of the companies that had already participated in the survey. 20 of these companies (two were excluded due to the unwillingness of the respondents shown for further participation in the research), plus a manufacturer from the white-good sector which was believed to be a well advanced and relatively agile organisation were targeted for examining the model.

A guided set of questionnaires was sent to these companies and 10 replies were received in response. The aims of the examination can be summarised as follows:

1. To test whether the model and its tools are meaningful to the responding companies.
2. To obtain a rough estimation of the average need of the company for agility according to the provided definitions.
3. To obtain the intuitive idea of the respondents about the level of agility the company needs based on the presented definitions and concepts.
4. To compare the results of items 2 and 3 to get some ideas about the usefulness of the assessment tool.
5. To indicate the relevant and irrelevant factors for different companies to use in refining the tool.
6. To take some detailed information for the purpose of examining and validating the practical tool of the methodology.

The results from this examination are depicted in Tables 8.1 and 8.2. Table 8.1 represents the average of the agility needs and current agility of each company according to the tools and the estimation of the respondents who are senior managers or directors of their companies.

Case Company No.	Average for Tool part 1	Number of factors involved	Intuitive level of need for agility	Average for Tool part 2	Number of factors involved	Intuitive level of agility of company
1	7.0	66	7-8	6.6	62	6
2	6.4	56	7	7.3	54	7
3	5.2	67	5	5.6	46	5
4	5.1	69	5	6.2	49	7
5	6.0	59	6	6.7	57	8
6	6.2	68	7	5.2	58	6
7	7.0	72	7	8.0	57	9
8	4.8	69	4	5.0	38	5
9	4.8	66	5	5.9	39	7
10	6.3	56	6	5.5	41	5

Table 8.1. Results from applying the assessment model in case companies and comparison with the respondents perception

Table 8.2 provides some conclusions, which generally supports the validity of the tools as a preliminary proposal.

- Most of the results from the two tools are equal or very close to the perceived level of need for and current level of agility by the case companies. This can be interpreted as a initial measure of validity of the approach, at least in the examined sector.
- Different companies have different circumstances in front for which the relevant factors in measuring the turbulence of their business environment are different. This is also shown in the extracted results where the number of involved factors for different companies is different. In fact the difference between the stated number of factors and the total number of the factors (72) are irrelevant items considered in the second part of the tool.
- Some factors can be found with a vast irrelevance among the respondents and also some factors are indicated with low importance by many companies that can be extended to most or all of the companies. However, it can be said that generally every company has it own specific conditions and even companies with close field of business and similar markets may be found to have different situations and positions in their surrounding environment.
- Almost all of the responding companies have approved the proposed approach as a realistic way of measuring the factors, which can indicate the level of need for agility and the abilities, the company possesses for responding to unpredicted changes. However, as it was already noticed by the researcher, there were comments suggesting that the measuring system needs further improvements in order to become more detailed.

Table 8.2. Some conclusions from the validation phase of the assessment model

8.2.2. Implementation of the Methodology

The methodology was applied in only two companies selected from the case study companies who had responded to the previous assessment work. Only two companies were selected for the implementation of the methodology, as it was not practical to do it in more companies because of the limited time and resources available. Also not many companies were keen to participate in this phase. The two selected companies, which had been considered as successful manufacturers, were using a high level of

technology and were interested in looking at new ideas and modern agendas in management of their business. The application of the methodology in the companies was based on the data and information gathered from those companies during the previous phases of the research though some live and valid aspects of the company's business might have been missed during the study.

The preliminary application has gone through various stages of the methodology to:

- Examine the business environment of the company,
- Determine the level of agility needed by the company,
- Speculate the strategic alternatives available for the company to pursue,
- Determine the abilities of the company in response to unpredicted changes,
- Determine the capabilities (and priorities in implementing the capabilities) required by the company to respond appropriately to changes, according to the specific circumstances surrounding it,
- Identify the practices that could support the company's approach towards agility and compare them with the practices already approached by the company.

The results of the application of the methodology with every single details including:

- The degree of need of the company for agility, and the current level of the company's agility,
- The main and sorted list of agility drivers for the company,
- The capabilities which the company needs to obtain in order to be able to respond to the change items (based on the application of the methodology tools), and
- The practices which correspond to the achievement of the identified capabilities (based on the application of the methodology tools) as a guide list,

were sent to the companies' representatives and their opinions were asked about the appropriateness of the adopted approach, and the suitability of the offered results including the proposed practices. Both companies found the approach highly positive and appropriate, and the results (practices) reasonably suitable and appropriate for their companies in the acquisition of agility. However one of the case companies which considers itself as highly agile and successful did not agree with the whole set of the proposed practices. The reason was stated by the contact person to be that the

company has already taken the necessary measures to achieve responsiveness (agility) to the market and competition. The other case company embraced the results as very positive, but the readiness of the company to take an agile strategy was commented as a barrier to approach the concept.

At the end of each case study some practices, which have been adopted by the company in responding to some of the changes in their business environment, are demonstrated to provide a comparative view of the methodology with the current practice of the company.

A summary of the results obtained from this study is given below.

8.2.2.1. Implementation of the methodology for agility - Company 1

Company number one is a leading manufacturer of domestic cookers with a high rank among European manufacturers. Apparently the company is the only manufacturer of cookers that profits from this business. Working with big retailers as main customers, managing a long chain of suppliers (about 80), and producing an average output of 1250 cookers per week in almost unlimited customised and fashionable varieties define a complicated business run by the company.

The Assessment Model

As detailed in the related section the assessment model consists of two parts. In the following sub-sections the results from applying each part will be explained.

Part one : Agility need level

Average of the factors in this part of the assessment model (devised for assessing the turbulence of the company's business environment) was 6.0 (out of 10). According to the assessment model a company in such a position needs a moderate level of agility. However, as the moderate level is defined by the model to include levels from 4 to 7, the level for the company tends to be closer to the high end.

On the other hand the company's perception of the agility need level, according to the respondent, is 6 (out of 10). This level is the same as the average of factors in part one of the tool.

Factors determining the turbulence of the business environment :

The preliminary assessment performed via the questionnaire indicated some factors pertaining to the company's business environment which are very turbulent so that they can cause threat or on the other hand be taken as opportunities.

Table 8.3 represents some of the factors with a degree of turbulence of 7 (out of 10 = highly turbulent) or above. These items should receive more attention when the company's strategy is studied and defined.

Factors of the tool	Degree of Turbulence
• Trend of market fragmentation and niche market growth for the company's products been in the past five years	7
• Tendency of the company's products to luxuries	7
• Price-conscious of markets/customers	7
• Important of following the fashion in product development in order to keep its position in the market	7
• The average rate of changes in product models in the marketplace [in the area where the company competes]	9
• Speed of the trend of change in products models in the marketplace for the company	9
• Market's power in determining the price	7
• Market's power in determining the delivery time	8
• Market saturation [Percentage of the potential markets/customers to which the type of company's products have reached]	8
•	

Table 8.3. Some of the factors with degree of turbulence 7 and more

Some factors are given turbulence level of 6, which can be considered to be less important, but still need to be looked after.

There have been some factors indicated as being not related to the company's business or not applicable to the company's circumstances. Other factors are recognised as not important or turbulent by the company.

Part two: assessing the current level of the company's agility

In total 66 factors are considered in this assessment. Application of the assessment tool in the company gives an average score of 6.4 (out of 10 where 10 = high level) for its abilities. This is achieved considering the factors related to the relevant and relatively important change factors. This score is supposed to be interpreted as the average degree of the ability of the company in dealing with the turbulent business environment and coping with changes. In other words it can be considered as the level of agility the company currently has. However, this score or level does not imply that the required level of need for agility, if is equal or less than the current level of agility, is already provided. In more accurate terms the mean level specified for the current level of agility indicates the average of the company's capabilities in different areas related to the turbulence of the business environment and changes. However, this level has a considerable association with the position the company lives in, and can relatively indicate the level to which the company can respond appropriately to changes.

The perception of the company (respondent) for the current level of agility on a 1 to 10 scale was 8. This is somehow different and higher than the average score obtained during the assessment.

Ability factors

Analysing the factors in the part two of the assessment model [for assessing the current abilities of the company] proposes that in total 42 factors have been scored for 7 and more (out of 10 where 10 = high ability), 12 factors are given level 6 and in 12 factors the company lacks sufficient or considerable strength. Table 8.4 shows some of the factors with level of 7 and more as a sample.

The following summary can be made as the result of the assessment process:

1. The company in the current circumstances needs a moderate level of agility with tendency to high. The strategy for the company with regard to agility can be; a better consideration of the growing turbulence in the business environment; taking on-time steps in becoming agile in order to sustain and maintain the competitive

advantage. However, it can be said that agility is not an urgent agenda for the company.

2. There are areas, which can potentially be threatening or be considered as opportunities. These areas must be taken into consideration when defining and designing the company's strategy. These areas are indicated in Table 8.3.

Factor No.	Factors of the tool	Degree of the company's ability
1	• Detecting, analysing, and understanding changes	
1-1	Detecting the changes in	
	• Marketplace (market's structure/demand/needs/taste or fashion/.)	8
	• Competitors' activities and position	8
	• Technology	7
	• Suppliers' activities and position	8
1-2	Quickness and efficiency of the company in analysing the information and data received about the changes in the business environment, and effecting them into its systems	
	• Top level management concern and commitment	8
	• Considering in top level/strategic planning of the company	7
3	• Exact understanding of the buyer (market) needs	
4	• Convincing (satisfying) the market with its products' specification, quality, price, delivery time	8 7
5	• Directing market's needs to the company's products and services	7
7	• Keeping up with the changes in the products life cycles, and controlling its products life cycles in order to obtain a competitive advantage	7
9	• Maintaining or progressing its position among its direct competitors in local markets in the current situation	8
11	• Trend of change in the company's marketshare in the past few years considering the intensity of competition (decreasing - increasing)	8

Table 8.4. Some of the ability factors the company has a level of 7 or more in them.

3. The company's perception of its current level of agility is higher than the perceived level of need and also than the average score of part two of the assessment tool. This does not necessarily mean that the company's requirements for agility have already been met. The large number of highly turbulent factors and areas in which

the company lacks sufficient abilities have questioned such optimistic view of the company and should be considered in formulating corporate strategies.

Applying the practical tool

The results from the assessment model are used to provide a practical base for the company to move towards agility. The assessment suggests that the company needs a moderate and not urgent level of agility, which should be taken into consideration when implementing the practical tool.

The practical tool is applied in three steps:

1. Determining the drivers of agility for the company
2. Determining the required capabilities
3. Determining the practices and actions

1. Agility Drivers

Table 8.5 lists agility drivers for the company with detailed sub-factors.

2. Agility Capabilities

The "Practical tool" is applied to determine the capabilities required by the company to respond to the agility drivers listed in Table 8.5. Table 8.6 lists 20 capabilities in the order of priorities, their corresponding levels of urgency to the company, and the company's abilities to present them.

Based on the capabilities and their priorities suggested by the practical tool as well as the relative strength of the company in presenting individual capabilities (as obtained from the assessment tool), following points are suggested as practical tips and guides for the company to consider its strategies about capabilities.

- The company needs to improve its position for the following important capabilities in which the company has ability level of 6.5 and less.
    1. Sensing, perceiving and anticipating changes
    2. Immediate reaction to changes by effecting them into system
    3. Strategic vision
    4. Co-operation (internal and external) [Joint Venture, Virtual Organisation]

5. Products/services quality
6. Cost effectiveness
7. People flexibility

Agility Drivers (areas)	Average degree of turbulence
• Marketplace	AVERAGE = 3.5 (out of 5)
• Growth of the niche market	5
• National and international political changes	1
• Increasing rate of change in product models	5
• Product lifetime shrinkage	3
• Competition	AVERAGE = 2.5 (out of 5)
• Rapidly changing market	0
• Increasing pressure on cost	5
• Increasing rate of innovation	1
• Increasing pressure of global market competition	5
• Decreasing new products time-to-market	4
• Responsiveness of competitors to changes	0
• Customer requirements	AVERAGE = 5 (out of 5)
• Demand for individualised products and services	5
• Quicker delivery time and time-to-market	5
• Quality expectation increasing	5
• Sudden changes in order quantity and spec.	5
• Technology	AVERAGE = 3.5 (out of 5)
• Introduction of more efficient, faster, and economic production facilities	0
• Introduction of new soft technologies (Software and methods)	2
• Introduction of new materials	0
• Inclusion of information technology in (new) hard and soft technologies	5
• Social factors	AVERAGE = 2.5 (out of 5)
• Environmental pressures	2
• Workforce/workplace expectations	3
• Legal/political pressures	3
• Cultural problems	3
• Social Contract changes	2

Table 8.5. Agility drivers and their degree of impact for the company

Capabilities	Rank	Company's degree of ability
1. Sensing, perceiving and anticipating changes	1	6.4
2. Product model/configuration flexibility	2	7.5
3. Immediate reaction to change by effecting them into system	3	6.4
4. Appropriate technology (hard and soft), or sufficient technological ability	4	7
5. Strategic vision	5	6.3
6. Co-operation (internal and external)[Joint Venture, Virtual Organisation]	6	5.0
7. Change management	7	6.9
8. Products/services quality	8	6.3
9. Products and services delivery quickness and timeliness	8	7.5
10.Quick new products time-to-market	9	8.5
11.Cost effectiveness	9	5.5
12.Operations efficiency and effectiveness (leanness)	10	6.6
13.People flexibility	11	8
14.Knowledgeable, competent, and empowered people	11	?
15.Fast operations time	12	-
16.Recovery from change	13	-
17.Organisation and organisational issues flexibility	14	-
18.Integration	15	-
19.High rate of new products introduction	15	-
20.Product volume flexibility	16	-

Table 8.6. Prioritised capabilities for achieving agility in the company

3. Agility providers/practices

Based on the "practical tool" devised in the methodology, a list of agility practices are proposed to assist the company to achieve the agility capabilities in four categories (Responsiveness, Competency, Flexibility, and Quickness) proposed in the last section. These practices are listed in Table 8.7. The stated practices were selected from a large number of practices, which were either supported by the literature, or found, to be applied effectively by companies participating in our survey and case studies. However, as it has been mentioned before, the appropriateness of a practice is subject to the specific circumstances of the organisation, the company's strategies and many other factors. Therefore, the recommended practices should be considered as a guide list among which the necessary practices can be found.

On the other hand Table 8.8 represents some of the practices, which have been adopted by the company in the past few years in responding to the change factors.

These actions would have provided some capabilities, which can be extended with further actions by referring to the proposed practices.

Agility Capabilities and Corresponding Practices Recommended for Achieving them
RESPONSIVENESS
1. SENSING, PERCEIVING AND ANTICIPATING CHANGES **PRACTICES :** • Strategic use of information system • Using Internet and other information tools for communication with outside of the company • Information interface with suppliers/customers • Internal information network • Empowerment of people • Information management plan or model
2. IMMEDIATE REACTION TO CHANGES **PRACTICES :** • Computerised manufacturing information system • Internal information network • Concurrent teamworking • Increasing market awareness with group marketing approach • Adoption of Time-Compact-Technology methods • Virtual organisation
FLEXIBILITY
1. PEOPLE FLEXIBILITY **PRACTICES :** • JIT • Continuous education and training of people • Empowerment of people • Developing niche skills
COMPETENCY
1. STRATEGIC VISION **PRACTICES :** • Establishment of high rank teams for dealing with the business • Strategic use of information systems • Continuous improvement as the company's strategy • Merging into/joining more powerful manufacturing group • Strategic planning techniques • Information management plan or model

Table 8.7 Practices recommended for acquiring the capabilities indicated as priority for the company

2. COST EFFECTIVENESS **PRACTICES :** • Quality programmes • DFMA (Design For Manufacturing and Assembly) methods • Outsourcing • Virtual organisation • FMS (Flexible Manufacturing System) • Streamlining the company's processes • Lean Manufacturing techniques • Continuous education and training of people • Adopting new/advanced technology • More system approach • Cost reduction initiatives • Continuous re-engineering of the organisation
3. PRODUCT/SERVICES QUALITY **PRACTICES :** • Information Technology adoption • Cellular manufacturing • Just-In-Time methods • Automation • Quality programmes • TQM (Total Quality Management) • Streamlining the company's processes • Investment in technology
4. COOPERATION(INTERNAL/EXTERNAL) **PRACTICES :** • Information system interface with suppliers/customers • Introduction of fast communication infrastructure (such as Video Conferencing, Internet connection) • Close relation with customers/suppliers and involving in the company's programmes • Virtual organisation • Establishing team working and concurrent methods inside the organisation • Establishing partnership with suppliers/customers/competitors

Table 8.7. Continued

Growth of the niche markets
• Increasing flexibility of manufacturing in both volume and configuration • Providing a wide range of choices for customers in every sections of the market • introduction of unlimited choice of colours and configurations • Increasing the capability and capacity of the company to produce more than the present demand of the market in terms of models and configuration
Increasing pressure on cost
•

Table 8.8. Some actions performed by the company in response to some of the agility drivers

One important capability, which must be considered by the company, is the cost effectiveness capability. Although it only takes the 9th place in the proposed priority list, it has already been considered by the company in the past few years with the implementation of practices such as; Streamlining processes; Lean production techniques; FMS; Continuous training of people and involvement of people in all aspects of the company's activities; Critical management of supply chain. Further efforts in this regard are needed to obtain the required level of ability given the slow nature of achieving such a goal.

8.2.2.2. Implementation of the methodology for agility - Company 2

Case study number two involves a manufacturer of high-technology electronics components and devices. As a subsidiary of a giant electronic group, the company has the main duty of supplying the mother company. The company was originally established for providing the mother company with devices, which are used in high-tech multi-million pounds special radar systems. But extensive changes in the business environment in recent years have resulted in the contraction of this market to only 20% of the company's capacity. Now 80% of the remaining capacity is being directed to serve other markets.

The Assessment Model

Part one : Agility need level

The average score of all factors in tool number one of the assessment model [devised for assessing the turbulence of the company's business environment] is 5.2 (out of 10) According to the assessment model a company in such a position needs a moderate level of agility. This need is not urgent and the company's business environment is not very turbulent.

On the other hand the company's perception of the agility need level, according to the respondent, is 5 (out of 10). This level is almost the same as the average score obtained from the assessment tool.

Factors determining the turbulence of the business environment :

Table 8.9 presents some of the factors pertaining to the company's business environment with a degree of turbulence of 7 or more. These items should receive more attention, especially when the company's strategy is studied and defined.

