DETERMINING INFORMATION SYSTEMS CONTRIBUTION TO MANUFACTURING AGILITY FOR SME's IN DYNAMIC BUSINESS ENVIRONMENTS.

A thesis submitted for the degree of Doctor of Philosophy

By

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Abstract

Since the concept of agile manufacturing was coined in the early nineties, the study of the contribution of information systems to agility has lacked a thorough analysis. Information systems have been labelled in the academic literature as critical, key and important in achieving and supporting agility. On the other hand, there is a large number of documented cases where IS have failed to deliver expected benefits. The aim of this study has been to determine the contribution of information systems to manufacturing agility. This study required the development of a research survey with the purpose of testing seven IT/IS proficiency characteristics of agility, three characteristics of a dynamic business environment and the type of IS applications used in manufacturing organisations. The analysis of the survey suggested that the business environment does not exert great influence on the IT/IS proficiency characteristics; also no association was found with the use of a specific type of manufacturing IS and the IT/IS proficiency characteristics. The results of the analysis of the survey were further expanded in a multiple case-study. Profitable SMEs with some agile processes in place participated in a multiple case-study that covered the agility of manufacturing and other business process, business and IT strategies, and skills and expertise of employees affecting the realisation of benefits of IS. The study revealed that information systems are neither the most important, the most overwhelming, the most difficult part of the equation to achieve agility nor are they principal enablers of manufacturing. Identified principal enablers of agile manufacturing include providing training to employees, right attitude of workforce towards change, having a flexible manufacturing base and people's knowledge and skills. Moreover, the use of low performing information systems was not an impediment to moving towards agility. The results of the multiple case-study tend to indicate that information systems play a more significant role in enhancing agility once principal enablers have been implemented. Certainly, IS may be required to support manufacturing agility but that information systems are not sufficient to achieve it. The study revealed that skills and expertise of people were used as means to overcome the problems and shortcomings generated by low performing IS. A new taxonomy of enablers of agility has been defined, identifying IS as second-order enablers of agility. Also, a proposed new framework has considered the adoption of an IT strategy to influencing a business strategy as a mean of enhancing the agility of business processes already achieved through the implementation of principal enablers.

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List of Abbreviations and Glossary of Terms.

AGV: Automatic Guided Vehicles.

AI: Artificial Intelligence.

ATM: Asynchronous Transfer Mode.

APS: Advanced Planning and Scheduling.

B2B: Business to Business.

B2C: Business to Customer.

BPR: Business Process Reengineering.

CAD: Computer Aided Design.

CAE: Computer Aided Engineering.

CALS: Computer Aided Logistic-Systems.

CAM: Computer Aided Manufacturing.

CAPP: Computer Aided Process Planning.

CBA: Cost Benefit Analysis.

CEO: Chief Executive Officer.

CIM: Computer Integrated Manufacturing.

CIO: Chief Information Officer.

CNC: Computer Numerically Controlled.

COTS: Commercial Off The Shelf.

CSCW: Computer Supported Collaborative Work.

DBMS: Database Management System.

EC: Electronic Commerce.

EDI: Electronic Data Interchange.

ERP: Enterprise Resource Planning.

EVA: Economic Value Added.

IRR: Internal Rate of Return.

IS application: An application programme is a programme designed to perform a specific function directly for the user or, in some cases, for another application programme.

IS platform: a platform is an underlying computer system on which application programmes can run.

ISDN: Integrated Services Digital Network.

JIT: Just-in-Time.

LAN: Large Area Network.

Middleware: any programming that serves to "glue together" or mediate between two separate and usually already existing programmes.

MRP: Materials Requirements Planning.

MRPII: Manufacturing Resource Planning.

MVA: Market Value Added.

Netware: the most widely-installed network server operating system.

NPV: Net Present Value.

RAD: Rapid Application Development.

PC: Personal Computer.

PLC: Programmable Logic Controller.

ROI: Return of Investment.

SCM: Supply Chain Management.

SME: Small Medium Enterprise.

SPC: Statistical Process Control.

SPSS: Statistical Package for the Social Sciences.

TCO: Total Cost of Ownership.

TQM: Total Quality Management.

WAN: Wide Area Network.

WIP: Work In Progress

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Chapter 1

Introduction:
Agile Manufacturing and Information Systems.

1.1 The need of manufacturing organisations to become agile.

Nowadays it is common to read news like this:

> *"Lucent technologies optical networking unit had failed to properly gauge its customers' changing buying patterns, and it lacked the manufacturing capacity to keep up with the red-hot demand for new, high-speed optical-networking equipment".*

The outcome of the situation is as follows:

> *"The company has failed behind rivals in introducing new-generation products, and it lost market share and customers".*

Wired News. Note on Lucent technologies optical networking unit after quarter profits fell below expectations, 28/07/2000 (Wired News 2000).

According to Mason-Jones (2000) getting the right product, at the right price, at the right time to the consumer is not only the linchpin to competitive success but also the key to survival. Manufacturing organisations need to be able to react to those situations where demand is volatile.

The need to become agile has been recognised for the last ten years. A decade before the concept of agile manufacturing was coined, Cooper (1983) described that the next generation of process models should be fluid, adaptable, conditional, situational and flexible. Smithson and Hirscheim (1998) stated that the key requirement for organisations to survive in a harsh environment are flexibility and speed of response to market changes, as well as the ability to innovate, in both product and process. According to these researchers, high productivity remains essential and there is a constant need to improve product and customer service. On the other hand, the classic organisation's structure is suffering drastic changes: traditional bureaucratic hierarchies are moving away to give place to new forms of work like cross-functional teams, networked organisations and virtual organisations.

Kidd (1994) emphasised that agile manufacturing is not another programme of the month or any other fashionable buzzword. Agile manufacturing is primarily a business concept. Goldman et al. (1995) have provided one of the most known definitions of agile manufacturing:

> *"For a company, to be agile is to be capable of operating profitably in a competitive environment of continually, and unpredictably, changing customer opportunities".*

Gunasekaran's (1998) definition of agile manufacturing expanded the original definition proposed by the Agility Forum. The researcher defined agile manufacturing as the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services. Other practitioners like Brandt (1998), have defined agile manufacturing as the linking of operations of co-operating enterprises to respond to changing market needs. In fact, agility means changing the paradigms of traditional manufacturing. In the view of Jagdev and Browne (1998), a traditional mass-production company is bureaucratic and hierarchical, under close supervision, workers repeat narrowly defined, repetitive tasks resulting in low-cost, standardised goods and services.

Agile manufacturing contemplates the integration of the organisation's highly skilled and knowledgeable people and advanced technologies to achieve co-operation and innovation in response to the need to supply customers with high quality customised products.

According to Kidd (1994), agile manufacturing is achieved through the integration of three primary resources into a co-ordinated, interdependent system. These primary resources are:

a) Organisation, innovative management structures and organisations.
b) People, a skill base of knowledgeable and empowered people.
c) Technology, flexible and intelligent technologies.

Figure 1.1 depicts the three primary resources for agile manufacturing enterprises described by Kidd (1994).

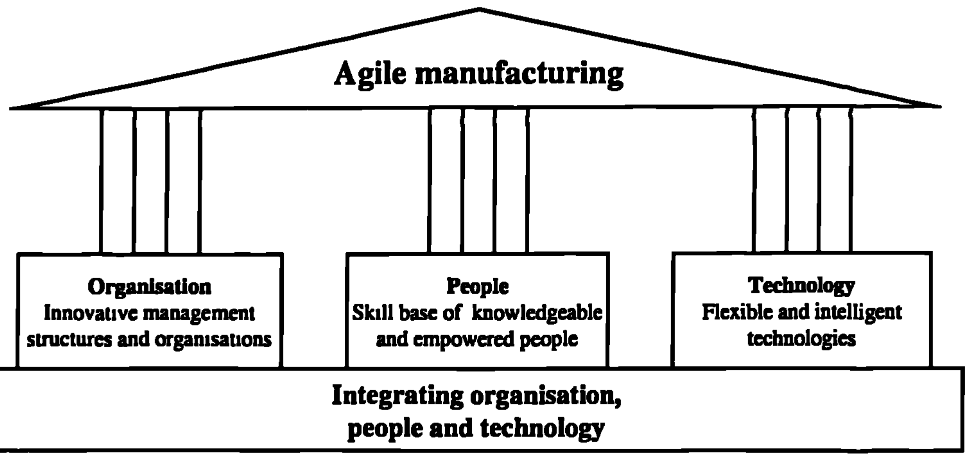

Figure 1.1 Structure of agile manufacturing enterprises.
Source: Kidd (1994).