Factors of the tool	Degree of turbulence
• Trend of market fragmentation and niche market growth for the company's products been in the past five years	7
• Uncertainty of the market needs and demanding individual products	8
• Speed of the trend of change in products models in the marketplace for the company	7
• Market's power in determining the price	9
• Market's power in determining the quality and reliability of products	9
• Predictability of the life cycle of the company's products (10 = Unpredictable)	7
• Intensity of the competition and battle for marketshare in global markets	9
• Strength and responsiveness of direct competitors of the company	8
• Difficulty of gaining and maintaining competitive advantage for the company considering the competitors	7

Table 8.9. Factors with degree of turbulence 7 and more

Again for this case there have been some factors indicated as being not related to the company's business or not applicable to the company's circumstances. Other factors are recognised as not important or turbulent by the company.

Part two : Assessing the current level of the company's agility

46 factors out of the total 66 factors considered in the assessment tool were found relevant and measurable (the corresponding factors in tool number one are more than 5). The results of assessment give the company an average score of 5.6 (out of 10 where 10 = high level). This score can be considered as the level of agility the company currently has. However, as discussed before, this score or level does not imply that the required level of need for agility is already met. As stated in case study one, the mean level corresponding to the current level of agility represents the average of the company's capabilities in different areas related to the turbulence of the business environment, and can only relatively reflect the level at which the company may respond appropriately to changes.

The perception of the company (respondent) for the current level of agility on a 1 to 10 scale was 5, which is almost same as the average score obtained.

Ability factors

Analysing the factors in part two of the tool proposes that in total 31 factors have been scored for 7 and more (out of 10 where 10 = high ability), 7 factors are given level 6 and in 28 factors the company lacks sufficient or considerable strength. Table 8.10 shows some of the factors with level of 7 and above as a sample.

The following summary can be made as the result of the assessment:

1. The company in the current circumstances needs a moderate level of agility. The strategy for the company with regard to agility can be; being concerned about the growing turbulence in the business environment; and getting prepared for taking preliminary steps in becoming agile in order to sustain and maintain the competitive advantage. However, agility is not an urgent agenda for the company.
2. The areas, which are indicated in Table 8.9, must be taken into consideration as potentially threatening factors or opportunities when defining and designing the company's strategy.

The company's current level of agility, according to the company's own perception, is almost the same as the perceived level of need and also the average score from tool number two (i.e., the current level of agility from the assessment).

This does not mean that the company's agility requirements are all met. Those highly turbulent factors and areas in which the company lacks sufficient abilities are items, which can cause problems for the company.

Factor No.	Factors of the tool	Degree of the company's ability
1	• Detecting, analysing, and understanding changes	
1-1	Detecting the changes in	
	• Competitor's activities and position	7
	• Political/social/economic factors	8
1-2	• Quickness and efficiency of the company in analysing the information and data received about the changes in the business environment, and effecting them into its systems	
	• Top level management concern and commitment	
	• Conducting strategic, marketing, technical, financial analysis of the information in the direction of the company's competitive advantage	7
2	• Producing high level of pr- and pro-sales and services and using it as a leverage	7
3	• Exact understanding of the buyer (market) needs	7
12	• Relative strength and responsiveness of the company in comparison with its competitors	
	• Quality	8
	• Response to unpredicted incidents	8
	• Coping tensions and shocks in different aspects of the business	8

Table 8.10. Some of the ability factors in which the company has level of 7 or more

Applying the practical tool

Based on the assessment results, a moderate and not urgent level of agility is required by the company. This level of need for agility should be taken into consideration when applying the practical tool. This means that, for instance, not radical changes and actions will be necessary to apply.

1. Agility Drivers

Table 8.11 lists the agility drivers for the company with detailed sub-factors.

Agility Drivers (areas)	Average degree of turbulence
• Marketplace	AVERAGE = 3.0 (out of 5)
• Growth of the niche market	5
• National and international political changes	1
• Increasing rate of change in product models	5
• Product lifetime shrinkage	1
• Competition	AVERAGE = 3.7 (out of 5)
• Rapidly changing market	5
• Increasing pressure on cost	3
• Increasing rate of innovation	5
• Increasing pressure of global market competition	1
• Decreasing new products time-to-market	5
• Responsiveness of competitors to changes	3
• Customer requirements	AVERAGE = 1.5 (out of 5)
• Demand for individualised products and services	1
• Quicker delivery time and time-to-market	1
• Quality expectation increasing	3
• Sudden changes in order quantity and spec.	1
• Technology	AVERAGE = 2.5 (out of 5)
• Introduction of more efficient, faster, and economic production facilities	1
• Introduction of new soft technologies (Software and methods)	3
• Introduction of new materials	1
• Inclusion of information technology in (new) hard and soft technologies	5
• Social factors	AVERAGE = 1.8 (out of 5)
• Environmental pressures	5
• Workforce/workplace expectations	1
• Legal/political pressures	1
• Cultural problems	1
• Social Contract changes	1

Table 8.11. Agility Drivers and their degree of impact for the company

2. Agility Capabilities

The "Practical tool" is applied to determine the capabilities required by the company to respond to the agility drivers listed in Table 8.11. This resulted in a sorted priority list of capabilities shown in Table 8.12. The average ability of the company to present individual capabilities in response to the drivers is also obtained from the results of assessment tool number two.

Capabilities	Rank	Company's degree of ability
1. Sensing, perceiving and anticipating changes	1	5.6
2. Appropriate technology (hard and soft), or sufficient technological ability	2	7.3
3. Product model/configuration flexibility	3	5.4
4. Strategic vision	3	6.6
5. Change management	4	5.9
6. Immediate reaction to change by effecting them into system	5	6.7
7. Quick new products time-to-market	6	3.5
8. Recovery from change	7	5.8
9. Products/services quality	8	6.5
10.High rate of new products introduction	9	3.5
11.Co-operation (internal and external)[Joint Venture, Virtual Organisation]	9	5.2
12.Knowledgeable, competent, and empowered people	10	-
13.Products and services delivery quickness and timeliness	10	-
14.Fast operations time	11	-
15.People flexibility	12	-
16.Product volume flexibility	13	-
17.Cost effectiveness	14	-
18.Integration	15	-
19.Organisation and organisational issues flexibility	15	-
20.Operations efficiency and effectiveness (leanness)	16	-

Table 8.12 Prioritised capabilities for achieving agility in the company

Based on the capabilities and their priorities suggested by the practical tool as well as the relative strength of the company in presenting individual capabilities (as obtained from the assessment tool), following points are suggested as practical tips and guides for the company to consider in its strategy-making process.

- The company needs to improve its position for the following important capabilities in which the company has ability level of 6.5 and less. The list of items is sorted in ascending order according to the company's available ability.
    1. Quick new products time-to-market
    2. High rate of new products introduction
    3. Co-operation (internal and external)[Joint Venture]
    4. Product model/configuration flexibility
    5. Sensing, perceiving and anticipating changes
    6. Recovery from change

7. Change management
8. Products/services quality

3. The agility providers/practices

A series of practices, which can assist the organisation to achieve the proposed capabilities, are derived and listed in Table 8.13. The recommended practices should be considered only as a guide list among which the necessary practices may be found.

Table 8.14 lists some of the practices, which have been adopted by the company in the past few years in responding to the change factors. These actions would have provided some capabilities, which can be extended with further actions based on the proposed practices.

Agility Capabilities and Corresponding Practices Recommended for Achieving them
RESPONSIVENESS
1. SENSING, PERCEIVING AND ANTICIPATING CHANGES **PRACTICES :** • Strategic use of information system • Using Internet and other information tools for communication with outside of the company • Information interface with suppliers/customers • Internal information network • Empowerment of people • Information management plan or model
2. RECOVERY FROM CHANGE **PRACTICES :** • Continuous re-engineering of the organisation • Concurrent team working • Adoption of advanced technology • Empowering people • Virtual organisation
FLEXIBILITY
1. PRODUCT MODEL/CONFIGURATION FLEXIBILITY **PRACTICES :** • FMS (Flexible Manufacturing System) • Information system/technology utilisation • Information connection with customers/suppliers • Mass Customisation methods • Integrated computer-based product development process • Colour proliferation of products • Basic design with flexibility in specification (design modularity)

Table 8.13. Practices recommended for acquiring the capabilities indicated as priority for the company

COMPETENCY
1. PRODUCT/SERVICES QUALITY **PRACTICES :** • Information Technology adoption • Cellular manufacturing • Just-In-Time methods • Automation • Quality programmes • TQM (Total Quality Management) • Streamlining the company's processes • Investment in technology
2. HIGH RATE OF NEW PRODUCT INTRODUCTION **PRACTICES :** • Mass customisation • Concurrent Engineering • TCT (Time-Compact-Technology) methods • DFMA methods • Virtual organisation • Strategic investment in technology • Structured and flexible manufacturing process • Integrated computer-based product development process • Computerised manufacturing information system • Enlarging the engineering department • Partnership with suppliers
3. CHANGE MANAGEMENT **PRACTICES :** • Employees involvement • Informal, coaching and encouraging management • Streamlining processes • More systematic approach to problem solving • Continuous re-engineering of the company's systems with changes • Strategy review • Integration of inter-organisational systems and modules
4. COOPERATION(INTERNAL/EXTERNAL) **PRACTICES :** • Information system interface with suppliers/customers • Introduction of fast communication infrastructure (such as Video Conferencing, Internet connection) • Close relation with customers/suppliers and involving in the company's programmes • Virtual organisation • Establishing team working and concurrent methods inside the organisation • Establishing partnership with suppliers/customers/competitors

Table 8.13 Continued

QUICKNESS
1. QUICK NEW PRODUCTS TIME-TO-MARKET **PRACTICES :** • DFMA • QFD • CAD/CAM integration in the system • Kanban • Outsourcing (delegation of functions) • JIT • MRP/MRPII • Quality programmes • Set-up time reduction • Tightening communication between design, engineering and manufacturing • Reduction of suppliers • Re-engineering processes • Re-structuring manufacturing process • Reducing time from design point • Joint venture/virtual organisation • Developing an effective communication infrastructure for the company

Table 8.13. Continued

Increasing rate of change in product models
• Improving response time (to customer in manufacturing, etc.), continuous improvement, developing JIT, Cellular Mfg., problem solving techniques
Increasing pressure of global market competition
• Reducing time-to-market
Decreasing new products time-to-market
• Rengineering the processes to reduce time as much as possible
Quality expectations increasing
• Investment in new plants to increase quality after identifying areas of improvement
• Taking advantage of this change as an opportunity and shifting a part of the company's capacity to satisfy demand for new commercial devices
Environmental pressures
• Embracing new environmental standards and coordinating systems to them

Table 8.14. Some actions performed by the company in response to some of the agility drivers

8.3. AN OVERVIEW OF THE RESULTS FROM INTRODUCTION OF THE METHODOLOGY

The introduction of the methodology to the industry was aimed at studying the applicability of the methodology and its associated tools in practice, and observing a sample result of implementing the methodology in an organisation. However, as the case companies are selected from two sectors, a comparison between the obtained

results for the studied companies would provide a further insight into the application of the methodology and also helps to find out the differences in the results when it is applied to two different organisations. As it is already stated in chapter seven the ultimate result of the methodology is identification of some (best) practices with which an organisation would obtain the required capabilities to achieve the strategic objective of becoming agile. A shortened overview of the practices recommended as the result of the implementation of the methodology in the two case companies is presented in Table 8.15 to give a quick comparison of the results. As it is shown in the Table there are similarities and differences in the type of capabilities identified as priority for the studied companies. This is the same with the practices, which address those capabilities according to the methodology and its associated tools. The difference in the results is in conformance with the basic aim of the methodology, which is providing appropriate solution for individual companies.

The same argument goes with other parts of the methodology as they are reported in this chapter. For instance, each company has found a different level of need for agility by applying the assessment tool, and also the level of the companies' current level of agility are different. The results from the application of the assessment tool is quite close to the companies' perception of their need for agility and their current level of agility which could be a promising sign of the applicability of the assessment tool.

For the agility drivers as it is evident from the results (Tables 8.5 and 8.11) the two companies live in different environments and the kind of pressures they face with the most are different in places. For instance the two companies are under the same high pressure of the growth of the niche market, but while the white good company has no problem with the change of the market, the electronic company finds it highly turbulent. As it is inherited in the methodology, different business circumstances could results into different solutions for action.

Finally, although the specified aims of the introduction phase are achieved, it should be said that due the limited access to the case companies' information and also the intuitive nature of some data used in the introduction of the model, it is not possible to provide a more conclusive analysis of the results.

Factors	Case Company No. 1	Case Company No. 2
SOME OF PRACTICES RECOMMENDED FOR THE COMPANY TO OBTAIN THE SPECIFIED AGILITY CAPABILITIES	**RESPONSIVENESS** 1. SENSING, PERCEIVING AND ANTICIPATING CHANGES **PRACTICES :** • Strategic use of information system • Using Internet and other information tools for communication with outside of the company • Information interface with suppliers/customers 2. IMMEDIATE REACTION TO CHANGES **PRACTICES :** • Computerised manufacturing information system • Internal information network • Concurrent teamworking • Increasing market awareness with group marketing approach • Adoption of Time-Compact-Technology methods • Virtual organisation	**RESPONSIVENESS** 1. SENSING, PERCEIVING AND ANTICIPATING CHANGES **PRACTICES :** • Strategic use of information system • Using Internet and other information tools for communication with outside of the company • Information interface with suppliers/customers 2. RECOVERY FROM CHANGE **PRACTICES :** • Continuous re-engineering of the organisation • Concurrent team working • Adoption of advanced technology • Empowering people • Virtual organisation

Table 8.15 The resulting practices recommended for two case companies as the result of the implementation of the methodology.

SUMMARY OF THE CHAPTER

This chapter reported the results of the introduction of the developed methodology for achieving agile manufacturing to manufacturing industry as the last objective of the research, i.e. to introduce the methodology to assist manufacturing organisations to adopt agility as a characteristic.

1. First the agility assessment model is examined in ten companies. The data from this stage together with previous data and information are used to introduce the methodology to two manufacturing companies in the Electrical and Electronics sector and study the results.
2. The methodology then was introduced to two selected manufacturing companies by applying the methodology to those companies using the previous data and information gathered from them in previous phases of the research. The results were reflected to the case companies and their views were asked with regard to the appropriateness and suitability of the solutions proposed by the methodology.

3. The introduction of the methodology included identification of the circumstances in the companies' business environment and determination of the important change items for the company, determination of the required capabilities for the company to respond properly to the identified changes, and also determination of the practices, which could support the achievement of the identified capabilities.
4. The proposed practices are categorically compared with the kind of practices, which have been approached by the companies recently in recognition of changes in their business environment. There are considerable similarity between the proposed practices by the research work and those already been considered by the company in a way.
5. The results from the cases studies comply satisfactorily with the specified aims i.e., developing a methodology for assisting manufacturing organisations to achieve agility, and the expected outcomes of the methodology. Also the representative managers of the two companies who studied and responded to the introduction of the methodology evaluated the methodology and its results as a reasonable means for the possible movement of their companies towards agility.
6. A simple comparison between the results from the introduction of the methodology to two case companies is made at the end, which reveals the differences between two companies from two different sectors. The analysis of the results, however, is provided only to a certain level due to the limitation of the research and available data.

CHAPTER NINE

DISCUSSION

9.1 INTRODUCTION

In this chapter a brief discussion will be made on the whole process and achievements of the research. The discussion is focused on how the research problems were identified, the way they were transformed into research questions and objectives, how the objectives were approached and achieved considering the inherited limitations of the research, and finally the contribution of the research to the existing literature on agile manufacturing.

9.2 RESEARCH OBJECTIVES, HYPOTHESES, AND APPROACH

The emergence of "agile manufacturing" as a new concept and the attention it received in the manufacturing management/engineering literature was a motive to initiate a research project for exploring the subject and making contribution to the existing body of the knowledge in this area. Although the idea was originated in early 1990s, there were still piles of unanswered questions about the subject such as; whether it is a different issue from the prevailing systems of manufacturing; how it could be defined or conceptualised; how the concept is understood or perceived in terms of the real world business; and how, if possible, it can be approached by individual organisations.

The literature was found to be brief, very general, and insufficient in answering the types of questions mentioned above. However, the expanding amount of concerns over the subject world wide, though sometimes in different phrases or words, and the philosophical reasoning behind the concept made it a worthwhile issue for consideration as a lively research topic.

Four specific objectives were set at the beginning of the research including conceptualising the subject, identifying the elements of the concept and relationships between them, developing a methodology for achieving agility, and finally introducing the methodology into industry.

The research was pursued based on some hypotheses, which were made about the subject after a preliminary investigation. For instance, it was hypothesised that agility could be achieved through strategic utilisation of business methods, manufacturing and management processes, practices and tools. To develop a practical approach required for this purpose some areas and questions were put into investigation including the trend of change in the business environment, the perceptions of manufacturing organisations about the concept, and some relevant and lively issues in the manufacturing business.

The research methodology was basically designed to encompass a review of the available literature in the particular area of agile manufacturing and its related subjects, and industrial surveys complemented by case studies. Four phases of studies were conducted including a pilot survey and case study, a questionnaire survey of UK manufacturing companies mostly form three sectors (Aerospace, Electrical and Electronics, and Vehicle components), and a detailed cases study (structured interview).

A conceptual model for agile manufacturing was first developed based on the literature review and a preliminary empirical study involving thirteen selected manufacturing organisations. The resulting model identified the areas requiring further research and extension in order to develop a practical methodology for assisting manufacturing organisations to achieve agility. An industrial questionnaire survey of another 900 manufacturing companies complemented by twelve case studies provided the required data and information to develop and propose a preliminary methodology for achieving agility in manufacturing organisations. Finally, the methodology was introduced to industry by applying it in two case companies. The whole idea as explained is depicted graphically in Figure 9.1.