Kidd (1994) described that agile manufacturing enterprises will be capable of responding rapidly to changes in customer demand. These enterprises will be able to take advantage of the windows of opportunity that, from time to time, appear in the market place. An agile enterprise needs new forms of organisational structures that engender non-hierarchical management styles and stimulate and support individuals, as well as co-operation and team working. Goldman et al. (1995) emphasised that in agility, choice is driven by consumers.

The concept of agile manufacturing emerged after lean manufacturing was introduced in the industry. According to Kalakota and Whinston (1997*l*) a lean manufacturing policy should try to achieve efficient use of resources through the enhancement of mass-production methods. The same researchers emphasised that agility goes beyond the concept of doing everything with less. Lean manufacturing is necessary for agile manufacturing but is not sufficient.

Agile manufacturing means shifting from the mass-production model to producing highly customised products. Kalakota and Whinston (1997_{II}) considered agile manufacturing as a concept that moves towards economies of scope instead of economies of scale, serving small market niches with minimum quantities and without the high costs of tailored solutions. For example, table 1.1 presents some of the basic differences between agile manufacturing and lean manufacturing identified in the academic literature.

Context	Agile Manufacturing	Lean Manufacturing
Product-line	Economies of scope	Economies of scale
View	Enterprise wide	Shop floor
Organisation	Rapid formation of multi-company alliances	Enterprise collaboration
Organisation structure	Dynamic	Bureaucratic and hierarchical

Table 1.1 Main differences between agile and lean manufacturing.

Kalakota and Whinston (1997_{II}) showed that agile manufacturing enterprises seek to achieve the following attributes:

- Greater product customisation.
- Rapid introduction of new or modified products.
- Interactive customer relationships.
- Dynamic reconfiguration of production processes.

According to Mason-Jones et al. (2000) agile manufacturing is adopted where demand is volatile, and lean manufacturing adopted where there is stable demand. Other researchers like Kidd (1994), have showed that lean is concerned with manufacturing products with less of everything, less time to design, less inventory, less defects, and so forth. In agile manufacturing the aim is to combine the organisation, the people and technology into an integrated and coordinated whole.

The agility arising from this integration can be used for competitive advantage, by being able to respond rapidly to continuous changes in the business environment and through the use and exploitation of skills and knowledge.

Gunneson (1997) developed a self-diagnostic maturity grid designed to sketch progress in the agile change domains of organisation, management, people and team-work. In this self-diagnostic maturity grid, lean is referred to as the flat and flexible, concurrent, efficient, customer-focused organisation of today. While agile is the fast, rapidly reconfigurable, self-directed, customer and supplier-integrated, virtual organisation of the future.

Mason-Jones et al. (2000) provided some definitions relating the agile and lean manufacturing paradigms in terms of supply chain strategies. The definitions provided by the researchers are intended to emphasise the features of each concept. According to them agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. While leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule. In lean production, the customer buys specific products, whereas in agile production the customer reserves capacity that may additionally need to be made available at very short notice.

1.2 Information Technology and Information Systems.

The pace of change in technology is one of the forces that are shaping the future business environment. Information technology/information systems are part of this technology in constant change. The information in the world is doubling every 18 months (Next Generation Manufacturing Project 1997) thus emphasising the importance of information technology/information systems for any organisation.

Information movement may take place between humans, humans and machines, and/or between machines. Information management assures the proper selection, deployment, administration, operation, and maintenance of the information technology assets.

Many people regard the concepts of information technology and information systems as synonymous. Angell and Smithson (1991) described that information systems are social systems whose behaviour is heavily influenced by the goals, values and beliefs of individuals and groups, as well of as the performance of the technology. Willcocks (1994) identified differences between Information Technology (IT) and Information Systems (IS). The researcher described information technology as the hardware, software and communication technologies, essentially equipment. While information systems represent a wider concept referring to how designed information flows attempt to meet the information needs of the organisation. Information systems may be more, or less, information technology based.

Boar (1994) described information technology as the asset on which the enterprise constructs its business information systems. Information technology is the preparation, collection, transport, retrieval, storage, access, presentation and transformation of information in all its forms (voice, graphics, text, video, and image).

The concept of information systems is broader than that of information technology. Information systems encompass the whole range of procedures that are in place in an organisation (Ezingeard 1996). Information systems have been defined as the set of applications that gather individuals and information flow on information technology based devices and infrastructure.

Technology developments and changing conditions in the business environment are forcing organisations to be more dependent on IT/IS. Information technology enables information flow between different business units of the organ'sation. Changes in market conditions and customer needs are putting pressure on manufacturing organisations to acquire the technology that will help them to cope with highly-competitive markets.

1.2.1 Information Technology/Systems in agile manufacturing.

In the view of Gunneson (1997), information systems for agile manufacturing enable the exchange and reuse of data through rapid communications and these are part of technologies for agility. As previously presented in figure 1.1, technology is a basic pillar of agility and IT/IS are part of such pillar.

The development of new technologies in IT/IS provides manufacturing organisations with tools to face competitive business environments. The Next Generation Manufacturing Project (NGM 1997) defined information systems as enablers to overcome the barriers to achieve attributes of next generation manufacturing enterprises. This project indicated that Next Generation Manufacturing enterprises will leverage new intelligent processes and flexible modular equipment to enable new levels of flexibility and responsiveness, and will augment human decision power with knowledge-based systems tapping a rich storehouse of captured knowledge. Next Generation Manufacturing (NGM) enterprises will have optimised manufacturing and it will satisfy not only the customer but all stakeholders.

Some barriers faced by NGM enterprises include: employee security without lifetime employment, rapid plant and cost recovery, satisfaction of all stakeholders needs, development of global markets and control of core competencies without owning them. According to the NGM project, information systems will impact the following attributes in a greater or lesser degree:

1. Customer responsiveness.
2. Plant and Equipment Responsiveness.
3. Teaming.
4. Human Resources Responsiveness.
5. Global Responsiveness.

The outcome of the NGM project recognised information systems as imperatives. Imperatives are generic enabling practices and technologies that are critical for achieving the attributes of NGM enterprises. In the NGM project, it is argued that the adoption of information systems lead to: reductions in product cost, reductions in cost of process development, enhancement in response, and mitigation of many of the risks associated with innovation.

The NGM project consisted of a series of reports on different imperatives. The report on Rapid Product Process Realisation determined four basic activities related to information systems. These include:

1. Information systems are used to perform system-level product/process tradeoffs between design features and real manufacturing feature costs.
2. Electronic databases used in the storage of all relevant information.
3. Set standards for unambiguous products/processes, digital data representation, and seamless, public but secure, accessible open systems exchange in a distributed environment.
4. Information systems are used to support new design processes and facilitate electronic commerce within and between the extended supplier chain.

The NGM project is a research work that has addressed the use of information technology/systems in manufacturing organisations facing a business environment in constant change. Today's global competitive markets demand manufacturing companies to increase their productivity. According to Kalakota and Whinston (1997$_{III}$) companies facing a global competitive environment should be aware of customer's needs. Manufacturers see product flexibility and mass customisation as necessary means for survival.

Developments on IT have enabled access to increasing on-line and real-time information. In manufacturing, this situation has provided the means for tracing parts and products within the production site. The utilisation of the Internet and World Wide Web are enabling access to information anywhere in the world. According to Gunasekaran (1998), the utilisation of the latest technological advances in information systems will give manufacturers more opportunities for cutting costs and to raise productivity. Benefits the researcher identified from the use of information systems to support agility include:

- Customer interactive computer systems that allow the customer or her/his representative to configure a design.
- Groupware that enables people located remotely from each other to work co-operatively.
- Improved multimedia human-interface systems.
- Enterprise-wide concurrent operations that cover all the functions of the company.

- Electronic commerce on international multimedia networks.
- Widespread use of networked distributed databases.
- Software 'agents' or 'borrowing' programs used to look for data on a network, answer requests, reply to proposals, order items and continuously update network-based catalogues.
- Open information systems in companies that make information much more widely and openly accessible than it is today.
- Software and computers that are much more powerful than those available today, enabling rapid and powerful simulations, modelling, analysis and approval of designs and production plans.
- Better mathematical understanding of representation methods used in design.
- Agreed communication and software standards.

The list of benefits is extensive and certainly many more could be added. However, the increase in the use of IT/IS in manufacturing organisations reminds the research community of the importance of materialising benefits from using IT/IS.

1.3 The importance of information systems evaluation.

The pressure to respond to changes in the business environment is driving some manufacturing organisations to invest in technology that will improve their business processes. Information technology is one of the areas that receive a considerable amount of expenditure in many organisations. Manufacturing organisations expect benefits from the use of information technology/information systems, making evaluation of IS an issue required in the development of agility policies.

Conrath and Sharma (1993) determined that the evaluation of computer-based information systems in general serves to five aspects. These include:

1) verify that the system meets requirements
2) provide feedback to development personnel
3) justify the adoption, continuation or termination of projects
4) clarify and set priorities for needed modifications
5) transfer responsibilities from developers to users

Angell and Smithson (1991) defined information systems evaluation as a cycle of "execution and feedback" and pointed out that the understanding gained from evaluation can be used to redirect efforts. Even though the problems to be dealt with are not entirely new, there is no general agreement or universally accepted methodology for the appraisal of information systems.

In the academic literature it is possible to find a large number of definitions of the evaluation of information systems. Farbey et al. (1999_1) provided a definition of IT evaluation that encapsulates the needs and expectations that organisations have when dealing with an assessment task:

> *"IT evaluation is a process, or group of parallel processes, which take place at different points in time or continuously, for searching and for making explicit, quantitatively or qualitatively, all the impacts of an IT project and the programme and strategy of which it is a part."*

Evaluation can provide useful guidelines for the implementation of successful strategic information systems. Evaluation gives an understanding of what information systems can and cannot do.

Myers et al. (1997) highlighted that credibility in identifying benefits from an information system is the top constraint followed by cost justification. Companies are aware of the potential benefits a new application can provide to them but on the other hand, companies are unable to quantify those benefits and therefore being sceptical of their scale. This scepticism may be strengthened by a degree of dischanment engendered with past experiences with IT projects.

The Compass World IT Strategy Census 1998-2000 (1998) reported that CEOs see the importance of information technology growing, but IT contribution is hard to measure. The executives surveyed agreed that information technology strongly influences corporate strategy, however the value of information technology remains difficult to measure.

According to Farbey et al. (1992), the role of information technology is changing from one of automating support functions in a quest for greater efficiency to one where core business processes are being transformed and wider strategic benefits are sought.

The evaluation of information systems is a problem that has been studied by researchers and practitioners for the last three decades. Examples include the works by Land (1976), Hirscheim and Smithson (1988), Angell and Smithson (1991), Farbey et al. (1992, 1999;), Willcocks (1994), Ballantine et al. (1994), Myers et al. (1997), Smithson and Hirscheim (1998), Weill and Vitale (1999). Also failure of IS projects has been widely documented (Ewusi-Mensah 1997, Buckhout et al. 1999, Abrahami 1999). The evaluation of information systems has been a main research topic for academic researchers and industry. Myers et al (1997) highlighted that information technology is often used without a full understanding of its applicability, effectiveness, or efficiency. Land and Hirshcheim (1983), showed that the complexity of information systems lies in the fact that information systems are social systems that evolve over time and so deciding when to carry out an evaluation is extremely difficult. According to Myers et al. (1997), measuring the effectiveness of information systems is consistently reported in the top 20 on the list of most important IS issues by the members of the Society for Information Management. Other researchers and practitioners like Niedermann et al. (1991) stated that the effectiveness of the IS function has proven practically impossible to define and measure. Researchers like Lincoln (1990) suggested that measuring information systems effectiveness is difficult because information systems evaluation is not adequately linked to business performance. Farbey et al. (1993) discussed evaluation as an important issue because not only IT evaluation is in doubt, but the value of the systems supported by the technology.

Many researchers and practitioners agree that the evaluation of information systems is a problem still with unsatisfactory answers. But why information systems evaluation is so important? Hirscheim and Smithson (1988) described IS evaluation as endemic to human existence. From a systems perspective, Angell and Smithson (1991) presented the evaluation of information systems as the provider of a basic feedback function to managers, as well as forming a fundamental component of the organisational learning process.

Farbey et al. (1992) described evaluation in organisations as a way to unite around a set of explicit common goals. Evaluation establishes the measures and, it is hoped, the motivation to achieve them. Those evaluation techniques focus on the process of establishing goals and values seek to achieve a consensus on the direction of the organisation.

Researchers and practitioners have explained the importance of IT/IS evaluation as the motivation for the development of new assessment frameworks. Remenyi (1993) highlighted that attention must be paid to the reasons why the assessment is undertaken, as the approach to the evaluation depends on the purpose of use. The researcher suggested that any measurement operation may be based on physical counting, assessment by ordering, ranking or scoring. An information system evaluation plan must have well defined objectives to be helpful and meaningful. According to Remenyi, vague defined objectives are useless whilst defining measures for information systems.

Powell (1992) declared that the apparent lack of enthusiasm for formal evaluation studies is not caused by a lack of tools but more likely to any of the following reasons:

- Ambiguity concerning organisational goals or systems requirements.
- The belief that IT is "strategic" and thus not available to formal evaluation.
- Situations where either there is no alternative or when cost is unimportant.
- A climate of failure perceived due to past IS disasters.
- Difficulties in obtaining senior management support for IT projects.

According to Willcocks (1994), IS effectiveness is not determined by the size of the expenditure. In fact, IS effectiveness depends more on how information systems are used and managed. It is the view of Giaglis et al. (1999) that IT can affect business operations in diverse ways and the ultimate impact on business performance depends on various intertwined factors that can render IT evaluation a difficult task. Many of these intertwined factors are related to what is called "the problem of measurement". The same researchers noticed that many IT benefits refer to strategic and competitive advantage which is inherently difficult to quantify. Strategic and competitive advantage benefits are realised in the long run and may be associated with a high degree of uncertainty and unpredictability. Also those benefits are indirect to the business and therefore indistinguishable from many other confounding factors (e.g. people).

1.4 Agility and Contribution of Information Systems: the convergence point.

This research work studied the old problem of identifying information systems contribution to business processes but from an agile manufacturing perspective. In the agile manufacturing literature, considerable emphasis has been put on the support of information technology/information systems to the business processes of a company. The continuous development and use of sophisticated information systems in manufacturing organisations is making evident the need to develop methods to identify the potential contribution of information systems to business processes, especially to manufacturing. The growing acceptance of the concept of agile manufacturing and its association to information technology/information systems makes imperative the definition of guidelines for the use *and management of IT*. Figure 1.2 shows the research convergence covered in this work.

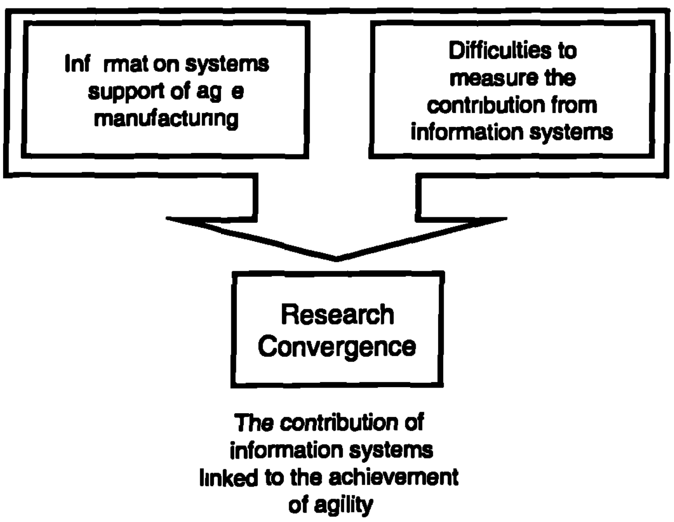

Figure 1.2 Research convergence.

1.5 Research aims and objectives.

A number of aims and objectives have been defined for the development of this research.

1.5.1 Research aims.

The aims of this research are presented in the following statements:

- To expand the available knowledge on the capability of information systems in supporting the concept of agile manufacturing through the development of a sound methodology.
- To generate guidelines to ensure the success of the use of IS in a dynamic business environment and guarantee the sustainability and enhancement of agility.

1.5.2 Objectives.

The introduction to this work has been clear in showing the need for manufacturing organisations to become agile, the significance of information systems within the concept of agile manufacturing and the importance of the evaluation of information technology/information systems. The following objectives have been generated based on the review of the current literature on agile manufacturing and information systems:

- To determine the contribution of information systems to the manufacturing agility of manufacturing organisations.
- To identify the association between a dynamic business environment, the use of a specific type of information system and IT/IS characteristics of agility.
- To determine the significance of information systems among other enablers of agile manufacturing.
- To determine how IT and business strategies affect the performance and hence the contribution of IS to manufacturing agility.
- To identify the impact non-IT based enablers may have on the use of information systems and in the achievement of agility.

1.5.3 Reasons for developing this research.

Some arguments used to support the development of this research work in the areas of information systems and agile manufacturing and information systems evaluation include:

- Manufacturing enterprises are facing dynamic business environments motivated by an increase in market competition, short-product life cycles and customers needs in constant change.
- The development of sophisticated information systems used to support the business processes of manufacturing organisations is enabling new ways of collaboration.
- Organisations have found difficulties to identify/evaluate benefits from IS. Existing research is limited in giving strong practical guidelines for evaluation.
- The importance awarded to information technology/information systems by some of the most renowned works in the literature of agile manufacturing.
- The documented evidence shows that on many occasions IT/IS have failed to deliver expected benefits and the same situation may be repeated in an agile context.