9.3 LIMITATIONS OF THE RESEARCH

The domain of the research area, which had to be defined so in order to answer the vast range of questions of the research, was so wide that obviously no single effort, especially in the time and budget frame of this research, could handle it in full details. In general the limitations inherited in the survey population and the chosen research

methodology, as have been explained before in related chapters, imposed restrictions in the extent of the research horizon and of course the details. In particular, the

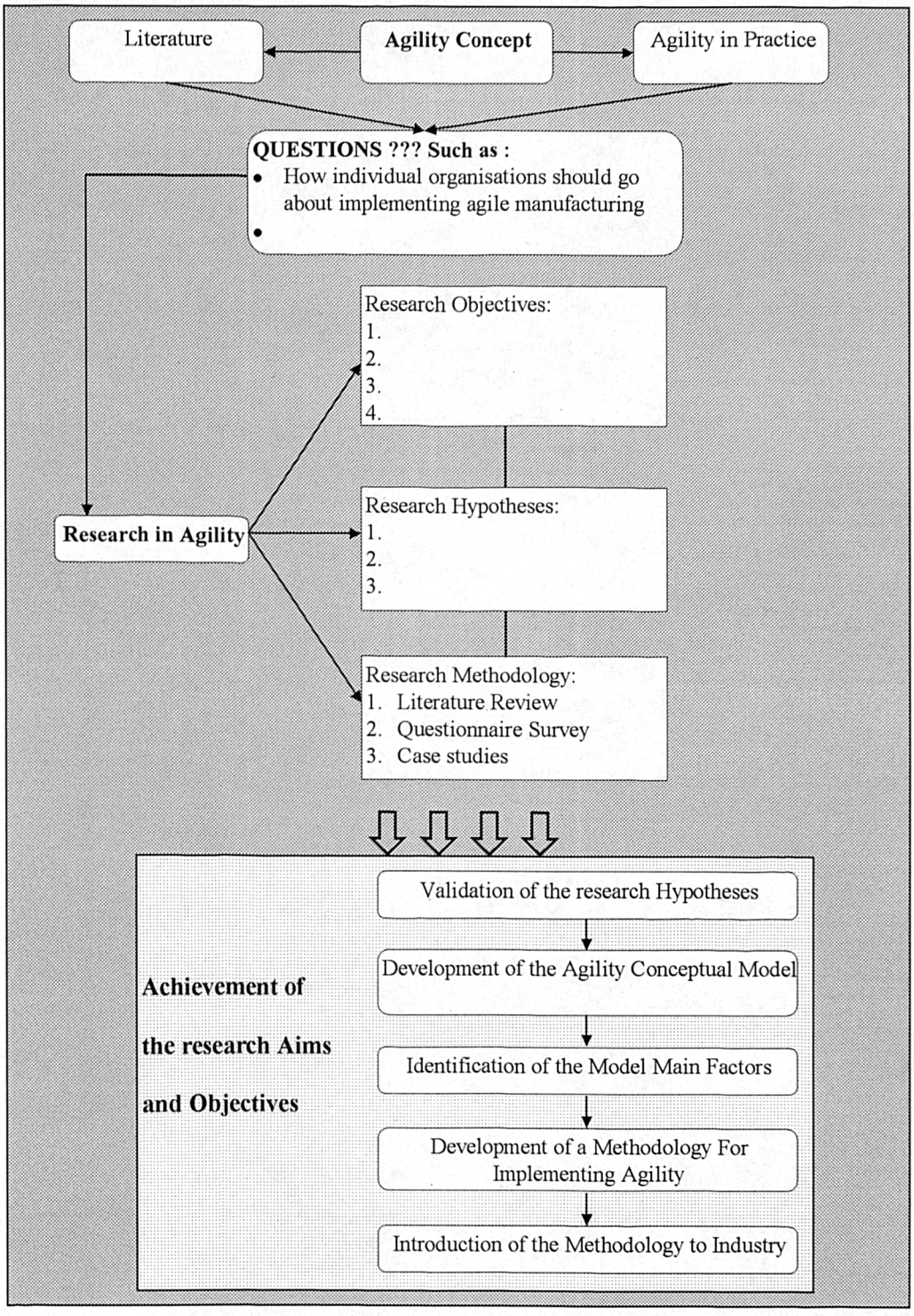

Figure 9.1- The research approach, objectives and achievements; Formation and completion of the research.

newness of the subject to manufacturing organisations which usually cause them to avoid getting involved in these kind of issues resulted in a low response rate to the questionnaire survey. Although the number of returned responses was scientifically convincing and provided the information required, the response percentage was lower than the initial expected rate. Also the limited amount of literature and prior work in this area to use in designing the research's empirical phases caused some redundancy of information.

However, the findings of the research including the conceptual model of agility and the main structure of the proposed methodology carry sufficient support from both literature and the conducted empirical studies.

9.4 THE ACHIEVEMENT OF THE RESEARCH

The research had four objectives and three hypotheses (chapter one, page 6). Despite the restrictions the research experienced, all the objectives were satisfactorily achieved and the hypotheses were convincingly, though partially validated. The research provided a mere, clear and realistic understanding of the subject, which was mainly reliant on the real experiences of the manufacturing industry and their perceptions of the concept. Details of the achievements of the research are provided below:

- The research hypotheses were examined and partially validated. Almost the entire surveyed sample approved the first hypothesis, which suggested that agility is an ability to survive and prosper in the new order of the global business environment. The empirical studies granted the required evidences to assume the second hypothesis about the difference of agility in concept and practice for different organisations as a valid perception. Also the studies showed that the practical way to approach and achieve agility is through strategic utilisation of agility practices, which was in conformance with the third hypothesis of the research.
- The diverse and general views on the issue were aggregated, analysed, completed, and presented in a comprehensive but simple conceptual model, which provides a practical view of the concept of agility in manufacturing organisations. The conceptual model contains the main elements of the modern manufacturing management philosophy at a strategic level with a direction towards practice and implementation of agility in manufacturing organisations. Based on a definition for

agility concluded from the early stages of the research, the proposed model attempts to link the core concept of agile manufacturing with the real environment of business in manufacturing organisations. This part satisfied the first objective of the research, i.e. to provide a comprehensive conceptual idea of the subject.

- The conceptual model was put into investigation to identify the main factors and elements of the concept. This was preceded through industrial survey and case studies, results of which supported the proposed structure and understandings about the concept of agility in manufacturing organisations and provided the required details. Objective number two of the research was achieved in this phase, which was to identify main factors constituting the concept and relationship between these factors.
- A methodology for assisting manufacturing organisations to achieve agility was developed based on the conceptual model of agility and the acquired data from empirical phases. The developed methodology, which meets the essential generic conditions assumed for the methodologies in manufacturing and technology management, is devised with some practical tools to deliver the methodology's goals into practice. The third objective of the research, i.e. to develop a methodology for manufacturing organisations to approach the concept in practice, was materialised in this part.
- An assessment model for agility was developed as part of the methodology. The assessment tool was introduced and examined in ten manufacturing organisations for validation.
- The methodology was introduced to two manufacturing companies and its practicality was studied and evaluated satisfactory. This attempt was the final objective of the research to be achieved.

9.5 RESEARCH MAIN CONTRIBUTION

Among the long list of unanswered questions about the subject of agility in manufacturing organisations identified by the research at first, the most important one was a cohesive understanding as to how individual organisations should go about implementing agile manufacturing. Contributing to the existing literature and body of knowledge in this area through providing some answers to this need was aimed and

achieved by the research. This was pursued by setting some objectives, which has been explained before. The research resulted in the proposal of a methodology for assisting manufacturing organisation to achieve agility. The methodology, which is developed considering the basic principles of manufacturing system methodologies, was satisfactorily introduced to two manufacturing companies. The major achievements of the research can be highlighted as follows:

1. A definition is concluded and presented for agility in manufacturing organisations. The definition is a fundamental but comprehensive understanding of the concept to include major aspects of the real world of business.
2. A conceptual model of agility is developed to present the concept in terms of real world business and to comply with the basic definition of agility. The conceptual model takes agility as the response to the changes in the business environment and devises the capabilities and abilities in order to respond to the changes. The model relates the changes in the business environment directly to strategy, and hence strategic capabilities of an organisation as the areas where the responses to the changes should be raised.

    2.1. Major drivers of agility or changes/pressures in the business environment of manufacturing organisations are identified and classified in five categories.

    2.2. Strategic capabilities of agility are identified and classified in four distinct areas to cover all aspects of the concept and manufacturing strategies.

    2.3. Agility practices are identified as the source to provide the required capabilities for an organisation. Integration and information system/technology are also identified as major supports for the agility providers (practices).

3. A methodology is developed as a guide tool for individual organisations, which want to go about implementing agility. This methodology is the first in this area to include all the required steps for individual organisations to approach agility. The methodology, which follows the basic rules and

principles of the methodologies in the area of manufacturing, consists of three practical tools, which are new to the area of the research. These are:

3.1. The assessment tool for agility, which is designed to address the level of need of an organisation for agility, and to estimate the current level of agility of the organisation.

3.2. Strategic evaluation tool for agility, or tool for the analysis of agility position of an organisation. This tool provides some general guidelines based on the results from assessment phase to draw the strategy of the organisation with regard to agility.

3.3. A network based tool to identify the required capabilities for responding to the identified changes in the business environment, and also to identify the practices, which could support the achievement of the determined capabilities. The relationships between three parts of the network (changes, agility capabilities, and agility practices) are determined in a preliminary level. So, the network will be applicable to determine the practices needed to be adopted by an organisation based on study of the changes in its business environment.

Figure 9.2 demonstrates the research main contribution.

9.6 LIMITATIONS OF THE RESEARCH ACHIEVEMENTS

The limitations faced by the research, as explained in section 9.3, imposed restrictions in the extent of the research achievements. Some specific limitations are described as follows, which could be, pursued as further issues for research.

- The developed model and methodology in this research are partially based on the results from studying and investigating a limited number of manufacturing companies (73 companies). Although the responses were statistically sufficient to obtain information from them, the newness of the subject, the extent of the issues involved, and the importance of the agenda necessitate the involvement of a larger sample of manufacturing companies in order to obtain more concrete data and

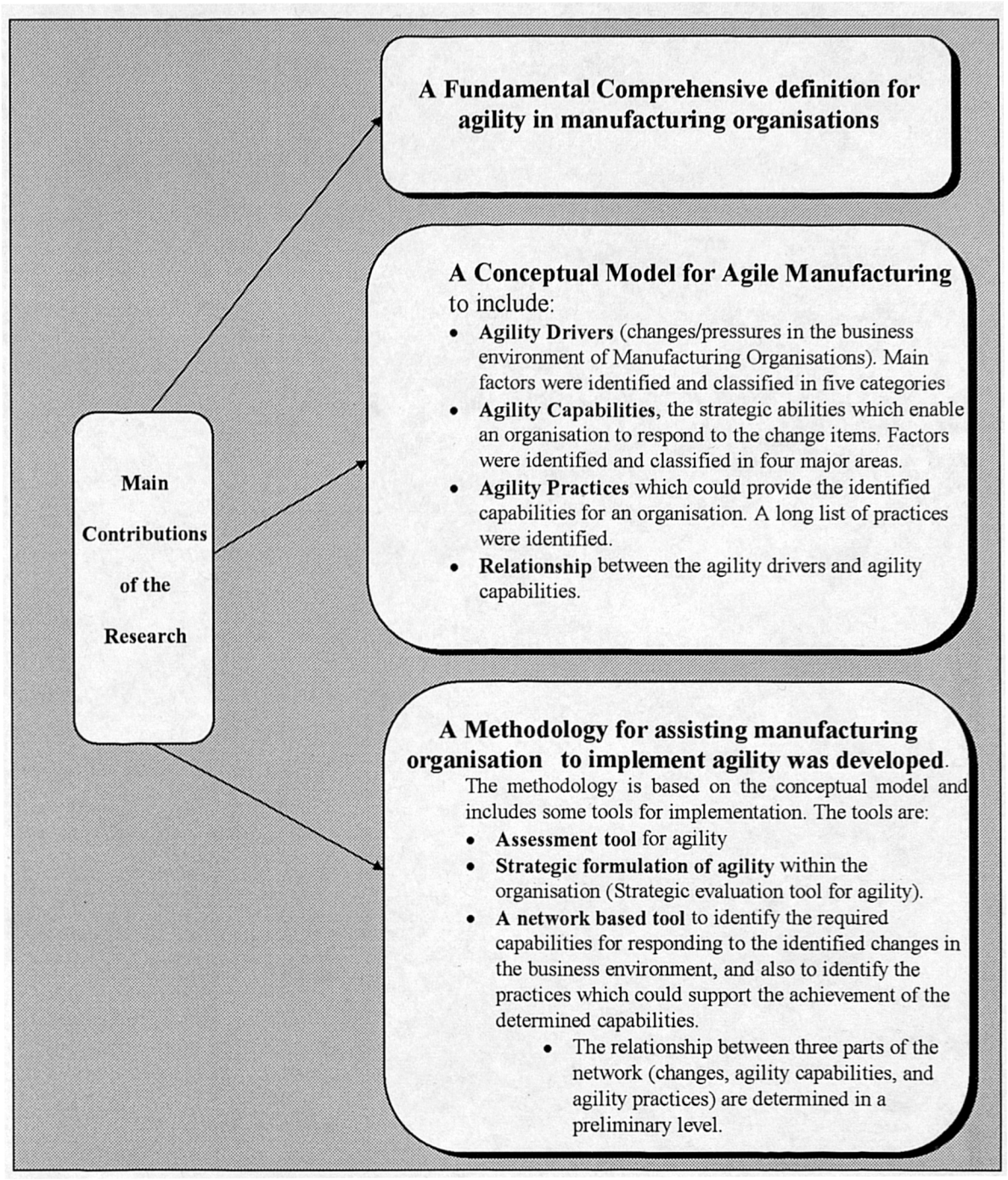

Figure 9.2 Main Contribution of the Research

information. On the other hand the research has mainly focused on three industrial sectors, which could limit the generality of the results.

- the assessment tool is derived and designed based on the conceptual model, the limited data available from the empirical studies, and with reference to the literature available in this area. The tool for agility assessment has therefore been designed as a preliminary proposal for assessing a company with regard to agility.

However, the importance of the assessment phase in the proposed methodology necessitates further refinement and completion, and

- the network model requires further investigation to be extended to all organisations. The established relationship between agility drivers and agility capabilities are based on the experiences of a few companies in three sectors, so it needs to be completed by studying other sectors and with more data. Also the relationship between agility capabilities and agility practices are not determined in a numeric way, which is subject to further study.

These issues will be taken into consideration when defining further research in chapter 10.

SUMMARY OF THE CHAPTER

This chapter was dedicated to provide a compact discussion of the research and its achievements. The objectives, approach, limitations faced, achievement of the aimed objectives, Hypotheses and validation of the hypotheses, and finally contribution of the research to the body of knowledge in this area are briefly discussed. The next chapter will provide some conclusions out of the research and put forward the grounds for further research in this area.

CHAPTER TEN

CONCLUSIONS AND FURTHER WORK

10.1 INTRODUCTION

In this chapter the overall conclusion of the thesis will be presented. A summary of the research main findings together with conclusions drawn will be provided. Finally issues for further research into the subject are discussed to conclude the chapter.

10.2 RESEARCH MAIN FINDINGS AND CONCLUSIONS

During the research various findings were attained which in aggregate composed the major findings of the research as described in chapter nine. To provide the reader with a more organised view of the research findings they are broken down into items, which are briefly described as follows. The itemised findings include the basic understandings from the literature survey which are investigated during the empirical studies to verify the validity of the research hypotheses, the elements considered in developing the conceptual model and its validation, and various steps taken in developing and validating the methodology. Some statements as conclusions follow each item.

- Evolution of manufacturing systems in the past century was followed to witness a systematic change in the business circumstances which ever since has tended to become more complicated, turbulent and uncertain. In particular essential changes in the business priorities have been occurring.

Conclusion: A new era in the business is emerging which has change as one of its major characteristics. The new circumstances exceed the current and conventional business systems and relates to all businesses.

- Every company views the business according to its own circumstances and hence has its very own perception of various concepts in manufacturing management including agile manufacturing. Most of companies find their organisations in a great need for agility, which is associated with the way companies, understand the agility concept. However, the various perceptions of manufacturing organisations are formed around the accepted core items of the concept which are change,

responding to change, and taking advantage of change. On the other hand, in concluding the understandings and perception from the literature and the conducted studies agility is defined to be the ability of an organisation to

- Respond to changes (anticipated or unexpected) in proper ways and due time, and
- Exploit changes and take advantage of changes as opportunities.

Conclusion: Agility could be defined in different ways to suite the specific situation of an organisation. Diversity of definitions would not cause problems in approaching the idea in an organisation, if changes and changing circumstances are taken as the major concern to be responded appropriately. However, further contemplation is necessary to refine the proposed definition in order to find the most accurate and possibly a universal definition of agility. This will be possible by extended study of manufacturing organisations in various disciplines, various sizes, and perhaps various locations of economical geography.

- The decreasing trend of new product development (NPD) time which is less than ever in the past, the importance of close relationship with suppliers and customers, and the increasing level of IS/IT utilisation to speed up communication inside the organisation and with external nodes are receiving much concerns as the important time compacting factors.

Conclusion: Responsiveness in both reactive and proactive ways is a new differentiating ability and a business priority, which will take the position of time in the former set of business priorities. The concept of responsiveness is taken differently from agility in this research. Whether responsiveness is the same concept as agility (which is perceived so by some workers) can be examined later.

- The business environment for almost all manufacturing organisations has changed in a way and tends to become more uncertain and turbulent. Marketplace, competition, customer requirements, technology, and social factors are the main areas, which cause chaos and uncertainty for business. Under each area some items are identified which provide a broad set of change items. The provided set could cover most of the possible changes in the business environment that may be faced

by manufacturing organisations. These change factors are recognised as pressures, which drive an organisation to become agile.

Conclusion: Change in the business environment is becoming a decisive element of success or failure of businesses. Responding to changes in appropriate ways, therefore, should be considered in the strategy of organisations, regardless of whether the agility concept is considered or not.

- Strategic intention is a main prerequisite for becoming agile. Various strategies and strategic positions were identified during the research, which are used in the establishment of the conceptual model of agility. The strategies in order to become meaningful and sensible for manufacturing organisations were considered and redefined as strategic capabilities, which can provide the ability of responding to change, being change proficient, or in other words having the required characteristics of an agile organisation.

Conclusion: Identification of change factors and the capabilities required for responding to these factors could be considered as strategic issues which should be dealt with in defining an organisation's strategy.

- Drivers of agility, strategy of becoming agile, and the strategic capabilities (agility capabilities) together with agility providers, which are the supporting practices that provide the agility capabilities, formed the conceptual model of agility. The conceptual model was studied during the research empirical study phases, which received support and approval for being meaningful and relevant to manufacturing organisations. The existence of logical relationships between various parts of the conceptual model was examined which provided a reasonably sufficient support for the validation of the model and also useful information.

Conclusion: The conceptual model of agility proposed by this research provides the opportunity to match and unify diverse perceptions about agility in a unique but general way. Strategic approach of the model with the consideration of practical aspects makes grounds for the academics and practitioners to share a basis for further works and results.

- No significant difference was found between the three main industrial sectors in the survey with regard to different aspects of the research subject.