1.5.4 Results of the research.

At the end of this work the researcher will be able to determine:

- The contribution-value of information systems within the concept of agile manufacturing,
- The role of information systems among other enablers of agility and the impact of information systems on manufacturing agility,
- Factors for the success and failure of information systems within the concept of agile manufacturing,
- Factors needed to ensure the success of information systems and their effect on the manufacturing agility of an organisation.

1.6 Thesis structure.

The model proposed by Phillips and Pugh (1994) was considered during the development of the structure of this thesis. Also Irani (1998) has made use of such framework. The structure of the Phillips and Pugh model includes:

- background theory,
- focal theory,
- data theory and
- novel contribution

A description on the above elements of the Phillips and Pugh model is provided next.

1.6.1 Background Theory.

The background theory is formed by activities such as assessing the field of research and identifying the problem domain. The background theory for this particular work includes the review of the evaluation of information systems and the relevance of information systems within the concept of agile manufacturing. Research trends are also part of the background theory. In this stage an extensive literature review helps to gather a complete view of the limitations of previous research done, enabling the generation of new paths of work.

1.6.2 Focal Theory.

In this section the area of research is identified and the nature of the issues under investigation described, and the process of analysis begins. Generation of research hypothesis, the examination of other's arguments and the analysis being undertaken by the researcher are tasks of this stage.

1.6.3 Data Theory.

Data Theory is involved in validating the relevance of the material that supports the thesis. The chapters devoted to data theory are those that represent the research methodology employed to answer the hypotheses generated in the study. The justification for the use of certain types of questions is also contemplated within the data theory.

1.6.4 Novel Contribution.

An important element of the Ph.D. thesis is the contribution to the discipline being researched. Discussions about the contribution of the thesis, research limitations and suggestions for further work are presented in the chapters devoted to analysis of data and results discussion.

The results of the research will help to identify the contribution of information systems to the achievement and support of agility in manufacturing organisations. According to the academic literature, the agile manufacturing paradigm requires the utilisation of sophisticated information systems to support agility. On the other hand, for more than two decades, the problem of the evaluation of information systems has been studied by researchers and practitioners.

The novelty of this research lies in identifying the contribution of information systems to the concept of agile manufacturing, showing if information systems are principal enablers of agility. Also, it identifies which factors are crucial in the achievement and support of agile manufacturing and in the use of information systems.

1.7 Organisation of the thesis.

The proposed research work starts with an introduction to the core concepts of agile manufacturing, the principal role given to IS within the concept of agility and the evaluation of IS benefits. Furthermore, the theoretical background of the thesis reviews examples on the use/support of IS to the concept of agile manufacturing in the academic literature. This work covers an extensive literature survey on the relevance of the evaluation of benefits of IS in manufacturing organisations, showing that the failure of IS in delivering expected benefits is widely documented.

The literature survey is followed by the identification of suitable research problems and the generation of the research hypotheses. The proposed research methodology for this work includes the design of a survey research and a multiple case-study to support/reject the research hypotheses and to answer the research objectives. One chapter of the thesis covers the survey research and three chapters cover the multiple case-study.

The accomplishment of the survey research and the multiple case-study enables the identification of: the role of information systems among other enablers of agility, manufacturing agility as a contribution of IS, IT/IS proficiency characteristics of agility. Furthermore, the results of the study are used to develop new concepts such as a new taxonomy of enablers of agility. Recommendations, the contribution to knowledge and guidelines for further research are provided in the conclusions.

1.8 Comments and remarks.

The tough business conditions faced by the manufacturing industry are a good reason to undertake research in the assessment of information systems in manufacturing. In fact, agility is the policy that some manufacturing enterprises have started to adopt in order to survive in harsh business conditions. As more sophisticated information systems are used to support business processes, it becomes imperative for managers to identify the potential benefits of the use of information technology/information systems to the whole organisation.

Technological advances are necessary to keep a competitive advantage (Kalakota and Whinston 1997$_{III}$), but as soon as the technology is widespread and available as off-the-shelf applications, new ways of getting more benefits from technology become imperative. The importance of doing research in information systems evaluation can be summarised in the following phrase received from an anonymous reviewer during the early stages of this work:

> *"If organisations can't effectively manage what they can't effectively measure the problems are not solved".*

Chapter 2

Theoretical background:
Evolution towards agile manufacturing and assessment of information systems in manufacturing.

2.1 Introduction.

Changes in the business environment represented by tough competition and variation in customer requirements are driving manufacturing organisations to adopt the concept of agile manufacturing. For an organisation, agility means the capability to grow and prosper in an environment of continuous and unpredictable changes driven by customer-designed products and services, Gunasekaran (1998).

The importance of information technology/information systems to support current and future manufacturing operations has been widely recognised by practitioners and academics. Information technology/systems occupy a relevant place in the literature of agile manufacturing (Goldman et al. 1995, Gunneson 1997, Kalakota and Whinston 1997_{I}, 1997_{II}). Given the importance of information technology/systems to support the concept of agile manufacturing, Huang and Nof (1999) classified the impact of modern information technologies in three categories: *a)* speeding up activities, *b)* providing intelligent and autonomous decision-making processes; and *c)* enabling distributing operations with collaboration. According to them, utilisation of information technology/information systems enables the creation of ways of collaboration such as:

- New manufacturing/services.
- Strategic information and knowledge management.
- Enterprise integration and management.
- Virtual enterprise.
- Virtual manufacturing/services.
- Concurrent engineering.
- Rapid prototyping.

The same researchers found that information technology improves enterprise activities in different areas, including:

Collaboration: Distributed designers can work together on a common design project through a computer supported collaborative work (CSCW) software system.

Decisions: Powerful computation allows many simulation trials to find a better solution in decision making.

Logistics: Logistics flows of productivity and packages are monitored and maintained by networked computers.

Recovery: Computer systems may apply techniques of artificial intelligence –AI- (e.g. knowledge based logic) to improve the quality of activities.

Sensing: Input devices (e.g. sensors, bar-code readers) can gather and communicate environmental information to computers or humans.

Partners: A computer system in an organisation may automatically find co-operative partners (e.g. vendors, suppliers and subcontractors) to fulfil a special customer order.

In recent years, other manufacturing improvement philosophies like lean manufacturing, world-class manufacturing and JIT have recognised the importance of the use of IT to support improvements in manufacturing organisations. In the particular case of agile manufacturing, different IT/IS based technologies have been conceived to support agility. These include electronic marketplaces, electronic commerce and integrated supply-chains.

This chapter provides the theoretical framework required to develop a research methodology that will make it possible to identify the contribution of IS to agility of manufacturing organisations. A thorough description of the evolution of manufacturing operations is provided next, highlighting the characteristics of those stages that preceded agile manufacturing. Recent examples of IS evaluation in manufacturing enterprises are presented and discussed in forthcoming sections. Also, comments on some well-known frameworks for IS evaluation are covered in this chapter. Furthermore, it has been considered pertinent to review the evaluation process within the development cycle of information systems, since evaluation is usually a process that involves different stages in the life of a system.

2.2 Evolution of manufacturing operations.

Agile manufacturing is the result of the evolution of manufacturing operations. Four main stages constitute the evolution process, which started with craft manufacturing, then mass production, followed by lean manufacturing and finally agile manufacturing. Table 2.1 and figure 2.1 show the evolution of manufacturing operations and include the main characteristics at each stage.

Stage	Characteristics
Craft	High cost, Highly responsive, Highly flexible.
Mass production	Medium cost, Medium responsiveness and low to medium flexibility.
Lean manufacturing	Low cost, Medium responsiveness, high flexibility.
Agile manufacturing	Low cost, highly responsive, highly flexible. From random-lot-size to one of-a-kind production.

Table 2.1 Manufacturing evolution.

Craft manufacturing, characterised by high cost and high customer responsiveness, was the very first stage of production. Then, the full development of mass production, made it possible for manufacturers to: reduce the cost of goods sold and make them accessible to the masses, gain more customers and increase their market share. Despite the improvements, brought by Just-in-Time and TQM strategies, mass production was essentially a system favouring large-scale and comprehensive corporate structures. With the mass-production model still in operation, Lean Manufacturing allowed manufacturers to remove non-value adding activities (Womack and Jones 1996, Katayama and Bennett 1999) and hence to reduce product costs significantly. The last stage represented in this scheme is agile manufacturing, characterised by production in a smaller scale –compared to mass production-, high customer responsiveness, modular production facilities, and co-operation between enterprises, DeVor et al. (1997).

If Cost Per Unit is added as an extra dimension to figure 2.1, a 3-dimensional representation is obtained as shown in figure 2.2. This figure clearly shows the characteristics of each production stage. In craft production, the cost per products is high, with high variety and a small number of units produced. Mass production has a reduced cost per unit, small variety and high volume of production.

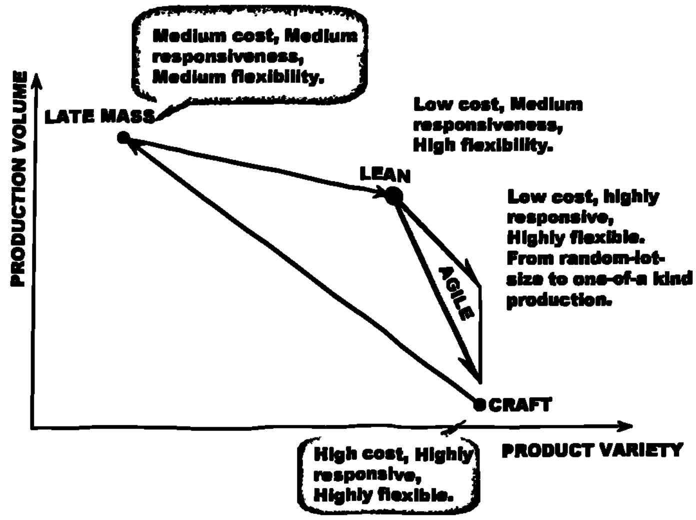

Figure 2.1 Manufacturing evolution.

Lean manufacturing presents a lower cost per unit than mass production, more product variety and a reduced volume of production. With this 3-D representation, it is possible to visualise the agility zone. The agility zone is the region where manufacturers can achieve agility in their operations. In ideal conditions –highly favourable conditions for the organisation-, the cost per unit in the agility zone can be lower than those in lean manufacturing, with product variety approaching those of craft production.

Agility is a concept suitable for the needs of today's manufacturing companies. One of the reasons is because turbulence and uncertainty in the business environment have become the main cause of failures in manufacturing industry, Small and Downey (1996). The literature on agile manufacturing has identified a significant number of drivers, attributes, benefits and business practices, Yusuf et al. (1999). Customer enrichment, core competencies management, concurrency in all activities and processes, readiness for change, leveraging the impact of people and information and formation of virtual alliances are some of the attributes identified in the literature. Researchers like Sharifi and Zhang (1998), showed that agility can be achieved in a manufacturing organisation through the strategic integration and utilisation of available managerial and manufacturing methods and tools, including those already developed an used in other paradigms and those recently developed for agile manufacturing.

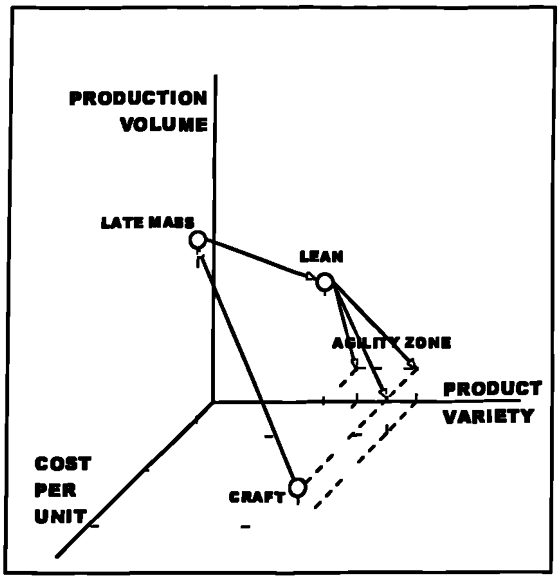

Figure 2.2 3-D Manufacturing evolution model.

2.3 Information systems evolution in manufacturing.

Shewchuk (1998) described that the function of information systems in manufacturing is to support the planning, scheduling and control activities of an organisation. In fact, information technology has been recognised as having a major influence on all manufacturing organisations, large or small, Shaw et al. (1997) and the rapid evolution of information technology brings new possibilities of work and collaboration. The NGM project (1997) provided a description of information systems requirements to support the operation of manufacturing organisations facing an increase in competition and unpredictable business changes. The NGM framework proposed the creation of adaptive/responsive information systems to facilitate rapid response between enterprise partners and their suppliers and customers, enabling inter-enterprise integration. Enterprise integration has been defined as the discipline that connects and combines people, processes, systems and technologies to ensure that manufacturing companies can function as a well co-ordinated whole, by itself and with other organisations, Noori and Mavaddat (1998). According to the NGM in the future, it will be the integration with other organisations that will enable manufacturing enterprises to survive. In an agile environment, the IS function of a company may deal with the problems of standardisation and integration of heterogeneous systems. Integration of information systems plays a significant role in the sense that legacy applications may be needed to keep an enterprise fully operational.

To better understand the significance of IS for agility, it is important to look at the evolution of IS experienced in the manufacturing industry. For example, at the operational level, SEMATECH -Semiconductor Manufacturing Technology Consortium- (NGM 1997) defined a hierarchy called the Applications Framework Specification for its Computer Integrated Manufacturing scheme. Figure 2.3 shows the three levels of this hierarchy. The enterprise level makes reference to corporate planning, accounting, payroll and invoices. The middle level includes manufacturing execution systems (manufacturing software) where it is possible to find shop floor scheduling among others. Human-machine-computer interaction and control are found in the tool level of this framework.

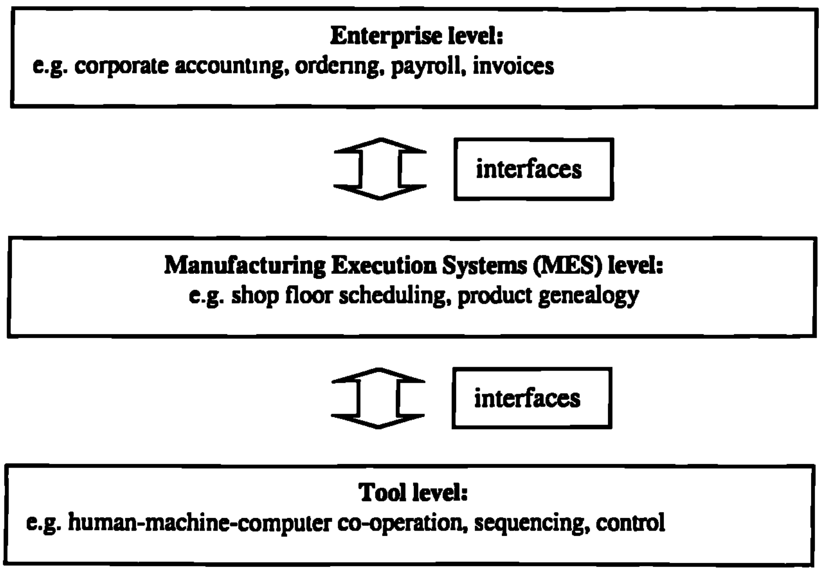

Figure 2.3 Information systems hierarchy.

Today's manufacturing information systems incorporate not only applications at the enterprise level but also applications at the MES level. Performance at the tool level has an immediate impact on the other two upper layers.

Also, the NGM provided a chronological review of the use of IS in the manufacturing sector. In the early 70's MRP (Materials Requirement Planning) was introduced to support manufacturing operations. Then, in the middle of the 70's until the middle 80's it was MRP_{II}, SPC, Data Management which represented the development of information systems for manufacturing companies, helping them to improve their operations drastically. The early 80's to the middle 90's witnessed the introduction of massive automation through the utilisation of PLC's, robots and AGV, giving birth to the concept of CIM, parallel to the integration between customers and suppliers through EDI. The early nineties included applications focusing on enterprise integration. The latest developments in information systems motivated the addition of an extra stage. This stage represents the utilisation of Internet based e-commerce applications, virtual enterprise and integration not only at the company level but with other organisations, requiring the implementation of wide computer-based operations management systems, Portugal and Janczewski (1998).

2.3.1 Electronic Commerce: the latest stage of information systems development in manufacturing.

Internet based e-commerce applications are in part aimed at enabling inter-enterprise integration. In fact, the latest developments in e-commerce show that the concept is very close to many of the characteristics of agility described in the literature. Kettinger and Hackbarth (1999) highlighted that e-commerce is about rethinking the business model by exploiting information asymmetries, leveraging customer and partner relationships and finding the right fit of co-operation and competition. In their work, the researchers never used the concept of agile manufacturing but their description of what an organisation with e-commerce practices should be is closely related to the attributes of agile enterprises.