Conclusion.: Agility is a concept for all manufacturing organisation over the time which basically tends to depend on the specific circumstances of the organisation's business structure and business environment.

- A range of practices was identified during the research, which could be an initial basis for further study to investigate application of these practices in providing agility.

Conclusion: Agility is very reliant on appropriate (best) practices, which could provide the required capabilities in an organisation. This side of the research could be an inspiration for practitioners to think on the importance and significance of various available practices on their way to become agile.

- The conceptual model was transformed to a methodology, the need and structure of which received support from both literature and industrial survey. The backbone of the proposed methodology is change and responding to change as the main issues of the agility concept. However the methodology presents a natural way of viewing the business. The methodology starts, therefore, from agility drivers as input which must be used in assessing the need level of an organisation for agility and its current level of agility. Defining strategy of the organisation for agility, identification of agility capabilities and agility providers, implementation of practices, and finally performance measurement are next steps of the methodology.

Conclusion: Application of methodologies in approaching major business concepts provides the opportunity for delivering complicated concepts into practical ways. For instance, the methodology developed in this research has carried such a purpose and flattened the way for similar approaches.

- Three supporting tools are designed to assist the implementation of the methodology, which are the assessment tool, the strategy determination tool, and the practical tool for determining agility capabilities and agility practices. The third tool is presented in the form of a network model, which works based on a logical relationship between three main elements; agility drivers, agility capabilities, and agility practices.

The existence of the relationships between these elements, which were already confirmed in the preliminary empirical study, and the questionnaire survey, was reconfirmed in the case study phase. A preliminary relationship was established between agility drivers and agility capabilities to be used in determining the capabilities required by industrial organisations based on their specific business circumstances.

Conclusion: Assessing the situation to picture the real position of an organisation and then plan for any improvements is an essential step in any practical approach. Assessment tools not only provide such an opportunity but also produce reliable data and information for further steps.

Conclusion: Practical approaches could be best used when the involved factors are somehow measured which preferably should be on a mathematical basis. Establishing relationships on such a basis makes a methodology more practical.

The following general conclusions could also be made with reference to the whole findings of the research:

Conclusion: The main difference between the agility concept and other modern business philosophies and concepts such as lean manufacturing is in considering the business environment as totally dynamic, and putting high emphasis on being vigilant and responsive to the changes.

Conclusion: For achieving agility, an organisation may not necessarily need to make entire changes in its systems and structure, or to attempt unbearable investment. The basic issue is getting a proper and realistic understanding of the business environment the organisation lives in and determining the areas which need to be improved in order to gain the required abilities considering the specific circumstances the company faces with. However, modern technologies and advanced managerial methods would be decisive in achieving the characteristics of agility in the modern world, which should be identified and adopted carefully.

Conclusion: Agility could be achieved through integration and adoption of manufacturing/management best practices. The identification of appropriate practices should be carried out based on the core concept of responding and taking advantage of change in the business environment.

10.3 ISSUES FOR FURTHER RESEARCH

Limitation of the research in terms of achievements as explained in section 6 of chapter nine, and the extent of the potential research area have produced many opportunities for further research. Many areas have been identified for continuation of this research programme. The research issues are mostly related to the open ended sides of the research or to the incomplete aspects of the developed methodology and its associated tools.

1. Study of the agility conceptual model and methodology in a larger sample.

The achieved findings by this research could be easily extended using the same research methodology in a larger scale to cover more manufacturing organisations in all main industrial sectors and also to include small to medium enterprises (SMEs). This attempt will provide a more comprehensive empirical basis for the findings and help to make the methodology generic for every company.

2. Studying the agility concept in service sector of the business.

Agility is an issue, which is not limited to only manufacturing organisations. Every business organisation, which is involved in competition for success, can benefit from this concept and build up its structure to be responsive to changes in the business environment.

3. Assessment model for agility

The proposed model for assessing agility in this research was a preliminary one, which could be refined to establish a far extended model with appropriate tools for conducting the assessment process.

4. Strategies for agility

The strategic intent was identified as one of the main steps in becoming agile. A preliminary analysis model for determining the strategies of an organisation with regard to agility is proposed in this research. Further investigation is needed to extend the model and provide comprehensive tools for applying the model.

5. Performance measurement for agile manufacturing

It is suggested that performance measurement system (PMS) in an agile environment is different from the conventional systems used for appraisal of an organisation's performance. This research has come to close conclusions to this idea. Considering the essential differences between basic principles of business in an agile environment and the prevailing systems, studying the new structure and elements of an appropriate PMS for agile manufacturing environments will be an open issue for investigation.

6. Network model of agility

The suggested network model as a tool for determining the agility capabilities and agility practices has been presented in a preliminary level, which needs further investigations to become a generic tool for use in every organisation. The following aspects could be considered in the extension and expansion of the network model;

- the relationships considered and proven to exist between the three main factors of the model, should be identified using a wider study to include all main industrial sectors and various classifications of manufacturing organisations. However, it remains a question to answer whether different sectors and different groups of companies should use different sets of relationships between the model's elements.
- The proposed network model in this chapter could be transformed to a neural network model. This will enable the model to take advantage of the strong capabilities of neural network models to define and calculate the relationships.
- The relationship between the model's elements does not seem to be appropriate if they are considered as deterministic measures. Instead it appears that a probabilistic or fuzzy relationship is more proper to be considered in defining the relationships. The research could study this issue and develop the appropriate form of the relationship.
- Considering the large amount of data involved in applying the model, and the suggested fuzzy system approach it will be necessary to develop an information system to handle the computations. Also this information system could include other parts of the methodology such as the assessment model and the strategy determination model.

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APPENDIX A - COPY OF THE POSTAL QUESTIONNAIRE USED IN THE PRELIMINARY SURVEY PHASE

Responsiveness in Manufacturing Organizations Questionnaire

With thanks for spending time in completing this questionnaire, please tick or circle the appropriate response or write in the provided spaces. Whenever you feel it is necessary tick more than one circle or provide any comments.

SECTION 1- ***Company profile and product information.***

1-1- name of respondent ----------Job Title----------Name of company----------

Address of company ----------

Postcode ---------- Tel. No.---------- Fax No. ---------- Email---------

1-2- To what industry sector does your company belong ?

1) Food /Drink 3) Chemical 5) Medical equipment 7) Car 9) Other(please specify)

2) Electric and Electronic 4) Pharmaceutical 6) Vehicle components 8) Aerospace ----------

1-3- Is company : 1- UK owned 2-Non UK owned 3- Subsidiary 4- Non subsidiary

1-4- On site employees

1) 1-50 3) 201-400 5) 601-1000 7) 1501-2500

2) 51-200 5) 401- 600 6) 1001-1500 8) More than 2500

1-5- Mean level of on site annual turnover in the last three years :

1) less than £3m 3) £10m - £50m 5) £100m - £500m 7) More than £1000m

2) £3m - £10m 4) £50 - £100m 6) £500 m - £1000m

1-6- What percent of annual turnover is spent on purchasing production material ?

1) Less than 10% 3) 31-50 % 5) More than 60 %

2) 10 -30 % 4) 51 - 60 %

1-7- Do you produce mainly :

1) Raw material 2) Intermediate products (Components need further assembly)

3) Finished marketable products

1-8- How many new products has your company introduced to market during the five past years ?

1) Less than 5 2) 5 - 10 3) More than 10

1-9- What percent of these products have been successful ?

1) Less than 30 % 2) 30 - 50 % 3) 50 - 70 % 4) More than 70 %

1- 10- Who are your main customers ?

1) End user consumers ------ % 2) Distributors ---------- % 3) Other companies ---------- %

SECTION 2 - *Company's Environment, Strategy, Manufacturing Features and Characteristics*

2-1- Which of the followings, best describe the company's production type :

1) Jobbing
2) Batch production
3) Mass production
4) Process
5) Other (Please specify) ----------

2-2- How do you rank following factors as priorities in success of your products ? (Please rank from 1 to 5. 1= The most important)

1) Cost ( ) 2) Profit ( ) 3) Quality ( ) 4) Time ( ) 5) Sales ( )

2-3- Is changing and being responsive in different aspects important to your company? To what extent? (Please circle the appropriate response)

1 2 3 4 5 6 7 8 9 10

1= Highly important 10= Not important

2-4- Which of the following items are generally or specifically considered in you company's strategy set, and with what degree of importance? (Please rank from 1 to 6. 1= The most important)

1) Proactive creation of new customers opportunities ( )
2) Rapid reaction to unanticipated opportunities ( )
3) Enhancing capabilities in strategic planning ( )
4) Selling and supplying solutions instead of products ( )
5) Being responsive and flexible to compact the time and enrich the customers ( )
6) Continuous improvement and being flexible for change. ( )

2-5- How do you figure the degree of your company responsiveness according to the definition given in the cover letter?

1 2 3 4 5 6 7 8 9 10

1= Highly responsive 10= not responsive

2-6- Some external and probably some internal factors cause the necessity of being responsive. In below please specify to what extent have each of the suggested drivers influenced your company business in recent years.

PLEASE CIRCLE THE APPROPRIATE RESPONSE.

1= HIGHLY INFLUENT (VITAL) 10= NOT IMPORTANT

A : External Drivers

1- Turbulence of the environment (Marketplace)	1 2 3 4 5 6 7 8 9 10
2- Various changes in competition bases and criteria	1 2 3 4 5 6 7 8 9 10
3- Fast changes and improvements in technology	1 2 3 4 5 6 7 8 9 10
4- Ever-changing customers' requirements	1 2 3 4 5 6 7 8 9 10
5- Others (please specify) ----------	1 2 3 4 5 6 7 8 9 10
----------	1 2 3 4 5 6 7 8 9 10
----------	1 2 3 4 5 6 7 8 9 10

B : Internal Drivers

Please specify any internal factors that drive the company to be responsive : ----------	1 2 3 4 5 6 7 8 9 10
----------	1 2 3 4 5 6 7 8 9 10
----------	1 2 3 4 5 6 7 8 9 10

2-7- To establish an environment supportive of responsiveness, some providers are necessary. In following please specify to what extent are each of suggested areas important to your company as an enabler of responsiveness.

Some explanations are given under each area to clarify it.

PLEASE CIRCLE THE APPROPRIATE RESPONSE

1= HIGHLY IMPORTANT 10= NOT IMPORTANT

1- Technology ; - Adopting and investing appropriate new technologies. - Strategic relation with science and technology partners. - Using multipurpose and adjustable technologies.	1 2 3 4 5 6 7 8 9 10
2- People ; - Lead, encourage and inspire people. - Taking advantage of knowledgeable, skilled, entrepreneurial, and empowered workforce as the ultimate differentiators of success. - Teamworking adopted people.	1 2 3 4 5 6 7 8 9 10
3- Organisation ; - Mission, goals, and objectives be aligned and integrated throughout all the organisation. - Authority and responsibility are enhanced into teams and people. - Flexible organisation in collaborating with suppliers and customers. - Organising around process and people.	1 2 3 4 5 6 7 8 9 10
4- Innovation and change ; - Innovation in all company levels and every activities is strongly encouraged and rewarded - Change and response to new opportunities and threats is an strategic view of the company - R&D concurrent with marketing, design, manufacturing and changes in customer requirements.	1 2 3 4 5 6 7 8 9 10
Others (Please specify) ----------	1 2 3 4 5 6 7 8 9 10
----------	1 2 3 4 5 6 7 8 9 10

2-8- For the company to achieve responsiveness and hence gain the competitive advantage it important to determine the

focus of responsiveness. In following categories, where would you put the emphasis?.

(Please rank in order from 1 to 6. 1= The most important)

1- Total product development process [including items 1 to 6] ( )

2- Customer links ( )

3- Design ( )

4- Manufacturing ( )

5- Suppliers links ( )

6- Others (please specify)

---------- ( )

---------- ( )

2-9- How do you figure the impact of integration in achieving responsiveness?

1 2 3 4 5 6 7 8 9 10

1= Highly important 10= not important

2-10- Does your company use any methodologies for integration? YES ❑ NO ❑

If yes please specify them :

SECTION 3 - *Information System*.

This section is aimed at finding the role of information and its different aspects in responsiveness.

3-1- Is Information valued and well used in your company? To what extent?

1 2 3 4 5 6 7 8 9 10

1= Highly valued and used 5= Not recognised as necessary 10= neither important nor used

3-2- Does your company have any information management plan or model? YES [ ] NO [ ]

*** IF THE ANSWER IS NO, PLEASE GO TO QUESTION NO. 3-4**

3-3- Does your company's information management plan identify the strategic use of Information system to improve its competitive advantage in the marketplace? To what extent?

1 2 3 4 5 6 7 8 9 10

1=Entirely 10= Not at all

3-4- What kind of information management systems are being used in your company?

1- Totally Integrated Information System ❑

2- Management Information System (Executive Information System, Business Information System, Accounting Information Systems, etc.) ❑

3- Manufacturing Information System ❑

4- Transaction Information System ❑

5- Decision support System ❑

6- Quality Information System ❑

7- Others (please specify) ---------- ❑

3-6- What kind of Product Data Transfer Standards and/or software is being used in your company?

STEP ❑ PDES ❑ CALS ❑ CITIS ❑ Others(please specify)----------

3-7- To what extent following statements are true about your company Information System?

PLEASE CIRCLE THE APPROPRIATE RESPONSE **1= ENTIRELY**

10= NOT AT ALL

1- You people, customers, suppliers, business partners have access to Corporate Information System.	**1 2 3 4 5 6 7 8 9 10**
2- Every employee in the organisation have access to all information required to do their job most effectively and efficiently.	**1 2 3 4 5 6 7 8 9 10**
3- Company use necessary tools for navigating, manipulating, and managing information resources.	**1 2 3 4 5 6 7 8 9 10**
4- Sufficient information technology is used all over the company.	**1 2 3 4 5 6 7 8 9 10**
5- Company use facilities and tools to access external information.	**1 2 3 4 5 6 7 8 9 10**
6- Company use facilities and tools in place to capture all customer information and requirements.	**1 2 3 4 5 6 7 8 9 10**
7- The Information System provide the capability and incentive for different users to update their information that relates to them including customers and suppliers.	**1 2 3 4 5 6 7 8 9 10**

SECTION 4- The concept and the general model examined in this questionnaire under "**responsiveness**", have been employed in the generation of a new manufacturing era that is called "*AGILE MANUFACTURING*".

How familiar are you with this concept ?

1 2 3 4 5 6 7 8 9 10

1=Completely Familiar 10= Not heard of

SECTION 5- *General ;*

5-1- Please feel free to add any comments or details here. (PLEASE CONTINUE ON THE REVERSE SIDE OF THIS PAGE IF NECESSARY)

5-2- The next stage of the research will involve structured interviews and/or case study. Would your company be willing to take part in this second phase?

Interview YES ❑ NO ❑

Case Study YES ❑ NO ❑

Thank you again for your assistance

APPENDIX B - CASE STUDIES REPORT FROM THE PRELIMINARY EMPIRICAL STUDY

Case study company number 2

1- Profile :

1-1- A non-UK owned ATM manufacturing (Electro-mechanical) company, with around 1500 employees and annual turnover of around £250 million.

1-2- Produces ATM machines for banks and retailers in form of low-volume-continuous production, and in another expression make-to-order (diverse combinations of machines could be ordered with no limits)

1-3- Exports to more than 100 countries, with average 23% of world market-share. Number one in sales and installing base in the world.

2- Characteristics :

2-1- Priorities :

Quality - Profit - Flexibility - Cost - Time

2-2- Responsiveness level 7 out of 10

2-3- Core competencies :

- Customising products
- Capacity flexibility
- Producing 70% of part numbers in house
- Skilled and motivated people
- Comprehensive information system
- Quick response to customers requirements
- Delivery integrity

2-4- Problems

- Lack of culture of free flow of ideas over the company

3- Company and change

3-1- Working in a relatively stable market, importance of change is 6 out of 10

3-2- Change areas as Drivers of agility ;

- Customer requirements change
- Markets change (Established banking and breakthrough in retail

market)

- Social factors
- Technology
- Strategy of continuous improvement (as internal driver)

3-3- Complexity of drivers : Relatively high

3-4- Strategy of the company in responding to change ;

- Being responsive to customers requirements and market needs.
- Flexibility in capacity
- Fast reaction time
- Streamlining products
- Fast track of products
- Continuous improvement
- Productive, empowered and knowledgeable people.

4- Areas in the company where response to changes are originated from (in the order of importance)

- Almost flexible semi-vertically-integrated organisation
- Structured processes
- Flexible, knowledgeable people
- Organisation innovation (R&D) and change (20% of head account)
- Technology
- Close and deep relation with suppliers and customers
- Integration to some certain level, and a reasonable level of information integration and use

5- Practices;

- Establishing of a mass-customisation manufacturing environment, through:
  - defining unlimited choices from a bill of material in ordering ATM machines
  - producing 70% of part numbers in house
  - very close relationship with suppliers and establishing a good supply chain.

- integration of PCB manufacturing and parts manufacturing sites.

- Establishing a factory in Canada in response to NAFTA the trade association of the North American countries
- Responding to inter-organisational policies and recovering from being vanished using responsiveness of the company.
- Taking and maintaining lead in market by continual innovation, and introduction of new products and more flexibility in choices.
- Changing manufacturing system to some sort of cellular manufacturing by:
    - training people for acting fast, productive, and do the right job first,
    - encouraging people and giving a sense of ownership and responsibility,
    - enhancing flexibility in production capacity (in one case the company produced portions of products of a contractive 60 weeks job in 3 weeks which made a notable flexibility in capacity).
- Integration of PCB(Printed Circuit Boards) and parts manufacturing sites,
- Working with suppliers as partners by
    - managing the supply chain powerfully
    - feeding suppliers with on-time and relevant information.
- Enhancing competency in
    - delivery integrity (company delivers any order in 30 days or less to any point)
    - product quality
    - effective performance of processes using simultaneous engineering methods.
- Quickening activities by :
    - product realisation process
    - focus on delivering as fast as possible
    - using CE methods.
- Reliance on core competencies

Case study company number 3

1- Profile

1-1- An aerospace manufacturer, with around 300 employees and turnover of around £30 million

1-2- Produces intermediate products for aeroplane manufacturers and other aerospace firms in batch production method.

1-3- Works mostly in Europe market with less than 20% of market-share, and some export to USA

1-4- Introduced 5-10 new products in 5 past years with an average success of 31-50%

1-5- Produces 600-700 different products which belong to a few number of product families

2- Characteristics

2-1- Priorities

Quality - Profit - Sales - Tome , Cost

2-2- Responsiveness level : 4 out of 10

2-3- Core competencies :

- High and precision technology
- Highly skilled design engineers and designing and engineering facilities
- innovation which used to be the differentiating factor from others in past

2-4- Problems;

- Dramatic change in market situation
- Possibility of easy access to high technology by small and low level competitors
- Inability to identify opportunities and using the vast available capabilities in responding to the opportunities.
- Seeing business as it was 20-30 years ago by some people (important ones) in the organisation.

3- Company and Change ;

3-1- Because of change in industrial and technological facts, aircraft market

has changed and changes continuously

3-2- Technology has changed as well for the company but not as fast as market

3-3- Change importance : 5 out of 10

3-4- Areas of change as drivers of agility

- Market place
- Competition criteria
- Technology

3-5- Complexity of drivers : Almost high (in marketplace turbulence)

3-6 - Strategy of the company in responding to change :

- Staying on high technology as a differentiating point.
- Increasing responsiveness of the company.
- Realising and viewing the new form of competition environment as it is, by the management and the people.

4- Areas in the company where response to changes are originated from (in order of importance)

- Organisation
- Processes
- Communication
- Technology
- People
- Innovation

The company does not have integrated systems, but a good communication and information system is established.

5- Practices

- Bringing marketing and engineering people together to perform simultaneously.
- Spreading the awareness and knowledge of new circumstances over the company by conducting training courses and seminars.
- Making close interface with customers and sending engineers to them in product realisation process or for getting their requirements.

- Expanding communication among people and organisation and supporting it with teamworking culture.
- Company-wide database in design, and relatively comprehensive information system though not well integrated yet.
- Focusing on quality, as company works in a market where quality is critical.
- The company is at 90% level of targeted quality (according to British Aerospace Standards)
- Practices which are found necessary by the company and planned for in order to increase agility
    - Completing information and communication infrastructure.
    - Exploiting new areas of technology which could not easily be copied by the rivals.
    - Quickening the product development as time is going to be more important for the company.
    - Empowering people more and more.
    - Extending focus on quality.

Case study company number 4

1- Profile ;

1-1- A filter and nonwoven textile company with around 200 employees.

1-2- A good situation in market with export to many countries and leading in some markets.

1-3- Produces a large range of products for different users.

2- Characteristics ;

2-1- Priorities

Quality - Cost - Time - Flexibility

2-2- Core competencies

- Multiskilled people
- Structured processes
- Flexibility in manufacturing.

2-3- Problems :

- Not enough flexibility in organisation at the moment.

2-4- Complexity of product development : relatively low

3- Company and change

3-1- Change areas as Drivers of agility :

- Competition bases
- Customer requirements
- Social factors (legislation, Europe Unity, etc.)

* Transition from traditional business towards excellence, beyond customer expectations

* Getting ready for stepping into the next millennium.

3-2- Complexity of agility drivers ; not very fast changing and complex, but the company needs to be and remain more agile than its competitors in order to maintain the competitive advantage.

3-3- Strategy of company in responding to change ;

- Being responsive to customer's requirements in specification of products, cost, quality, quantity, and delivery time.
- Being flexible
- Being Competent

4- Areas in the company where response to changes are originated from (in order of importance)

- System, organisation, processes (procedures), interrelationships, systematic definition of people and processes roles
- People
- Technology
- Innovative product development

* Integration (understood, but not achieved) plus a relatively company-wide comprehensive information system in use.

5- Practices

- Quick reaction to enquiries (dealing positively with customers)
- Focusing on quality with a plan to achieve TQM.
- Teamworking through establishing several improvement teams such as cost and waste management, product development, etc.

- Special training course called " Investment in Excellence " to train people to act differently from the way they used to. It is intended to be offered to all employees in long term
- Enhancing flexibility in operations (planning/manufacturing), machines (Shopfloor), organisation, people.
- Initiating long range strategic planning considering the new environment of competition.
- Attempt to organise around processes.

Case study company number 5

1- Profile

1-1- A UK-owned manufacturer of construction machines with around 2000 employees and turnover of more than £500 million.

1-2- Market leader in some products and works with USA and Singapore markets overseas.

1-3- Has introduced more than 10 new products to market in the past 5 years with an average success of 70%.

1-4- Mass production is the type of company's production system, though they produce to order not for stock.

1-5- Consists of independent units each of which acts in a specific field of manufacturing.

2- Characteristics;

2-1- Priorities

Quality - Time - Profit - Cost - Flexibility

2-2- Responsiveness level : 7 out of 10

2-3- Core competencies :

- Quickness
- Fast decision making
- Introduction of new products

2-4- Problems;

- Not enough communication between units
- Moving so fast that planning is overlooked and not taken seriously

2-5- Complexity of product development : relatively complex.

3- Company and Change

3-1- The company possesses a notable market share in some product ranges but continuously faces change in the environment which it has to fight and overcome to prosper. However, it is not a very difficult situation for the company.

3-2- Importance of change : 9 out of 10

3-3- change areas as Drivers for agility:

- Customer requirements
- Market place turbulence
- Competition pressures
- Technology change
- Social factors

3-3- Complexity of agility drivers : relatively high

3-5- Strategy of company in responding to change

- Urgency as a general strategy
- Attacking threats and new opportunities as fast as possible
- Increasing quickness and people competency.

4- Areas in the company where response to changes are originated from (in order of importance)

- People
- Organisation
- Technology and innovation

(Innovation is the way to avoid incremental change and direct a huge spend of money in finding better ways of doing things. [Definition by the company's contact person])

* A good level of integration through implementation of information system is traceable in each unit, but not all units are integrated. This integration is an important factor in the success of units.
* Good, but traditional relationship with suppliers. The company works only with a few number of suppliers as main suppliers.

5- Practices

- Change in the organisation in responding to market change and focusing on a specific product using the quick character of the company.
- Reliance on suppliers and good relationship with customers
- Enhancing competency in people by continuous education and training.
- Taking a specific concept of TQM and planning to achieve it. It is called CCQ (Concept - Customer - Quality) and people are trained to use it.
- Doing every efforts in reducing cost and becoming cost efficient. This includes a rewarding system to encourage people in this regard.
- Operating cross-functional teams which brings about quickness and concurrency.
- Tools/techniques in use :

  JIT, some levels of CIM, CE, MRPII, CAD/CAM/CAE, teamworking, flexible organisation (to certain extents in the form of project working organisation)

* More works needed on innovation
* More works needed on providing company-wide access to information, including internal, external historical (database) information. Also connection with suppliers and customers through information lines is a future target to reach.
* Improvements required in quickness using any possible means

Case study company number 6

1- Profile

1-1- A non-UK owned vehicle components manufacturer with more than 200 employees and about £30 million annual turnover.

1-2- Produces finished vehicle components including train breaks for local and overseas markets, in a batch production system.

1-3- Has introduced 5-10 new products in the 5 past years with average success of more than 70%.

2- Characteristics ;

2-1- Priorities :

Quality - Cost - Flexibility - Time - Sales

2-2- Responsiveness level : 7 out of 10

2-3- Core competencies :

- reliable planning and control systems
- flexible workforce
- flexible manufacturing system

2-4- Complexity of product development : Not very complex, but because of safety factors it must be accurate.

2-5- Problems :

- Uncertainty in internal political factors as company is owned by a foreigner owner.
- Lack of enough flexibility in the organisation.

3- Company and Change

3-1- For every single action of the company's business there are problems, threats, and opportunities which must be accounted.

3-2- Change importance for the company : 7 out of 10

3-3- Change areas as agility Drivers :

- Marketplace
- Technology
- Social factors
- Customer requirements

3-4- Complexity of agility drivers : not very complex

3-5- Strategy of company in responding to change

- Competency (Quality, customer focus, people, ...)
- Flexibility
- Quickness

4- Areas in the company where response to changes are originated from (in order of importance)

- People
- Technology
- Innovation

* Integration is necessarily needed by the company but is not achieved yet.
* A relatively company-wide manufacturing-based information system is in use which needs further improvements.

5- Practices :

- Conducting an initiative called MSRI (Manufacturing System Reorganisation Initiative)
- Recruiting experts through TCS (Teaching Company Scheme) for exploiting new insight in manufacturing and management
- Using FMS units
- Establishing cell manufacturing systems in shopfloors
- Initiating 4c 95 (FORESEE 95) strategic planning with following concerns: Customer, Competition around the company, Cost-effective, Capital-effective which focused on customer
- Combining an important manufacturing site in the main factory for reducing costs
- Employing short-term contractors, extendible to a certain period

Establishing Quality Council (managerial Committee) to control the whole business including quality audit, suppliers audit, vendors rating, benchmarking, ...

- Combining inspection in the operators job
- Company Suggestion Scheme (pay for productive suggestions)
- Continuous training for people
- Leaving responsibility of every action and problems in any section to people and expecting resolution from them
- Watching the main areas that concern customers
- Getting to an agreement with a major competitor about the ways to better results for both sides and probably merging two in one in order to compete with for other powerful competitors
- Tools/Techniques in use : FMS, CAD/CAM/CAE, Teamworking, ...

APPENDIX C - COPY OF THE POSTAL QUESTIONNAIRE USED IN THE MAIN SURVEY PHASE

Agility in Manufacturing Organisations

Please tick or circle the appropriate response(s) or write in the provided spaces.

1- Company profile

1-1- Name of respondent ----------Job Title----------

Name of company----------

Address of company ----------

Postcode ----------Tel. No.---------- Fax No. ---------- Email--------

1-2- To what industry sector does your company belong ? ☐ Aerospace/Defence ☐Auto Parts Manufacturing ☐Others------

1-3- How many on site employees are there? ---------- APPROX.

1-4- What was the average level of on site annual turnover in the last **THREE** years ? £ m----APPROX.

1-5- How many different types of finished products does the company manufacture ? ------ APPROX.

1-6- How many new products has your company introduced to market in the last **THREE** years ?
------ APPROX.

1-7- What percentage of these products have been successful (as defined by the company)? ----% APPROX.

1-8- What percentage of your products are exported ? ---------- % APPROX.

1-9 - Which of the following best describe the company's production type :

1) Engineering to order
2) Assemble to order
3) Manufacture to order
4) Mass customisation
5) Manufacture to stock (Mass production)
6) Other (Please specify) ----------

1-10- What is the average lead time for your major product (From concept to cash (sale)) ?
----------**Months** APPROX.

1-11- How new are your products usually ? (Please indicate an approximate percentage)

1- Complete Innovation ----------%
2 - New lines (not new to market) ---------- %
3 - Improved Products ----------%
4 - Custom made (Tailored) ---- %

1-12- What percent of turnover is being invested in R&D programmes ? ----------% APPROX.

1-13- What are the real priorities of the company's Business and Manufacturing Strategy?
(please rank in order from 1 to 5 (**1 = The most important**)

1- Time ( ) 2- cost ( ) 3 - Flexibility ( ) 4 - Quality ( ) 5 - Other (please specify)

1-14- Which of the following manufacturing systems or methods are being utilised in the company ?
For how many years ?

1- MRPI/MRPII for----------Yrs
2- JIT/Kanban for----------Yrs
3- Optimised Production Technology (OPT) for------Yrs
4- CIM for ------Yrs
5- TQM for ----------Yrs
6- Concurrent Engineering for ---Yrs
7- Flexible Manufacturing system(FMS) for ------Yrs
8- Lean Manufacturing for ----Yrs
9- CAD/CAM/CAE for ----------Yrs
10- Robot Technology for ----Yrs
11- Joint Venturing for ----------Yrs
13- Other (please specify) ---------- for---years

1-15- How many **main suppliers** does the company work with? ---------- APPROX.

1-16- How critical do you express Co.'s relationship with suppliers ?
1 = Not important 5 = Highly critical

1 2 3 4 5

1-17- How many **main customers** does the company have ? ---------- APPROX.

1-18- How many of suppliers and customers are chosen as partners ? ---------- APPROX.

1-19-What is the approximate market share of the company for its major product(s) ?
HOME --------% , GLOBAL ----------%

1-20-How familiar are you with the concept of AGILITY ?
1 = Not heard of it 5 = Completely Familiar

1 2 3 4 5

1-21- On a scale of 1 to 5, and referring to the definitions and concepts provided first, how do you express the level of agility that your company needs to achieve.
1 = No need 5 = Highly Agile

1 2 3 4 5

1-22- To what extent do you consider your company as a World Class Manufacturing Co.
1 = Not at all 5 = Completely World Class

1 2 3 4 5

2- Agility Drivers

How do you evaluate the position of the following environmental pressures for your company (These are considered as Agility Drivers). 1= Stable with the Least Changes (No Threats)
5= Highly Changing and Turbulent

2-1 : MARKETPLACE	**1 2 3 4 5**
2-2 : COMPETITION BASIS	**1 2 3 4 5**
2-3 : CUSTOMER REQUIREMENTS	**1 2 3 4 5**
2-4 : TECHNOLOGY	**1 2 3 4 5**
2-5 : SOCIAL FACTORS	**1 2 3 4 5**

3- Strategy

In response to the changing circumstances, which of the following capabilities are more important for your company to be considered as a strategic action for success. (**please tick in the left box**). Also please indicate degree of importance from 1 to 5: **1= The least important 5 = The most important**

☐ 3-1- Acting **proactively** instead of reactively (attacking threats and opportunities)

1 2 3 4 5

☐ 3-2- Increasing **responsiveness** to change (refer to definition) 1

2 3 4 5

❑ 3-3- Increasing total **competency** of the co. and organising around core competency

1 2 3 4 5

❑ 3-4- Increasing **flexibility**

1 2 3 4 5

❑ 3-5- Increasing **quickness (speed)**

1 2 3 4 5

❑ 3-6- Focusing on **customer**

1 2 3 4 5

❑ 3-7- Concrete relationship with **suppliers** and moving towards partnership

1 2 3 4 5

❑ 3-8- Establishing and maintaining **Innovation** as a characteristic of the co.

1 2 3 4 5

4- Agility Practices

This section is aimed at studying the practices that are suggested to be important in achieving Agility.

In the following questions: *First* please specify whether the generalised practice is being considered and completely implemented by the company (**in the first column**),

If YES, please indicate its resulted effects on the company's ability to respond to changes. (**in the second column**).

If NO, how important do you consider it to be as a means of achieving agility. **(in the second column)**

	YES = Implemented **NO = Not implemented**	1= No effects 5= Highly effective	1= Not applicable 5= Highly important
4-1- Establishing partnership with suppliers and/or customers	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-2- Establishing Virtual Organisation for quicker capture of market opportunities	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-3- Close relationship with suppliers/customers, and involving them in co.'s planning and product development process	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-4- Adoption of advanced technology to achieve strategic goals and manufacturing objectives of the co.	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-5- Mass-customisation through utilising adequate technology to respond to the changing market and customer needs	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5

4-6- Partial integration of inter-organisational systems and modules	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-7- Total integration of the manufacturing system	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-8- Flexible, responsive to change, flat, learning, and team and process focused organisation	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-9- Continuous reengineering of the organisation and business processes, based on benchmarking	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-10- Informal, coaching, and encouraging management style	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-11- Structured, flexible manufacturing processes to ensure timeliness, quality, and flexibility	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-12- Concurrent and team working methods/models	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-13- Empowerment of people throughout the Co.	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
4-14- Continuous training and education of all people	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5

---

5 - Information System

This section is aimed at finding the role of information and its different aspects in agility.

In the following questions: *First* please specify whether the mentioned information system or practice is being considered and

completely implemented by the company (**in the first column**),

If YES, please indicate its resulted effects on the company's ability to respond to changes. (**in the second column**).

If NO, how important do you consider it to be as a means of achieving agility. **(in the second column)**

	ES = Implemented **NO = Not implemented**	1= No effects 5= Highly effective	1= Not applicable 5= Highly important
5-1- An Information Management Plan or Model	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-2- Strategic use of information system through the company's information management plan identify to improve its competitive advantage in the marketplace	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-3- Using Internet and related information tools as a means of communication with outside of the Co., and capturing market and the co.'s environment information.	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5

5-4- Internal Information Network, that makes information available company-wide.	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-5- Integrated Computer-based product development process	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-6- Computerised Manufacturing Information System	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-7- Computerised Manufacturing Information System, compatible to International standards of data exchange and transfer such as STEP	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-8- Information System Interface with suppliers to provide them with information, and updating their information	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5
5-9- Information System Interface with customers to provide them with information, and updating their information	❑ YES ❑ NO	1 2 3 4 5	1 2 3 4 5

6- *General*

6-1- Please feel free to add any comments or details here.

6-2- The next stage of the research will involve structured interviews and/or case studies. Would your company be willing to take part in this second phase?

Interview	YES ❑	NO ❑
Case Study	YES ❑	NO ❑

6-3- Would you like to receive a copy of the results ? YES ❑ NO ❑

Thank you again for your assistance

H. Sharifi,
Researcher,
Manufacturing Engineering and Industrial Management - Dept. of Engineering,
The University of Liverpool, P.O.Box 147, Liverpool, L69 3BX.
Tel.: 0151-794 4776, Fax.: 0151-794 4693, Email: h.sharifi@liv.ac.uk

APPENDIX D - COPY OF THE CASE STDY (INTERVIEW) QUESTIONNAIRE

Agility in Manufacturing Organisations
Interview Questions

Company :	
Respondent Name :	Job Title:

Part 1. Information on the company;

1- Which of the following manufacturing methods are being mostly used in your company.

☐1- Jobbing ☐2- Batch ☐3- Mass Production ☐4- Other (Please specify)

2- Which of these best describes your products ?

	Low Complexity	Med. Complexity	High Complexity
None or few subassemblies	1	2	3
Some subassemblies	4	5	6
Many subassemblies	7	8	9

3- Is there any strategy in the company with regard to determining the life cycle time of your products ?
If Yes what does it say ?
Why is it important for the company ?

4- What percent of the company's sales has come from new products introduced in past 3 years ?

5- Is the number of new products introduced by the company :
☐ Increasing ☐Decreasing ☐ Remaining same
Why ?

6- What factors are considered in determining the number of new products introduced to market ?

7- What are the determinants of a new product's specification to be introduced to market?

8- What is the level of products **customisation** in your company ?

Totally standard		Moderate customisation		Highly customised (One Off's)
1	2	3	4	5

9- How do you express the company based on the level of technology in use ?

- ☐ 1- Low technology
- ☐ 2- Moderate technology
- ☐ 3- High technology

10- How flexible are your products :

1- In volume

very low	low	med.	high	very high
1	2	3	4	5

2- In specification

very low	low	med.	high	very high
1	2	3	4	5

11- Which of the following best describes the level of your manufacturing process complexity ?

very low	low	med.	high	very high
1	2	3	4	5

Why do you perceive it as so ?