Possible levels of development of e-commerce in organisations are shown in table 2.2. These levels of development have many similarities with agile manufacturing dimensions and attributes. For example, in the Scope area, cross-enterprise involvement interconnected is compatible with the attributes of enterprise integration and close supplier relationships, Yusuf et al. (1999), or customer satisfaction in the area of Payoffs is compatible with the agility attribute of satisfaction of customer requirements. The agility dimension of leveraging the impact of people and information, Kidd (1994), is addressed in the level three of the Levers area.

Area	Level 1	Level 2	Level 3
E-commerce strategy	No EC strategy	EC strategy supports current business strategy	EC strategy supports breakout ("to be") business strategy
Business strategy	EC not linked to business strategy	EC strategy	EC is a driver of business strategy
Scope	Departmental/functional orientation	Cross-functional participation	Cross-enterprise involvement interconnected (customers, suppliers and consumers)
Payoffs	Unclear	Cost reduction, business support and enhancement of business processes	Revenue enhancement, increased customer satisfaction, drastic improvement in customer service.
Levers	Technological infrastructure and software applications	Business processes	People intellectual capital and relationship
Role of information	Secondary to technology	Supports process efficiency and effectiveness	Information asymmetries used to create business opportunities

Table 2.2 Levels of development of e-commerce in organisations (adapted from Kettinger and Hackbarth 1999).

A close interaction between customers and suppliers is essential for agile manufacturing. The main motivation behind electronic commerce is to improve the response time to customer's demand as quickly as possible by directly collecting the customer's requirements through an online communications system (Gunasekaran 1998). The primary benefit of EDI to business is a considerable reduction in transaction costs by improving the speed and efficiency of filling orders.

E-commerce is a digital platform that pervades all functions and departments within a company. According to Gunasekaran (1999), e-commerce can ensure higher quality, reduced costs, and increased responsiveness. The author declared that applications within this stage are intended to provide the capabilities to manage the supply chain, that is the ability to deliver products faster, shortening the cycle from order to cash receipts. The addition of e-commerce as the latest stage in the development of information systems in manufacturing is compatible with attributes associated to agile manufacturing like the extended enterprise, Childe (1998), and the extended supply-chain, Marchand (1999). In fact, e-commerce through the utilisation of the Internet makes possible the seamless integration of suppliers and customers. According to Kasarda and Rondinelli (1999) today, even small and medium-sized enterprises increasingly rely on international networks of suppliers, distributors, and customers to improve their global competitiveness.

With the utilisation of e-commerce, the supply chain extends far beyond the traditional supplier-to-customer model. This extension is commonly referred to as the virtual enterprise or extended supply chain (Kalakota and Whinston 1997_I). Manufacturing organisations are moving towards the utilisation of the Internet to maintain their edge with a well-managed supply chain.

The utilisation of e-commerce to integrate operations with customers and suppliers makes it possible to meet some characteristics of agile organisations such as responding to changing customer demand, adapting to a changing business climate, flexibility to redesign their processes towards suppliers and customers while enabling decentralised operations. Furthermore, the adoption of Internet based e-commerce applications should be within easy reach of manufacturers, compared to other more expensive applications in previous stages such as ERP solutions. However the ubiquitous access to information and acquisition of technology necessarily demands adequate management policies to deliver competitive advantage.

2.3.2 Virtual organisations and information systems.

Future operations in manufacturing organisations will require the integration of information systems through scattered manufacturing plants. The utilisation of technologies such as the Internet will bring together applications related to resource planning (MRP, ERP and cost accounting systems); manufacturing execution (factory level coordinating and tracking systems) and distributed control (floor devices and process control systems). This integration is the previous step towards the consolidation of operations to form virtual organisations.

The wide utilisation of Internet based e-commerce supported by an IT/IS infrastructure and applications for execution and planning, are key to the development of virtual organisations. Reid et al. (1996) described that a virtual enterprise is conceived when a need is recognised in the marketplace and a business objective or set of objective(s) is/are established. To conceive a virtual enterprise it is important for organisations to understand customer expectations and what it will take to satisfy them. An enterprise is created when relationships are established to eventually bring together the requisite competencies. Different researchers (Venkatraman and Henderson 1998, Grimshaw and Kwok 1998, Kanet et al. 1999) have provided guidelines to the formation of virtual organisations.

The virtual enterprise concept has been used to characterise the global supply chain of a single product in an environment of dynamic networks of companies engaged in many different complex relationships (Fouletier et al. 1997, Su and Poulin 1996, Bechler 1997, Mathieu 1997). Manufacturing organisations need to implement information systems able to cope with several technical constraints such as concurrent engineering, inter-network applications, hardware heterogeneity, software for application communication and time constraints. Also a sound methodology will be required to define the different tasks which are part of business process, the states of synchronisation, the way collaboration is achieved and once a virtual enterprise has been formed under which organisation it will be managed.

2.4 IS in general frameworks for agility.

Different frameworks to achieve agility in manufacturing organisations have recognised information systems behind technologies such as e-commerce, virtual enterprise, business information systems, multimedia, etc. For example, figure 2.4 depicts a framework developed by Gunasekaran's (1998) that covers the dimensions of co-operation, value-based pricing strategies, investment in people and information and organisational changes.

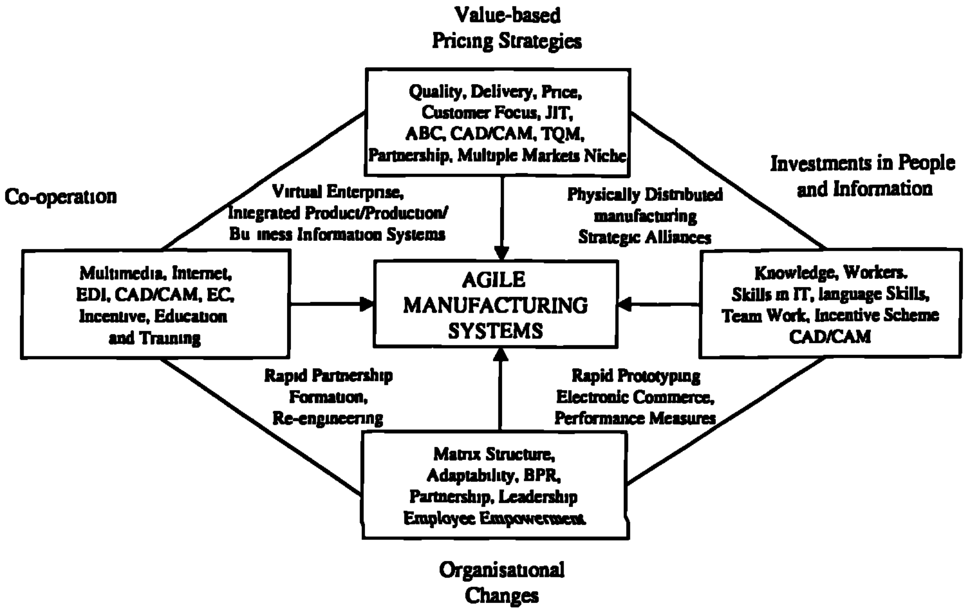

Figure 2.4 Gunasekaran's framework for agility.

The above framework covers several technologies/tools which are IT/IS based. Those technologies/tools include virtual enterprises, business information systems, multimedia, Internet, EDI, CAD/CAM, Electronic Commerce and related enablers for agility such as skills in IT. Information systems in an agile company should contribute to responsiveness as well as to overall corporate and organisational aims, Thoburn et al. (1999). The next section presents and discusses a number of prototypes of IS applications aimed at supporting agility.

2.5 Developments on information systems to support the concept of agile manufacturing.

There is consensus among researchers about the enabling capabilities of information systems within the concept of agile manufacturing. DeVor et al. (1997) stated that recent advances in information networking, processing and electronic commerce are rapidly expanding the capability to achieve powerful interactive links among organisational and functional units of the agile enterprise. The researchers discussed how the Internet and the evolution of global networking capabilities will make possible the creation of an architecture for an open data network. Agile manufacturing will become a consumer of such information infrastructure functionality, and will focus on building information tools and resources. This approach focuses mainly on the technical difficulties to join heterogeneous information systems, however there is no mention of non-technical factors behind the performance of information systems used by those organisations wishing to take part in the virtual enterprise.