12- Does the company use a production planning system ?
How important do you consider it ? Why ?

13- Which of the following best describes company's policy regarding entering marketplace ?

- ☐ First to market
- ☐ Following the leader and beating it
- ☐ Following others (Me Too!)

14- How <u>important</u> is marketing for your company ?

very low	low	med.	high	very high
1	2	3	4	5

15- Does the company use any special marketing method ?
If YES, why ?

16- How do you express the market your company acts in from the competition point of view?

- ☐ Solely captured by your company, or not competitive
- ☐ Low competitive
- ☐ Moderately competitive
- ☐ Totally competitive

17- Does the company use any benchmarking methods ?
If yes :
How do you evaluate its importance in determining and establishing the right strategy for the company ?

very low	low	med.	high	very high
1	2	3	4	5

18- What would you consider as the **core competency** or capability of your company ?

Does the company put any emphasis on it as a powerpoint and a leverage in marketing and capturing marketplace ?
How ?

19- How threats and opportunities in marketplace are being detected by the company ?
Is there any mechanism used by the company for the above purpose?
If yes, what is it?

20- Is there any process of strategy making and/or strategic planning over the company?
Would you briefly explain this process?

Part 2. Change in the Business Environment

1- Do you feel any significant change in the circumstances of the business environment in past 5-10 years ?.....
How do you express it ?

2- Has the company had any remarkable experience regarding sudden changes in the business environment in recent years ?..... If yes, What was that ?
How did it affect the company?

3- In order to generalise the resulting effects of changes in the business environment on the company's business, we believe that the changes could affect the company's activities and benefits in one of the following three ways.
Please indicate to what extent do you agree with this categorisation ?

<u>These changes would have effects :</u>

1. On the current activities, programmes and plans of the company. These effects will be received mostly by the bottom line of the manufacturing process in the form of change in order quantity and/or delivery time, product specification, model or configuration, required services and support for the products, also problems with effective completion of the product line schedule due to supplier problems.

AND/OR

2. on company's business by endangering its position in market for some specific products and/or in some specific sectors of the market.

AND/OR

3. on company's business by creating new horizons of opportunity for the company through introduction of new markets, an instant tendency in customers and market, fall of main competitors, a totally novel and innovative idea for products and services, etc.

1= Completely disagree, 2= Slightly disagree, 3= Neutral, 4= Slightly agree, 5= Completely agree
1 2 3 4 5

Please give any further suggestions in completing the above domains, if you have.

4.

4- In the following question please indicate the change items with regard to "MARKETPLACE" that have been faced by the company in some ways. [Tick in the left box]. Then please estimate the degree of each relevant item's impact on the company's business (on the right, first column). L = Low, M = Moderate, or H = High effect.
Also in the second column on right, with considering the given categorisation in question number **3** please indicate in what way the named change item has affected the company's business.

	Degree of effect			The way that the change has affected company's business			
☐ 4-1- Growth of the niche market	L	M	H	1	2	3	4
☐ 4-2- National and international political changes	L	M	H	1	2	3	4
☐ 4-3- Increasing rate of change in product models	L	M	H	1	2	3	4
☐ 4-4- Product lifetime shrinkage	L	M	H	1	2	3	4
☐ 4-5- Other if any (Please specify).....	L	M	H	1	2	3	4

For each item with Moderate or High degree of effect, please explain what has the company done in responding to it?

4-1-

4-2-

4-3-

4-4-

4-5-

5- Please do the same as previous question regarding changes in "COMPETITION".

	Degree of effect			The way that the change has affected company's business			
☐ 5-1- Rapidly changing market	L	M	H	1	2	3	4
☐ 5-2- Increasing pressure on cost	L	M	H	1	2	3	4
☐ 5-3- Increasing rate of innovation	L	M	H	1	2	3	4
☐ 5-4- Increasing pressure of global market competition	L	M	H	1	2	3	4
☐ 5-5- Decreasing new products time-to-market	L	M	H	1	2	3	4
☐ 5-6- Responsiveness of competitors to changes	L	M	H	1	2	3	4
☐ 5-7- Other (please specify)	L	M	H	1	2	3	4

For each item with Moderate or High degree of effect, please explain what has the company done in responding to it?

5-1-

5-2-

5-3-

5-4-

5-5-

5-6

6-Please do the same as previous question for changes regarding "CUSTOMER REQUIREMENTS".

	Degree of effect			The way that the change has affected company's business			
☐ 6-1- Demand for individualised products and services	L	M	H	1	2	3	4
☐ 6-2- Quicker delivery time and time-to-market	L	M	H	1	2	3	4
☐ 6-3- Quality expectation increasing	L	M	H	1	2	3	4
☐ 6-4- Sudden changes in order quantity and spec.	L	M	H	1	2	3	4
☐ 6-5- Other (Please specify)	L	M	H	1	2	3	4

For each item with Moderate or High degree of effect, please explain what has the company done in responding to it?

6-1-

6-2-

6-3-

6-4-

6-5-

7- Please do the same as previous question for changes regarding "TECHNOLOGY".

	Degree of effect			The way that the change has affected company's business			
☐ 7-1- Introduction of more efficient, faster, and economic production facilities	L	M	H	1	2	3	4
☐ 7-2- Introduction of new soft technologies (Software and methods)	L	M	H	1	2	3	4
☐ 7-3- Introduction of new materials	L	M	H	1	2	3	4
☐ 7-4- Inclusion of information technology in (new) hard and soft technologies	L	M	H	1	2	3	4
☐ 7-5- Other (Please specify)	L	M	H	1	2	3	4

For each item with Moderate or High degree of effect, please explain what has the company done in responding to it?

7-1-

7-2-

7-3-

7-4-

8- Please do the same as previous question for changes regarding "SOCIAL FACTORS".

	Degree of effect			The way that the change has affected company's business			
☐ 8-1- Environmental pressures	L	M	H	1	2	3	4
☐ 8-2- Workforce/workplace expectations	L	M	H	1	2	3	4
☐ 8-3- Legal/political pressures	L	M	H	1	2	3	4
☐ 8-4- Cultural problems	L	M	H	1	2	3	4
☐ 8-5- Social Contract changes	L	M	H	1	2	3	4

For each item with Moderate or High degree of effect, please explain what has the company done in responding to it?

8-1-

8-2-

8-3-

8-4-

8-5-

9- Has the company ever had to redefine its strategy because of facing these sorts of change? What new strategies has the company taken ?

Part 3. Agility Drivers and agility capabilities

Please indicate the degree of importance of capabilities in the following list for the company to adopt in facing and responding to each of the numbered change items, and maintaining the competitive advantage (please refer to questions No. 4 to 8 in part 2 for change item titles). PLEASE GIVE A RANK OF IMPORTANCE FROM 1 TO 5.

1 = not important 5 = Highly important

CHANGE ITEMS / CAPABILITIES	MARKETPLACE					COMPETITION							CUSTOMER					TECHNOLOGY				SOCIAL FACTORS				
	4-1	4-2	4-3	4-4	4-5	5-1	5-2	5-3	5-4	5-5	5-6	5-7	6-1	6-2	6-3	6-4	6-5	7-1	7-2	7-3	7-4	8-1	8-2	8-3	8-4	8-5
Responsiveness;																										
• Sensing, perceiving and anticipating changes																										
• Immediate reaction to change by effecting them into system																										
• Recovery from change																										
Competency;																										
• Strategic vision																										
• Appropriate technology (hard and soft), or sufficient technological ability																										
• Products/services quality																										
• Cost effectiveness																										
• High rate of new products introduction																										
• Change management																										
• Knowledgeable, competent, and empowered people																										
• Operations efficiency and effectiveness (leanness)																										
• Co-operation (internal and external)																										
• Integration																										
Flexibility ;																										
• Product volume flexibility																										
• Product model/configuration flexibility																										
• Organisation and organisational issues flexibility																										
• People flexibility																										
Quickness ;																										
• Quick new products time-to-market																										
• Products and services delivery quickness and timeliness																										
• Fast operations time																										

Part 4. Agility circumstances in your company

1- How *important* is innovation for the company in taking and maintaining the competitive advantage ?

very low	low	med.	high	very high
1	2	3	4	5

2- Is innovation equivalent to Research and Development (R&D) in your company?

3- Has there been any initiative in the company to enhance the innovativeness as a characteristic of the company?

What are the major issues of this initiative ?

4- Has integration of different functions, processes and departments in the company been considered in your

company in order to improve the company's business performance ?

If yes, what specific goals have been followed as the result of integration

To what extent have you found it effective in achieving the above mentioned goals ?

very low	low	med.	high	very high
1	2	3	4	5

If no, why ?

5- Has there ever been a situation for the company that a golden opportunity could be taken advantage of, but

insufficient resources including time impeded it, unless a quick and temporary co-operation with some other

companies be provided ? Please explain it.

6- Is virtual organisation a subject that could suggest benefits from unpredicted opportunities or threats for your

company ?

7- Has the company had any real experience of a virtual organisation (inside or outside it). Please explain it.

8- Could agility, as defined in the attached report, be considered as the solution to the new position needed by

your company ?

9- How do you define agility as a new ability for the company ?

10- How necessary do you perceive it for your company ?

1= Not necessary				5= Highly necessary
1	2	3	4	5

11- How agile do you think your company is on a scale of 5 ?

1= Not Agile 5= Highly agile

1 2 3 4 5

12- How do you evaluate the company's ability in detecting the changes in the environment ?

1= very low 5= very high

1 2 3 4 5

13- How capable is the company in affecting the imposed or necessary changes in the company's programmes,
and providing the right solutions in the shortest possible time ?

1= very low 5= very high

1 2 3 4 5

14- How able is the company in tackling unprecedented opportunities and taking advantage of them ?

1= very low 5= very high

1 2 3 4 5

APPENDIX E - COMPLETE SETS OF TABLES 6.11 AND 6.12 FROM CHAPTER SIX, INDICATING THE REALTIONSHIP BETWEEN AGILITY DRIVERS AND AGILITY CAPABILITIES, AND THE RESPONSES OF THE CASE STUDY COMPANIES TO CHANGE ITEMS

Increasing pressure on cost	Case number
• Reducing cost by every means up to the possibilities and the acceptable level of customers	2
• Streamlining the processes; Lean production techniques; FMS; Continuous training of people and their involvement in all aspects of the company's activities; Critical management of supply chain	3
• Using DFMA; Increasing volume of products, Sorting the problems of cost areas; Looking critically at all components of the products for their necessity and possibility of replacing them with cheaper alternatives.	4
• Aiming at reducing a typical; 5% per year off products manufacturing costs and sales margins I terms of improvement in purchasing material cost, marginal changes in manufacturing costs.	5
• Adopting lean manufacturing; Looking at best practices basically theory of constraints and Toyota production system	6
• Uptaking new technology and investment in machines; people flexibility (one man works on 3 to 4 machines); looking at management tools and establishing a high rank team to deal with the cost problem; Cooperation with customers and suppliers	7
• Budgeting better; More systems; Refining reporting system.	8
• Developments to lower cost creator standardisation	10
• Major cost reduction initiatives in all aspect	12
Increasing rate of innovation	
• Introducing a new innovative major device in products; An innovative method of welding metal body resulted in time and cost reduction	4
• Staying ahead in driving the market needs by investing in a couple of core technological innovations and establishing a winning criteria for products	3
• Encouraging innovation in every aspects of the company with rewarding schemes	3
• Aiming innovation as one of the main strategies of the company	3
• Linking to the group members on a global basis; Establishing R&D centres of excellence as a step beyond conventional R&D; Continuous search for new materials, modules and fashion.	6
• Reorganising technical department	8
• Utilising ideas for development	9
• Focusing on core competencies to gain competitive advantage	10
Increasing pressure of global market competition	
• Reducing time-to-market	1
• Keeping on stay innovative, flexible and continuous improvement, as company's strategy	3
• Focus on major competition on "One Stop Purchasing" solution	5
• Merging strategy to form a more powerful base with other companies in the field	5
• Global vertical integration to cover more sectors of the global markets	6
• Cost reduction; Lead time reduction; Reorganising sales	8
• Better marketing through increasing market awareness with a group marketing approach	9
• Investment in R&D	10
• Moving the business into a larger group	11

Table 6.11. Responses of the case study companies to change items

Decreasing new products time-to-market	Case number
• Rengineering the processes to reduce time as much as possible	1
• Investment in technology; Restructuring the manufacturing process	2
• Cellular manufacturing; Kanban; system; FMS	3
• Investment in some technologies to gain flexibility	4
• Establishing a platform type of products (Building blocks), which is transferable to customer specifications fast	5
• Reducing time, basically from design point	6
• Introduction of ISDN, and video conferencing for a fast and reliable communication infrastructure which helps global projects be managed quickly	6
• Machine tool investment; Adoption of managerial techniques for new product development	8
• Better management of off line development programmes	9
• Development in new product introduction processes	12
Responsiveness of competitors to changes	
• Integration of all components and parts of products to beat competitors	6
• Better marketing	9
• Working harder, smarter, and quicker	10
• Relying on the group's abilities to enhance the company's competitiveness	11
Demand for individualised products and services	
• Establishing a mass-customisation environment	3
• Colour proliferation;; Basic design with flexibility in specification	4
• increasing engineering capabilities	11
Quicker delivery time and time-to-market	
• Cellular Manufacturing; FMS; Kanban	3
• Changing procedures of ordering and stocking; Modifying and renewing old procedures such as scheduling	4
• Reducing product work in process lead time and delays by 25%; Introducing new computer system to change rapidly with changes	5
• Design modularisation	6
• Internal time reduction through revisiting processes	8
• Adoption of CE; Emphasis on planning for control structure in manufacturing	10
Quality expectations increasing	
• Investment in new plants to increase quality after identifying areas of improvement	1
• Automation; Cellular manufacturing	2
• Increasing expected operating life of products; Introduction of warranty in/out scheme	5
• Continuous improvement of quality in manufacturing	6
• Investment in technology to improve products reliability; TQM methods; educating people	7
• Major new quality process and six-sigma implementation	10
• Adopting policy of deliver right-first-time and quality management techniques	12

Table 6.11. continued

Sudden changes in order quantity and specification	Case number
• Increasing flexibility of design processes	2
• Flexibility in volume and specification as factors of the mass-customisation system used	3
• Management of supplier chain; Balance between forecast horizon in production system and inventory for shorter forecast and lower inventory including a good management of supply chain	5
• Cost management for less and capacity management for more	8
• New computer system; Business rengineering	9
• Cycle time reduction	10
Introduction of more efficient, faster and economic production facilities	
• Introduction of new manufacturing facilities	5
• Complete reorganisation/rationalisation of all factories and significant capital investment	10
• Investing heavily in capital equipment	11
Introduction of new soft technologies (software and methods)	
• MRPII system (off the shelf with 30 to 50 % twist to get fit)	2,8
• Trying to overcome the old fashion technology as a barrier in uptaking new soft technologies	4
• Adding information and software into products as a major part of them	5
• Trying to develop peripheral; hardware/software products to add value to core products	9
• Planned strategy to replace the old system with new process capable soft technologies	10
• Using computer controlled machinery	12
Introduction of new materials	
• Complete change of production facility because of the new introduced material and new techniques involved for quality and cost purposes	6
• Developing the capability of the company by absorbing newly introduced materials and devices	9
• Better management of R&D	10
Inclusion of information technology in (new) hard and soft technologies	
• Taking advantage of this change as an opportunity and shifting a part of the company's capacity to satisfy demand for new commercial devices	1
• Uptaking new tools and techniques and upgrading the facilities to level the company's movement with the developments in this area	3
• Planning for expansion of information system and interconnection of different plants, facilities and also customers	4
• Direct link to customers for design data transfer	5
• Introducing a new central computing system with links to manufacturing facilities	9
• Introduction of new process capable soft technologies	10

Table 6.8. continued

Environmental pressures	Case number
• Embracing new environmental standards and coordinate systems to them	1
• Reconsidering production methods to reduce pollution	2
• Subscribing to ISO 1004	3,4,6,10
• Using new technologies to reduce pollution	5
• Capital investment in environmental friendly equipment	10,11
Workforce/Workplace expectations	
• Establishing a friendly environment in which people are participated in the whole system	3,11
• Training people continuously	4
• On work training with the help of Universities	5
• Managing worker unions by settling disputes friendly and creating an entrepreneurial environment	6
• Putting efforts to change the traditional workforce to a modern basis	9
• Employees communication and involvement programmes	10
Legal/Political pressures	
• Improving commercial relations with the contractual market	
Cultural problems	
• Design products to match the new cultural norms of the customer market and cultural habits of different overseas market	
• Cross-cultural training/exposure	

Table 6.11. continued

INCREASING PRESSURE ON COST		DECREASING NEW PRODUCT TIME-TO-MARKET	
Capabilities	Wts	Capabilities	Wts
• Cost effectiveness (competency)	4.1	• Quick new products time-to-market (speed)	4.3
• Appropriate technology/Sufficient technological ability (competency)	3.9	• High rate of new products introduction (competency)	3.7
• Strategic vision (competency)	3.4	• Knowledgeable, competent, and empowered people (competency)	3.7
• Products/services quality (competency)	3.4	• Co-operation (internal/external, competency)	3.7
• Operations efficiency and Effectiveness-leanness (competency)	3.4	• Strategic vision (responsiveness)	3.6
• Sensing, perceiving and anticipating changes (responsiveness)	3.4	• People flexibility (flexibility)	3.6
· Change management (competency)	3.3	• Integration (competency)	3.6
· People flexibility (flexibility)	3.3	• Appropriate technology/sufficient technological ability (competency)	3.4
• Immediate reaction to change by effecting them into system (responsiveness)	3.1	• Products and services delivery quickness and timeliness (speed)	3.4
· Co-operation(Internal/external, competency)	3.1	• Fast operations time (speed)	3.4
• Organisation and organisational issues flexibility (flexibility)	3.1	• Sensing, perceiving and anticipating changes (responsiveness)	3.3
· Fast operations time (speed)	3.0	• Immediate reaction to change by effecting them into system (responsiveness)	3.3
• Recovery from change (responsiveness)	2.9	• Products/services quality (competency)	3.3
• Product volume flexibility (flexibility)	2.9	• Change management (competency)	3.3
• Products and services delivery quickness and timeliness (Speed)	2.9	• Operations efficiency and effectiveness-leanness (competency)	3.3
• High rate of new products introduction (competency)	2.7	• Product model/configuration flexibility (flexibility)	3.3
• Integration (competency)	2.7	• Cost effectiveness	3.0
• Product model/configuration flexibility (flexibility)	2.7	• Product volume flexibility	3.0
• Knowledgeable, competent, and empowered people (competency)	2.6	• Organisation and organisational issues flexibility	3.0
• Quick new products time-to-market (speed)	2.4	• Recovery from change	2.9