Many works available in the literature have put emphasis on technical factors regarding the development of information systems to support agile manufacturing. For example, Song and Nagi (1997) described that agile manufacturing makes use of modern information technology to form virtual enterprises, which agilely respond to the changing market demands. They proposed the creation of an Agile Manufacturing Information System with the idea of providing partners with integrated and consistent information. Considerations for the system included partner information interoperability across companies, information consistency across partners in the virtual enterprise, partner policy independence and autonomy maintenance, and finally, open and dynamic system architecture. The researchers proposed in their model that each participating company becomes a node in a network linking companies to the virtual enterprise. Each company has its own systems (CAD, MRP, CAPP, DBMS) and it is an autonomous unit. Also data and workflow hierarchies that would enable organisations share information and carry-on queries and requests were contemplated in this model. However, this framework does not take into consideration the current level of performance of the information systems used in participating companies. Also, attributes like skills of employees have not been considered in this model. Moreover, for the average SME the formation of virtual enterprises and collaboration with other organisations through information systems is still under development in most of the manufacturing sectors.

On the same theme, Cheng et al. (1997) developed an approach to implementing agile manufacturing based on AI and the Internet. This work was deployed to enable remote and quick access to design and manufacturing expertise. The researchers recognised that agile manufacturing is primarily a business concept but new technology is still one of its most important driving forces. Moreover, the researchers provided a scenario where the Internet is used to speed up information flow in a product development cycle and thus to achieve reduced development time and costs. The proposed approach fails to consider the information systems background of the companies integrated to this Internet based architecture. Bullinger et al. (1998) developed an integration concept for heterogeneous legacy systems. Legacy systems are integrated into a company-wide IT architecture through the encapsulation of these systems into several business objects that can be re-used and transformed into an object-oriented architecture. The proposed architecture relies on the use of Middleware standards for the integration of legacy systems.

Other researchers like Wolfe et al. (1998) and Whiteside et al. (1998) have investigated the use and development of Middleware and distributed computing to develop robust information architectures that can be used in the integration of physically distributed design and manufacturing facilities within an enterprise. Wolfe et al. (1998) recognised it as an implication of Agile Manufacturing. Bocks (1995) has focused on the development of seamless enterprise data management solutions in support of agile manufacturing environments.

Zhou et al. (1998) developed an information management system for production planning in virtual enterprises. The researchers presented a distributed information management architecture for production planning and control in semiconductor manufacturing. The proposed architecture is based on the Internet and the use of an Object Request Broker.

Herrman et al. (1995) presented the information required for three functions of agile manufacturing: prequalifying partners, evaluating a product design with respect to the capabilities of potential partners, and selecting the optimal set of partners for the manufacture of certain product. The implemented model is used as part of a decision support system for design, evaluation and partner selection in agile manufacturing.

O'Connor (1994) recognised software as key to the agility of many manufacturing systems. The author gave an example of how a Unigraphics CAD/CAM system has played a key enabling role in making an automotive components manufacturing enterprise agile in the USA. It seems that the author conceded high importance to tasks enabled by the information system in this company and did not provide a description about the performance of the system and business processes. Perhaps, non-technical issues are behind the successful operation of the company.

The reviewed works on information systems use for/in agile manufacturing have focused mainly on the technical implications of information systems. None of them have addressed the non-technical implications of developing such IS. Moreover, they have assumed as granted that all companies participating in a virtual enterprise have information systems with a satisfactory performance level and also that participating companies have agile business processes in place. Most of the reviewed works have targeted the design of information architectures that can support the integration of manufacturing companies with heterogeneous information systems.

2.6 The relevance of evaluation of information systems in manufacturing organisations.

During the introduction to this work it was possible to highlight the reasons why evaluation of information systems is so important. In order to provide answers to the problems of identifying the contribution of information systems, academics have defined different methodologies and frameworks for that purpose. Some of these methodologies and frameworks are presented in this section. This section also contains examples of IS evaluation in manufacturing.

2.6.1 Assessment frameworks employed to identify the contribution of Information Systems.

Myers et al. (1997) described that many steps towards the development of a general IS assessment framework have been taken but the journey is still in progress. Researchers and practitioners have made significant contributions to the field of information systems evaluation. For example, Moad (1993) developed a model based on a 3-by-3 matrix of 9 different categories for performance of the IS function. These categories are: individual, work group, business unit, technology import, organisational process outcome and economic performance. Another framework that has been considered a principal one by many researchers and practitioners in industry is the DeLone and McLean IS Success Model (1992). In fact, this framework is one of the most accepted in academic circles involving the evaluation of information systems. To design this framework the researchers began with the definition of information as the output of an information system, or the message in a communication system, and they highlighted that it can be measured at different levels. Their model depicts the relationships of six IS success dimensions. They counted that system quality and information quality singularly and jointly affect both use and user satisfaction, Watson et al. (1993). Additionally the amount of use may affect the degree of user satisfaction, positively or negatively, as well as the reverse being true. Use and user satisfaction are direct antecedents of individual impact and lastly, this impact on individual performance may eventually have some organisational impact. The complete framework is depicted in figure 2.5.

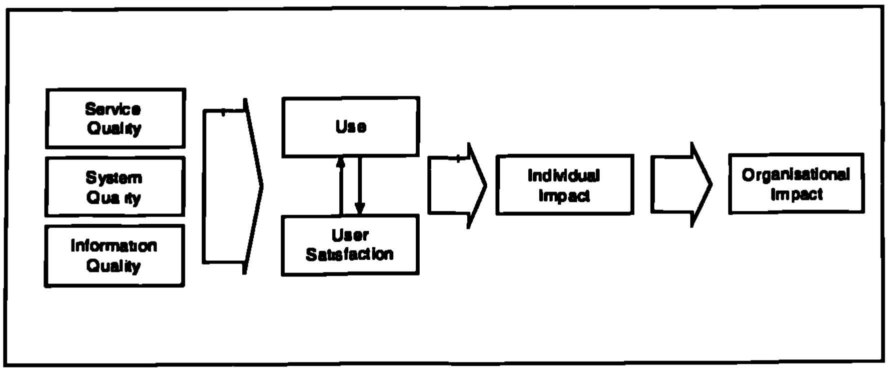

Figure 2.5 DeLone and McLean model.

Based on the model developed by DeLone and McLean (1992), researchers and practitioners have provided different performance measures for the categories defined in the IS Success Model. Remenyi and Money (1994) showed that if the information systems function is considered as a service, the application of the principles of service quality could yield many opportunities to show the value of the IS function in the organisation.

Saunders and Jones (1992) developed the "IS Function Performance Evaluation Model" which was used to describe how measures should be selected from the multiple dimensions of the IS function, relative to specific organisational factors and based on the perspective of the evaluator.

In the system quality dimension Ford (1994) presented measures of the value of individual information systems like reliability, response time, ease of use, usefulness, flexibility accessibility and cost benefit analysis. Other dimensions like use and user satisfaction are based on the idea that information systems can improve the productivity of the individuals and then improve the productivity of the organisations. Zirn (1998) carried out a study on the utilisation of MRP_{II} systems based on user's satisfaction. However, it may be argued from Zirn's findings, that measuring user satisfaction is a very subjective area.

Myers et al. (1997) developed a framework for the assessment of information systems success, providing eight different dimensions that include system quality, information quality, use, user satisfaction, individual impact, organisational impact, work group impact and service quality and a number of related measures. Figure 2.6 depicts their framework which is similar to the one proposed by DeLone and McLean (1992).

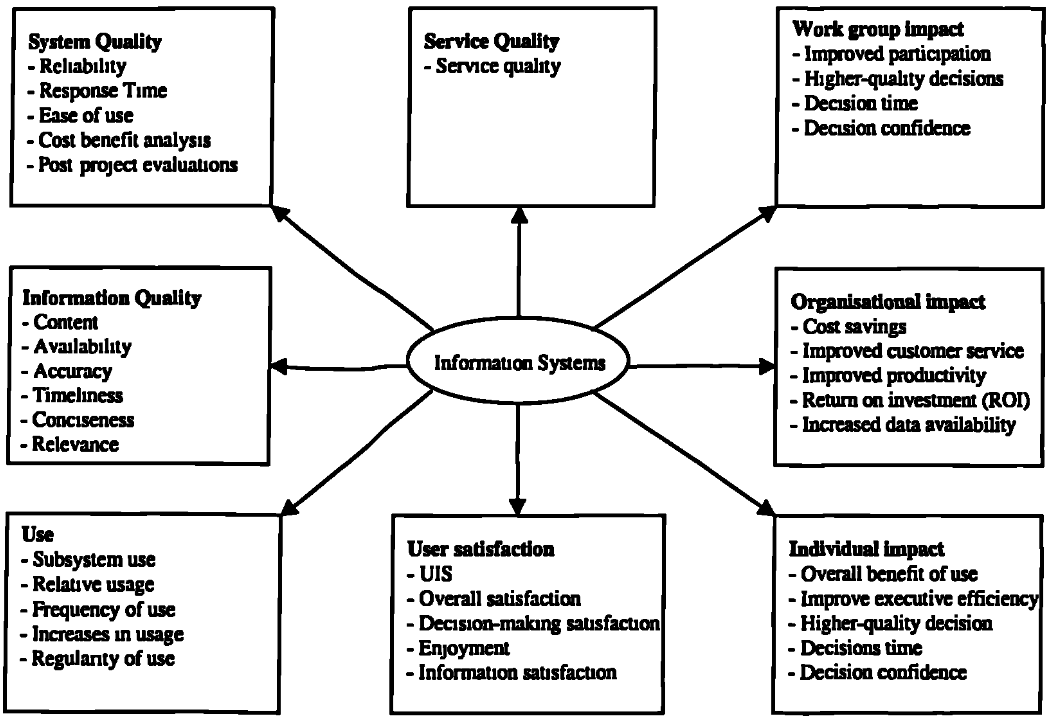

Figure 2.6 IS success dimensions in organisations.