Table 6.12. Relationship between agility drivers and agility capabilities

INCREASING RATE OF CHANGE IN PRODUCTS MODEL		QUICKER DELIVERY TIME AND TIME-TO-MARKET	
Capabilities	Wts	Capabilities	Wts
• Product model/configuration flexibility (flexibility)	4.2	• Quick new products time-to-market (speed)	4.4
• Change management (competency)	4.0	• Sensing, perceiving and anticipating changes (responsiveness)	4.0
• Immediate reaction to change by effecting them into system (responsiveness)	3.8	• Products/services quality (competency)	4.0
• High rate of new products introduction (competency)	3.8	• Products and services delivery quickness and timeliness (speed)	4.0
• Quick new products time-to-market (speed)	3.8	• Immediate reaction to change by effecting them into system (responsiveness)	3.8
• Products and services delivery quickness and timeliness (Speed)	3.8	• Appropriate technology/sufficient technological ability (competency)	3.8
• Product volume flexibility (flexibility)	3.6	• Cost effectiveness (competency)	3.8
• Fast operations time (speed)	3.6	• Operations efficiency and effectiveness-leanness (competency)	3.8
• Sensing, perceiving and anticipating changes (responsiveness)	3.4	• Recovery from change (responsiveness)	3.6
• Strategic vision (competency)	3.4	• Strategic vision (responsiveness)	3.6
• Products/services quality (competency)	3.4	• Integration (competency)	3.6
• Co-operation(Internal/external, competency)	3.4	• Product volume flexibility	3.6
• Integration (competency)	3.3	• Organisation and organisational issues flexibility	3.6
• Operations efficiency and Effectiveness-leanness (competency)	3.2	• People flexibility (flexibility)	3.6
• Recovery from change (responsiveness)	3.0	• Change management (competency)	3.3
• Appropriate technology/Sufficient technological ability (competency)	3.0	• Knowledgeable, competent, and empowered people (competency)	3.1
• Cost effectiveness (competency)	3.0	• Fast operations time (speed)	3.1
• Knowledgeable, competent, and empowered people (competency)	3.0	• High rate of new products introduction (competency)	3.0
• People flexibility (flexibility)	2.8	• Co-operation (internal/external, competency)	3.0
• Organisation and organisational issues flexibility (flexibility)	2.8	• Product model/configuration flexibility (flexibility)	3.0

Table 6.12. Continued

INCREASING PRESSURE OF GLOBAL MARKET		QULAITY EXPECTATIONS INCREASING	
Capabilities	Wts	Capabilities	Wts
• Sensing, perceiving and anticipating changes (responsiveness)	4.4	• Products/services quality (competency)	4.7
• Strategic vision (competency)	4.4	• Knowledgeable, competent, and empowered people (competency)	4.1
• Products/services quality (competency)	4.0	• Sensing, perceiving and anticipating changes (responsiveness)	3.7
• Products and services delivery quickness and timeliness (Speed)	4.0	• Immediate reaction to change by effecting them into system (responsiveness)	3.7
• Cost effectiveness (competency)	3.8	• Appropriate technology/sufficient technological ability (competency)	3.7
• Co-operation(Internal/external, competency)	3.8	• Cost effectiveness	3.7
• Product model/configuration flexibility (flexibility)	3.8	• Operations efficiency and effectiveness-leanness (competency)	3.7
• Immediate reaction to change by effecting them into system (responsiveness)	3.6	• Co-operation (internal/external, competency)	3.7
• Appropriate technology/Sufficient technological ability (competency)	3.6	• Integration (competency)	3.7
• Knowledgeable, competent, and empowered people (competency)	3.6	• People flexibility (flexibility)	3.6
• Operations efficiency and Effectiveness-leanness (competency)	3.6	• Recovery from change	3.4
• Integration (competency)	3.6	• Strategic vision (responsiveness)	3.4
• Product volume flexibility (flexibility)	3.6	• Organisation and organisational issues flexibility	3.3
• Recovery from change (responsiveness)	3.1	• Change management (competency)	3.3
• People flexibility (flexibility)	3.1	• Product model/configuration flexibility (flexibility)	3.3
• Organisation and organisational issues flexibility (flexibility)	3.1	• High rate of new products introduction (competency)	3.0
• Fast operations time (speed)	3.1	• Quick new products time-to-market (speed)	3.0
• High rate of new products introduction (competency)	3.1	• Product volume flexibility	2.9
• Change management (competency)	2.8	• Products and services delivery quickness and timeliness (speed)	2.9
• Quick new products time-to-market (speed)	2.8	• Fast operations time (speed)	2.4

Table 6.12. Continued

ENVIRONMENTAL PRESSURES		INTRODUCTION OF NEW SOFT TECHNOLOGIES	
Capabilities	Wts	Capabilities	Wts
• Sensing, perceiving and anticipating changes (responsiveness)	3.5	• Appropriate technology/sufficient technological ability (competency)	4.4
• Immediate reaction to change by effecting them into system (responsiveness)	3.5	• Change management (competency)	4.0
• Recovery from change (responsiveness)	3.5	• Knowledgeable, competent, and empowered people (competency)	4.0
• Change management (competency)	3.5	• Integration (competency)	3.8
• Appropriate technology/Sufficient technological ability (competency)	2.9	• People flexibility (flexibility)	3.4
• Product model/configuration flexibility (flexibility)	2.7	• Operations efficiency and effectiveness-leanness (competency)	3.2
• Strategic vision (competency)	2.5	• Co-operation (internal/external, competency)	3.2
• Knowledgeable, competent, and empowered people (competency)	2.5	• Organisation and organisational issues flexibility	3.2
• Operations efficiency and Effectiveness-leanness (competency)	2.5	• Strategic vision (responsiveness)	3.0
• Co-operation(Internal/external, competency)	2.5	• Sensing, perceiving and anticipating changes (responsiveness)	2.8
• Organisation and organisational issues flexibility (flexibility)	2.5	• Products/services quality (competency)	2.8
• Fast operations time (speed)	2.5	• Cost effectiveness (competency)	2.6
• Integration (competency)	2.4	• Product model/configuration flexibility (flexibility)	2.6
• Products/services quality (competency)	2.3	• Quick new products time-to-market (speed)	2.6
• Cost effectiveness (competency)	2.3	• Fast operations time (speed)	2.6
• Products and services delivery quickness and timeliness (Speed)	2.3	• Immediate reaction to change by effecting them into system (responsiveness)	2.4
• Quick new products time-to-market (speed)	2.2	• Recovery from change (responsiveness)	2.4
• People flexibility (flexibility)	2.0	• High rate of new products introduction (competency)	2.4
• High rate of new products introduction (competency)	1.8	• Product volume flexibility (flexibility)	2.0
• Product volume flexibility (flexibility)	1.7	• Products and services delivery quickness and timeliness (speed)	2.0

Table 6.12. Continued

GROWTH OF NICHE MARKET		RAPIDLY CHANGING MARKET	
Capabilities	Wts	Capabilities	Wts
• Quick new products time-to-market (speed)	4.5	• Sensing, perceiving and anticipating changes (responsiveness)	4.8
• Sensing, perceiving and anticipating changes (responsiveness)	4.3	• Immediate reaction to change by effecting them into system (responsiveness)	4.3
• Products/services quality (competency)	4.3	• Recovery from change	4.0
• Product model/configuration flexibility (flexibility)	4.3	• High rate of new products introduction (competency)	4.0
• Products and services delivery quickness and timeliness (Speed)	4.0	• Strategic vision (responsiveness)	3.8
• Fast operations time (speed)	4.0	• Product model/configuration flexibility (flexibility)	3.8
• High rate of new products introduction (competency)	3.8	• Quick new products time-to-market (speed)	3.8
• Product volume flexibility (flexibility)	3.8	• Appropriate technology/sufficient technological ability (competency)	3.5
• Immediate reaction to change by effecting them into system (responsiveness)	3.5	• Change management (competency)	3.3
• Strategic vision (competency)	3.5	• Integration (competency)	3.0
• Co-operation(Internal/external, competency)	3.5	• People flexibility (flexibility)	3.0
• People flexibility (flexibility)	3.5	• Cost effectiveness	2.8
• Appropriate technology/Sufficient technological ability (competency)	3.3	• Knowledgeable, competent, and empowered people (competency)	2.8
• Recovery from change (responsiveness)	3.0	• Operations efficiency and effectiveness-leanness (competency)	2.8
• Organisation and organisational issues flexibility (flexibility)	3.0	• Co-operation (internal/external, competency)	2.8
• Change management (competency)	2.8	• Product volume flexibility	2.8
• Cost effectiveness (competency)	2.3	• Organisation and organisational issues flexibility	2.8
• Knowledgeable, competent, and empowered people (competency)	2.0	• Fast operations time (speed)	2.8
• Operations efficiency and Effectiveness-leanness (competency)	2.0	• Products/services quality (competency)	2.5
• Integration (competency)	1.7	• Products and services delivery quickness and timeliness (speed)	2.5

Table 6.12. Continued

DEMAND FOR INDIVIDUALISED PRODUCTS AND SERVICES		SUDDEN CHANGES IN ORDER QUANTITY AND SPECIFICATIONS	
Capabilities	Wts	Capabilities	Wts
• Sensing, perceiving and anticipating changes (responsiveness)	4.0	• Immediate reaction to change by effecting them into system (responsiveness)	4.5
• Immediate reaction to change by effecting them into system (responsiveness)	3.8	• Product model/configuration flexibility (flexibility)	4.5
• Operations efficiency and Effectiveness-leanness (competency)	3.8	• Sensing, perceiving and anticipating changes (responsiveness)	4.0
• Product volume flexibility (flexibility)	3.5	• Co-operation (internal/external, competency)	4.0
• Recovery from change (responsiveness)	3.3	• Product volume flexibility	4.0
• Appropriate technology/Sufficient technological ability (competency)	3.3	• Recovery from change	3.5
• Products/services quality (competency)	3.3	• Change management (competency)	3.5
• Cost effectiveness (competency)	3.3	• Appropriate technology/sufficient technological ability (competency)	3.0
• Integration (competency)	3.3	• Knowledgeable, competent, and empowered people (competency)	3.0
• Product model/configuration flexibility (flexibility)	3.3	• Operations efficiency and effectiveness-leanness (competency)	3.0
• Fast operations time (speed)	3.3	• Organisation and organisational issues flexibility	3.0
• Quick new products time-to-market (speed)	3.0	• People flexibility (flexibility)	3.0
• Products and services delivery quickness and timeliness (Speed)	3.0	• Fast operations time (speed)	3.0
• Strategic vision (competency)	2.8	• Strategic vision (responsiveness)	2.5
• Co-operation(Internal/external, competency)	2.9	• Cost effectiveness	2.5
• Change management (competency)	2.7	• High rate of new products introduction (competency)	2.5
• High rate of new products introduction (competency)	2.5	• Products and services delivery quickness and timeliness (speed)	2.5
• Knowledgeable, competent, and empowered people (competency)	2.5	• Products/services quality (competency)	2.0
• Organisation and organisational issues flexibility (flexibility)	2.5	• Quick new products time-to-market (speed)	1.5
• People flexibility (flexibility)	2.3	• Integration (competency)	N/A

Table 6.12. Continued

INCREASING RATE OF INNOVATION		PRODUCT LIFE TIME SHARINKAGE	
Capabilities	Wts	Capabilities	Wts
• Strategic vision (competency)	4.2	• Product model/configuration flexibility (flexibility)	4.3
• Sensing, perceiving and anticipating changes (responsiveness)	4.0	• Quick new products time-to-market (speed)	4.3
• Appropriate technology/Sufficient technological ability (competency)	4.0	• Products and services delivery quickness and timeliness (speed)	4.3
• Knowledgeable, competent, and empowered people (competency)	4.0	• Product volume flexibility	4.0
• Immediate reaction to change by effecting them into system (responsiveness)	3.8	• Sensing, perceiving and anticipating changes (responsiveness)	3.8
• Change management (competency)	3.8	• Fast operations time (speed)	3.8
• Product model/configuration flexibility (flexibility)	3.8	• Strategic vision (responsiveness)	3.5
• People flexibility (flexibility)	3.8	• High rate of new products introduction (competency)	3.5
• Recovery from change (responsiveness)	3.6	• Immediate reaction to change by effecting them into system (responsiveness)	3.3
• High rate of new products introduction (competency)	3.6	• Organisation and organisational issues flexibility	3.0
• Quick new products time-to-market (speed)	3.6	• People flexibility (flexibility)	3.0
• Co-operation(Internal/external, competency)	3.2	• Change management (competency)	2.8
• Operations efficiency and Effectiveness-leanness (competency)	3.0	• Co-operation (internal/external, competency)	2.8
• Organisation and organisational issues flexibility (flexibility)	3.0	• Products/services quality (competency)	2.5
• Products/services quality (competency)	2.8	• Cost effectiveness	2.5
• Integration (competency)	2.8	• Recovery from change	2.3
• Products and services delivery quickness and timeliness (Speed)	2.6	• Appropriate technology/sufficient technological ability (competency)	2.3
• Cost effectiveness (competency)	2.4	• Knowledgeable, competent, and empowered people (competency)	2.3
• Product volume flexibility (flexibility)	2.4	• Operations efficiency and effectiveness-leanness (competency)	2.3
• Fast operations time (speed)	2.1	• Integration (competency)	2.3

Table 6.12. Continued

RESPONSIVENESS OF COMPETITORS TO CHANGES		NATIONAL AND INTERNATIONAL POLITICAL CHANGES	
Capabilities	Wts	Capabilities	Wts
• Sensing, perceiving and anticipating changes (responsiveness)	4.3	• Strategic vision (responsiveness)	3.3
• Strategic vision (competency)	4.3	• Sensing, perceiving and anticipating changes (responsiveness)	3.0
• Operations efficiency and Effectiveness-leanness (competency)	4.3	• Cost effectiveness	
• Products/services quality (competency)	4.0	• Knowledgeable, competent, and empowered people (competency)	2.8
• Recovery from change (responsiveness)	3.8	• Co-operation (internal/external, competency)	2.8
• Change management (competency)	3.8	• Products/services quality (competency)	2.5
• Immediate reaction to change by effecting them into system (responsiveness)	3.5	• Change management (competency)	2.5
• Product model/configuration flexibility (flexibility)	3.3	• Products and services delivery quickness and timeliness (speed)	2.5
• Products and services delivery quickness and timeliness (Speed)	3.5	• People flexibility (flexibility)	2.3
• Fast operations time (speed)	3.5	• Immediate reaction to change by effecting them into system (responsiveness)	2.0
• Appropriate technology/Sufficient technological ability (competency)	3.3	• Recovery from change	2.0
• Cost effectiveness (competency)	3.3	• Operations efficiency and effectiveness-leanness (competency)	2.0
• High rate of new products introduction (competency)	3.3	• Product volume flexibility	2.0
• Knowledgeable, competent, and empowered people (competency)	3.3	• Product model/configuration flexibility (flexibility)	2.0
• Co-operation(Internal/external, competency)	3.3	• Organisation and organisational issues flexibility	2.0
• Product volume flexibility (flexibility)	3.3	• Quick new products time-to-market (speed)	2.0
• Organisation and organisational issues flexibility (flexibility)	3.3	• Appropriate technology/sufficient technological ability (competency)	1.8
• People flexibility (flexibility)	3.3	• Integration (competency)	1.8
• Quick new products time-to-market (speed)	3.0	• Fast operations time (speed)	1.8
• Integration (competency)	2.8	• High rate of new products introduction (competency)	1.3

Table 6.12. Continued

INCLUSION OF NEW SOFT TECHNOLOGY IN (NEW) HARD AND SOFT TECHNOLOGY	
Capabilities	Wts
• Appropriate technology/Sufficient technological ability (competency)	4.3
• Change management (competency)	4.0
• Cost effectiveness (competency)	3.7
• Knowledgeable, competent, and empowered people (competency)	3.7
• Integration (competency)	3.5
• Strategic vision (competency)	3.3
• High rate of new products introduction	3.3
• Product model/configuration flexibility (flexibility)	3.3
• Products/services quality (competency)	3.0
• Operations efficiency and Effectiveness-leanness (competency)	3.0
• Co-operation(Internal/external, competency)	3.0
• Product volume flexibility (flexibility)	2.7
• Organisation and organisational issues flexibility (flexibility)	2.7
• People flexibility (flexibility)	2.7
• Quick new products time-to-market (speed)	2.7
• Products and services delivery quickness and timeliness (Speed)	2.7
• Sensing, perceiving and anticipating changes (responsiveness)	2.3
• Immediate reaction to change by effecting them into system (responsiveness)	2.3
• Recovery from change (responsiveness)	2.0
• Fast operations time (speed)	2.0

Table 6.12. Continued

APPENDIX F - TOOLS FOR ASSESSING AGILITY (NEEDS AND CURRENT LEVEL) IN MANUFACTURING ORGANISATIONS

Direction for completing the assessment tools

1. Questions throughout the first tool are followed by a ticking box to check the relevance of the question to the matter of turbulence of the business environment ("♦ Irrelevant"). Please specify by ticking the box if you think the question is irrelevant to the subject or your company's circumstances do not conform with it.
2. For each question of tools one and two please indicate a number on the provided continuum to represent the closest position of the company with regard to the questioned subject.
3. At the end of tool number one in page 17 a guide is given for calculating the level of the need of the company for agility.

TOOL NUMBER ONE - Assessing the level of need to agility

1. MARKETPLACE

1.1. How is the trend of the market demand function for the company's products [with regard to its predictability] ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= constant and no change 10 = very variable and unpredictable

1.2. How often does the company have to review the market's demands in order to monitor its ***stability***? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= once a year 10 = weekly

1.3. How has the trend of market fragmentation and niche market growth for the company's products been in the past five years ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= No changes 10 = No. of markets has multiplied

1.4. What kind of market needs does the company have to respond to ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= Easily defined and standardised products

10= uncertain needs and individual requirements (especially designed and one-off)

1.5. What kind of products does the company sell ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= basic necessities 10= luxuries

1.6. How price-conscious are markets/customers ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low prices-conscious (loyal to the company regardless of the price)

10= High price-conscious (easily switch to better deals)

1.7. What percentage of the company's marketshare has been gained or lost in the past 3 years due to price-consciousness of markets/customers ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= 0% 10 = 100%

1.8. How fashion oriented is the market for the company's products? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= Not at all 10 = Highly fashion oriented

1.9. How important is following the fashion in product development for the company in order to keep its position in the market? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1 = not at all 10 = vital

1.10. How is the average rate of changes in product models in the marketplace [in the area where the company competes] ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and decreasing 10 = high and increasing

1.11. How fast has the above trend of change been for the company ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= Slower than the company's movement in introducing new changes

10 = A multiple of the changes the company has introduced

1.12. How is the market (buyer) power in

1.12.1. Defining the needs [specification. configuration]? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= No influence 10= Market driven

1.12.2. Determining the price ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= No control by market 10= market defines the price for suppliers

1.12.3. Determining the delivery time? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= No influence 10= Market driven

1.12.4. Determining the quality and reliability of products? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= No influence 10= Market driven

1.13. Percentage of the potential markets/customers to which the type of company's products have reached [market saturation]? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= 0 % 10= 100%

1.14. Percentage of company's products for which markets are saturated? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= 0% 10= 100%

1.15. How is the average life cycle of the company's products [from introduction to its withdrawal] ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= Long (>10 years) 10= short (<1 year)

1.16. How has the trend of products life cycles been in the past 5 years (decreasing - increasing) ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= increasing 10= decreasing

1.17. How predictable and planned is the life cycle of the company's products (predictable - unpredictable) ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= easily predictable and planned in advance

10= unpredictable and adhoc

1.18. For what percent of products has the company faced an unpredicted/unprecedented change in their life cycle [imposed by the market and competitors] ?♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= 0% 10= 100%

2. COMPETITION

2.1. Number of direct competitors in local markets? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= few and decreasing 10= many and increasing

2.2. Number of competitors in global markets ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= few and decreasing 10= many and increasing

2.3. How intense is the competition and battle for marketshare in local markets? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= comfortable and easy competition

10= highly intense and fierce competition

2.4. How intense is the competition and battle for marketshare in global markets? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= comfortable and easy competition

10= highly intense and fierce competition

2.5. Average strength and responsiveness of the company's direct competitors in comparing with company's position? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

2.6. How challenging is gaining and maintaining competitive advantage for the company considering the competitors? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= not difficult 10= very challenging and difficult

2.7. Type of competition the company is involved in ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= competition on price only

10= competition on product differentiation/time/quality

2.8. Trend of new entrances to market [where the company competes]? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

2.9. Number of substitutes for the company's products? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= none 10= many

2.10. Rate of introduction of new substitute products into the market by competitors ? ♦

Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

3. CUSTOMER REQUIREMENTS

3.1. Type of the desire of the company's customers? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= homogeneous 10= heterogeneous

3.2. How is the rate of changes in customers' requirements? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low (only for a few number of products and rarely) and slow

10= high (for most of products and very often) and quick

3.3. How often do changes in customers' requirements happen for the company? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= on less than 10% of orders/products

10= on almost 100% of orders/products

3.4. How often does the company have to retool its manufacturing system because of changes in the customer requirements ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= never 10= on a daily to weekly basis

3.5. How critical is the quality of products for your customers? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

3.6. How has the rate of changes in the customers' expectations for quality [in concept and practice] been in the past 5 years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= high

3.7. What quality means to your customers and your company? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= statistically meeting specifications 10= customer satisfaction

3.8. To what extent has the company had to amend and adjust its systems with changes in customers' expectations for quality during the few past years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= total renovation

3.9. How critical is fast/on-schedule delivery time for your customers? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= high

3.10. How has the customers' expectations for delivery time been changing in the past 5 years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= high

3.11. To what extent has the company had to amend and adjust its systems with changes in the customers' expectations for delivery time during the few past years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= total renovation

4. TECHNOLOGY

4.1. Number of newly introduced product technologies and process technologies [hard facilities, material, software, methods] in the area of the company's business in the past few years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= not at all 10= many

4.2. Rate of change in introduction of new product technology and process technology related to the company's business area? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

4.3. To what extent has the company had to amend and adjust its systems with changes in product and process technology in the past few years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= total renovation

5. SOCIAL FACTORS

5.1. Pressure for environmental health, more secure and safer products and services, waste treatment, etc. ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no pressure 10= high pressure

5.2. To what extent has the company had to amend and adjust its systems and products to comply with the requirements for a healthy environment in the few past years? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no change 10= total renovation

5.3. Change in the number and severity of regulations with regard to environment? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

5.4. Number and change rate of regulations and laws effecting the normal trend of the company's business? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

5.5. Rate of change in the governmental policies with regard to :

5.5.1. Trade union protection and negotiations ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

low and no change 10= high and increasing

5.5.2. Deregulation of industries ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

5.5.3. Research support and creation of incentive for investment ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

5.5.4. Privatisation ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

5.6. Occurrence of severe economic changes such as recession, inflation, growth or decline, etc.? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low and no change 10= high and increasing

5.7. Dependence of the company on such changes that the company happens to face? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= no dependence 10= highly depended

5.8. Extent of the effects the company has received in the past 5 years from the economic changes?

5.8.1. Loss of marketshare/customers ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

5.8.2. Loss of human resources ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

5.8.3. Loss of assets value ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

5.8.4. Loss of competency ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

5.9. Rate of changes in international political/economic issues related to the company's business [where the company competes in]? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

6. SUPPLIERS

6.1. Number of suppliers [main] on which the company's business is depended on? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low (♋ 10) 10= high (♍ 80)

6.2. Dependence of the company's products quality, manufacturing processes, and delivery time on the suppliers' performance? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low 10= high

6.3. Reliability, strength, and responsiveness of the company's suppliers ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= high 10= low

7. PRODUCTS/PROCESS COMPLEXITY

7.1. Number of products/product families manufactured ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= few (♋ 5) 10= many (♍ 100)

7.2. Number of parts in products [average for the company] ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= few 10= high

7.3. Number of sub-assemblies in products [average for the company] ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= few 10= high

7.4. Complexity of technology used in products [average for the company] ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= low (ordinary consumable products)

10= high (aerospace products)

7.5. Number of stages products pass during the manufacturing ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1= a few 10= high

7.6. Complexity of the technology involved in the manufacturing process? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1=low (hand tools)

10= high (high-tech/robots/CIM)

7.7. Complexity of products design process ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1=low 10= high

7.8. Complexity of manufacturing planning and control processes ? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1=low 10= high

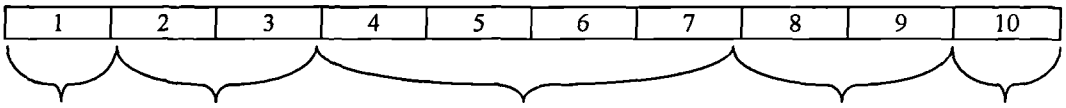
7.9. Complexity of manufacturing processes including assembly operations? ♦ Irrelevant

1	2	3	4	5	6	7	8	9	10

1=low 10= high

After scoring the factors on the given scales, the average score will indicate the position of the company on the following continuum ;

Low Turbulence of the Business Environment — High Turbulence of the Business Environment



Low level of need to agility

High level of need to agility

Very Low level of agility [No need]

Moderate level of need to agility

Very High level of need to agility [Vital]

1. Regardless of the above questions what would you consider as the degree of turbulence of the business environment for the company ?

1	2	3	4	5	6	7	8	9	10

TOOL NUMBER TWO - Determining agility level of a firm

FOR ALL QUESTIONS **1 = VERY LOW AND 10 = VERY HIGH**

1. Detecting, analysing, and understanding changes [RESPONSIVENESS]

1-1. Ability of the company in detecting the changes in

- Marketplace (market's structure/demand/needs/taste or fashion/.) (1.1, 1.2, 1.3, 1.4, 1.8)

1	2	3	4	5	6	7	8	9	10

- Competitors' activities and position (2.3, 2.4)

1	2	3	4	5	6	7	8	9	10

- Customer demands and needs (3.2)

1	2	3	4	5	6	7	8	9	10

- Technology (4.2)

1	2	3	4	5	6	7	8	9	10

- Political/social/economic factors (5.1, 5.3, 5.5, 5.6)

1	2	3	4	5	6	7	8	9	10

- Suppliers' activities and position

1	2	3	4	5	6	7	8	9	10

1-2. Quickness and efficiency of the company in analysing the information and data received about the changes in the business environment, and affecting them into its systems [Responsiveness, Competency] ;

- Top level management concern and commitment

1	2	3	4	5	6	7	8	9	10

- Considering in top level/strategic planning of the company

1	2	3	4	5	6	7	8	9	10

- Conducting strategic, marketing, technical, financial analysis of the information in the direction of the company's competitive advantage

1	2	3	4	5	6	7	8	9	10

- Interorganisational transfer of the information and resulted outputs

1	2	3	4	5	6	7	8	9	10

2. Ability of the company in producing high level of pre- and pro-sales and services and using it as a leverage [Competency] ?

1	2	3	4	5	6	7	8	9	10

3. Ability of the company in exact understanding of the buyer (market) needs [Responsiveness] .

1	2	3	4	5	6	7	8	9	10

4. Ability of the company in convincing (satisfying) the market with its products' specification, quality, price, delivery time [Responsiveness, Competency].

1	2	3	4	5	6	7	8	9	10

5. Ability of the company in directing market's needs to the company's products and services [Competency].

1	2	3	4	5	6	7	8	9	10

6. Ability of the company in profitable presenting in saturated markets [Responsiveness, Competency]. (1.13, 1.14)

1	2	3	4	5	6	7	8	9	10

7. Ability of the company to keep up with the changes in the products life cycles, and controlling its products life cycles in order to obtain a competitive advantage [Responsiveness, Competency, Flexibility]. (1.15, 1.16)

1	2	3	4	5	6	7	8	9	10

8. Ability of the company in understanding and predicting the trend of products life cycles [Responsiveness, Competency]. (1.17, 1.18)

1	2	3	4	5	6	7	8	9	10

9. Ability of the company in maintaining or progressing its position among its direct competitors in local markets in the current situation [Competency]. (2.1)

1	2	3	4	5	6	7	8	9	10

10. Ability of the company in maintaining or progressing its position among its direct competitors in global markets in the current situation [Competency]. (2.2)

1	2	3	4	5	6	7	8	9	10

11. Trend of change in the company's marketshare in the past few years considering the intensity of competition (decreasing - increasing) [Competency].

1	2	3	4	5	6	7	8	9	10

12. Relative strength and responsiveness of the company in comparison with its competitors (2.3, 2.4, 2.5):

- Cost effectiveness [Competency]

1	2	3	4	5	6	7	8	9	10

- Investment and development (expansion) [Responsiveness, Competency]

1	2	3	4	5	6	7	8	9	10

- Customer satisfaction [Competency]

1	2	3	4	5	6	7	8	9	10

- Quick/on time delivery [Quickness]

1	2	3	4	5	6	7	8	9	10

- Quality [Competency]

1	2	3	4	5	6	7	8	9	10

- Response to unpredicted incidents [Responsiveness, Flexibility]

1	2	3	4	5	6	7	8	9	10

- Coping tensions and shocks in different aspects of the business [Responsiveness, Competency, Flexibility]

1	2	3	4	5	6	7	8	9	10

- New product introduction (time, number, innovativeness, cost effectiveness, ..) [Competency, Quickness, Flexibility]

1	2	3	4	5	6	7	8	9	10

13. Ability of the company in challenging and outperforming new entries to market [Competency]. (2.8)

1	2	3	4	5	6	7	8	9	10

14. Strategic basis for the company in competition (Competition on price - Competition on product differentiation/time/quality) [Competency]. (2.7)

1	2	3	4	5	6	7	8	9	10

15. Ability of the company in differentiating its products [Competency, Flexibility, Quickness].

1	2	3	4	5	6	7	8	9	10

16. Ability of the company in responding accordingly to the substitutes introduced into markets for its products by competitors [Responsiveness, Flexibility, Quickness]. (2.9, 2.10)

1	2	3	4	5	6	7	8	9	10

17. Rate of introduction of new products by the company in the past three years (decreasing - increasing) [Responsiveness, Flexibility, Quickness]. (2.9, 2.10)

1	2	3	4	5	6	7	8	9	10

18. Ability of the company in responding to heterogeneous desires of customers [Flexibility, Competency]. (3.1)

1	2	3	4	5	6	7	8	9	10

19. Speed of the company's response to the changes required by customers in their orders [Quickness, Flexibility]. (3.2)

1	2	3	4	5	6	7	8	9	10

20. Percent of changes in customers requirements which can be handled by the company [Competency, Flexibility]. (3.2, 3.3, 3.4)

1	2	3	4	5	6	7	8	9	10

21. Ability of the company in providing high quality as standard and totally satisfying customers [Competency]. (3.5, 3.6, 3.7)

1	2	3	4	5	6	7	8	9	10

22. Success of the company in keeping its customers satisfied with cost, quality, delivery time, flexibility in the past 3 years [Responsiveness, Competency, Flexibility, Quickness]. (Low, declining - High, increasing)

1	2	3	4	5	6	7	8	9	10

23. Where is the company located for its possessing technology considering the highest available level [Competency]. (4.1, 4.2)

1	2	3	4	5	6	7	8	9	10

24. Percentage of the company's in-use technology as a result of renovation with regard to the newly introduced technology into the market in the past few years [Responsiveness, Competency]. (4.1, 4.2)

1	2	3	4	5	6	7	8	9	10

25. Level of changes in the company's processes technology including material and software in response to the newly introduced technologies into the market in the past few years [Responsiveness, Competency]. (4.1, 4.2)

1	2	3	4	5	6	7	8	9	10

26. Ability of the company in standing the new environmental pressures and regulations, coping with changes in them, and adjusting its systems with these changes [All Capabilities] (5.1, 5.3):

- Marketing activities and product definition

1	2	3	4	5	6	7	8	9	10

- Planning

1	2	3	4	5	6	7	8	9	10

- Design

1	2	3	4	5	6	7	8	9	10

- Manufacturing

1	2	3	4	5	6	7	8	9	10

- Control

1	2	3	4	5	6	7	8	9	10

- Waste management

1	2	3	4	5	6	7	8	9	10

27. Ability of the company in dealing with trade unions and the government supports from them [Competency]. (5.5.1)

1	2	3	4	5	6	7	8	9	10

28. Ability of the company in taking advantage of new opportunities provided by the government support for research and/or investments and/or privatisation [Responsiveness, Competency]. (5.5.3, 5.5.4)

1	2	3	4	5	6	7	8	9	10

29. Ability of the company in coping with or taking advantage of economic changes [Responsiveness, Competency] (5.6, 5.7) :

- Recession

1	2	3	4	5	6	7	8	9	10

- High inflation rates

1	2	3	4	5	6	7	8	9	10

- Growth/Decline

1	2	3	4	5	6	7	8	9	10

30. Ability of the company in standing and/or taking advantage of international political/economic changes [Responsiveness, Competency]. (5.9)

1	2	3	4	5	6	7	8	9	10

31. Ability of the company in managing its suppliers [Responsiveness, Competency].

1	2	3	4	5	6	7	8	9	10

32. Ability of the company in constructing a strong relationship with suppliers and take them as partners [Competency]. (6.1, 6.2)

1	2	3	4	5	6	7	8	9	10

33. Ability of the company in substituting non-conforming suppliers with new ones and recovering the tensions and problems caused by this action [Competency]. (6.3)

1	2	3	4	5	6	7	8	9	10

34. Effectiveness of the communication and information distribution within the organisation [All Capabilities].

1	2	3	4	5	6	7	8	9	10

35. Ability of the company in reorganising its organisation according to the different changes that may necessitate this action [Competency, Flexibility].

1	2	3	4	5	6	7	8	9	10

36. Capability of the people in the company in coping with sudden changes in programmes affected by the management [Competency, Flexibility]

1	2	3	4	5	6	7	8	9	10

37. Ability of the company in establishing close cooperatin with other companies in the form of [All Capabilities]:

- Joint venture

1	2	3	4	5	6	7	8	9	10

- Virtual organisation

1	2	3	4	5	6	7	8	9	10

- Partnership

1	2	3	4	5	6	7	8	9	10

38. Ability of the company in restructuring, rearranging, retooling and adjusting its production lines with changes in the business environment.

1	2	3	4	5	6	7	8	9	10

39. Ability of the company in fast problem solving and providing quick reaction to sudden problems :

- In strategic management levels

1	2	3	4	5	6	7	8	9	10

- In medium management levels

1	2	3	4	5	6	7	8	9	10

- In operational levels

1	2	3	4	5	6	7	8	9	10

1. Regardless of the above questions what would you consider as the ability of the company in responding appropriately to changes (Anticipated/Unpredicted/Unprecedented) in the business environment ?

1	2	3	4	5	6	7	8	9	10

APPENDIX G - LIST OF PAPERS PRODUCED DURING THE RESEARCH

1. H Sharifi, Prof. I Barclay, Prof. P Gough; "Agility Drivers and a conceptual framework for introducing agile manufacturing into production development", Advances in Industrial Engineering Applications and Practice, Proceeding of the 1st Annual International Conference on Industrial Engineering Applications and Practices, Houston, Texas, USA, Dec. 4-7, 1996
2. H Sharifi, Prof. P Gough, Prof. I Barclay, "Moving towards agility; a way for UK Manufacturing Industry to go", IEE 5th International conference on Factory 2000, The technology Exploitation Process, 2-4 April 1997, Churchill College, Cambridge, UK.
3. H Sharifi, Z Zhang; "Enabling practices assisting achievement of agile manufacturing", Sixth IASTED International Conference; Robotics and Manufacturing; July 26-31, 1998, Banff, Canada
4. H Sharifi, Z Zhang; "A methodology for achieving agility in manufacturing organisations; An introduction"; Special Issue on Agile Manufacturing, International Journal of Production Economics, May, 1999.
5. Z Zhang, H Sharifi, "Agile Manufacturing, A methodological Approach", Progress in Rapid Prototyping Manufacturing and Rapid Tooling, Proceedings of the first International Conference on Rapid Prototyping and Manufacturing '98, Beijing, China
6. Z Zhang, H Sharifi; "A methodology for achieving agility in manufacturing organisations", International Journal of Operations and Production Management, TO BE PUBLISHED
7. H Sharifi, Prof. I Barclay; "Agile Manufacturing, A structured perspective"; IEE workshop on responsiveness in manufacturing, 23rd February 1998, IEE, Savoy place, London
8. H Sharifi, Z Zhang; "Agile Manufacturing in Practice; Application of a Methodology", Accepted for publication in Special Issue on Next Generation Manufacturing: Manufacturing in the 21st Century, International Journal of Operations and Production Management, January 1999.