Studies in the academic community have contemplated the definition of performance measures for individual impact and work group impact. Barua et al.

(1995) found that the most significant contributions of information technology investments occur at low organisational levels where they are implemented. Venkatraman and Henderson (1998) agreed that performance objectives should move from a traditional organisation that uses ROI, improved operating efficiency, towards a new organisation where measure should be MVA, market value added, for sustained innovation and growth passing previously through EVA, enhanced economic value added.

More recently Smithson and Hirscheim (1998) suggested a new approach for the evaluation of information systems. Their framework classifies the literature on IS evaluation in three major dimensions: efficiency, effectiveness and understanding.

The efficiency zone is characterised by fairly objective/rational assumptions regarding the nature of evaluation. For example, the idea here is evaluating performance (or quality) compared to fairly detailed benchmarks. The second zone, effectiveness is more concerned with doing the right things rather than the efficiency view, concerned more with eliminating wasted time and effort. The effectiveness zone is shown in figure 2.7.

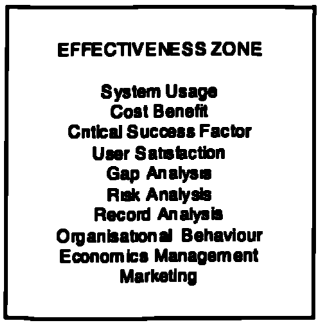

Figure 2.7 Effectiveness Zone.

The understanding zone is the most complex because it studies subjective aspects like social action and cognitive psychology.

Assessment methods also differ in the perspective they employ. Some of them use a quantitative perspective and others use a qualitative one. The aim of quantitative methods is to describe and to assess the phenomenon objectively by using numbers within defined formal frameworks. The measures tend to relate mainly to the overall organisational impact and economical benefit, based on values such as materials, costs, materials savings or number of customer complaints. Traditional methods include Return on Investment, Cost Benefit Analysis and Information Economics. More recent works using economic models for the evaluation of IS include real options pricing analysis, Benaroch and Kauffman (1999).

Fitzgerald (1998) highlighted that the evaluation of IT/IS is a notoriously difficult area. Due to large amounts being spent on IT/IS by organisations, the increasing focus on value for money permeates all areas of business activity. The author provided a method that included a series of stages like identifying costs, contribution to business strategy, analysis of benefits, and second order effects like flexibility, implementability and risk. Unfortunately the proposed methodology lacks a practical example showing its applicability.

Different approaches to IS evaluation can be found in the literature and all of them are valid in trying to give answers to a problem that is of concern to researchers and practitioners. More recently, Ballantine et al. (2000) addressed the evaluation of information systems from an ethical perspective. The researchers developed a framework that demonstrates that ethical considerations are implicit in the concept of evaluation of IS in terms of their purposes, their processes, and their involvement of people.

Furthermore, analytical methods have been employed for the evaluation of information systems, particularly when attributes need to be assessed using value-scales, Coronado et al. (1999, 2000). Such analytical techniques include AHP (Analytical Hierarchy Process) developed by Saaty (1980), ANP (Analytic Network Process) and the use of fuzzy sets. Appendix A contains an explanation of using fuzzy sets and AHP for evaluation purposes.

Evaluation in a qualitative context is approached in terms of understanding the complexity of organisational situations, systems and events. It includes performance measures, which usually are difficult to quantify, like intangible benefits, the perception of individuals or their satisfaction with a system.

2.6.2 Information systems evaluation in manufacturing organisations.

As it has already been indicated in this work, evaluation of IS has been studied by many researchers (Kennerley and Neely 1998, 1998_{II}, Ross et al. 1998, Jiang and Klein 1999, Changchit et al. 1998). However, the literature on information systems does not provide many examples on the evaluation of IT/IS in manufacturing enterprises and many areas lack research, Kathuria and Igbaria (1997). Manufacturing is one industry/sector suffering from the lack of proper assessment methods for information systems. Most of the available studies on IS evaluation in manufacturing enterprises fall within the organisation level dimension defined in the models developed by Myers et al. (1997) and De Lone and McLean (1992). Also these studies fall within the effectiveness zone of IS evaluation proposed by Smithson and Hirscheim (1998). Some representative works of IS evaluation in manufacturing are discussed in this section.

Brynjolffson and Hitt (1995) studied the contribution of IT to the productivity of a group of companies. During their study they found that some strategic goals for IS investments are focused on costs savings and improved management control while others had a customer orientation -investments in quality, customer, service, flexibility and speed-. Even though their productivity analysis was based on hard numbers such as revenue, labour costs, and capital costs, the customer oriented companies that participated in their study had significantly better productivity performance and also achieved higher profits.

Other studies have found that information technology investment provides negligible benefits (Loveman 1994). In fact the "productivity paradox" was first exposed by Brynjolfsson (1993), his study showed that although computing power has increased exponentially in the last decades, productivity has stagnated.

Kelley (1994) analysed the effects of information technology on the efficiency of production operations in a specific machining process. Instead of focusing on the entire organisation as a whole, she decided to concentrate her attention on the upgraded process by the implementation of programmable automation. She proposed a process-specific model for assessing technology effects on productivity, avoiding the problem of classification for the entire production system. The researcher findings showed that with programmable automation technology, manufacturers can produce the same output in about three-fifths of the time it would ordinarily take on conventional machinery.

Dasgupta et al. (1999) investigated the impact information technology has on firm productivity. Their study investigated this phenomenon in both manufacturing and service firms. The methodology chosen used a combination of various data envelopment analysis models and non-parametric statistics to test the influence of information technology investment on firm productivity. The findings of their study revealed that productivity in the service and manufacturing sectors seem to lag as increased investment occurs, confirming the "productivity paradox" theory, which stated that information technology has negligible or even a negative effect on a firm's performance.

In a pilot survey carried out by Wybrow and Cameron-MacDonald (1996), it was found, for a group of manufacturing enterprises in Scotland, that information systems lacked continuity and did not contain up to date information. In this study one company indicated that around 30-40 percent of the information in their centralised database was unused, out of date or lacked continuity. Some of the systems found in participating companies covered a wide range of issues and information generation such as Material Requirements Planning (MRP) systems, Manufacturing Resource Planning (MRP_{II}) systems, financial systems, production and scheduling systems and inventory systems. Also, it was found that these systems have not worked to the extent which they were expected to do and organisations have been frustrated with undelivered promises. Few of existing proprietary packages have actually addressed the issues of what information is required by each level of the organisation. Finally the researchers concluded that the reason why manufacturing information systems fail is mainly because of the lack of realistic expectations and the lack of any thought as to how, once the system is running, the users utilise such system.

Xu and Kaye (1997) classified information systems in manufacturing in four major groups: manufacturing operating process, automation systems, manufacturing process control and monitoring systems and manufacturing information systems. The idea of this framework was to study how external strategic information can be improved from an information systems perspective, to generate better manufacturing strategic decision-making. The study is limited because the concept has not been tested empirically in industry.

Another technology widely used in manufacturing organisations is EDI. The literature contains examples on the utilisation and impact of EDI. Mukhopadhyay et al. (1995) determined the financial impact of EDI on the Chrysler Corporation. The researchers estimated from reduced inventory holdings, costs, as well as savings that arose from preparing and processing documents electronically rather than manually, that Chrysler was saving more than $100 US dollars per car.

Fearon and Phillip (1998) implemented a self-assessment study in order to measure the strategic and operational benefits from EDI. "Three benefit states" were used to denote the degree of the gap between expectations and perceptions of realised benefits with Electronic Data Interchange in nine leading companies in Northern Ireland. The researchers developed a "benefit success matrix" to illustrate the relationship between benefits states, implementation success and the implementation approach.

Others researchers and practitioners like Harris (1995) have focused on the information technology planning side in the manufacturing industry. Li (1997) has identified a total of 46 factors associated with success in information systems, such factors include: top management involvement, accuracy of output, correction of errors, etc.

Before proceeding with the generation of research hypotheses for this work it is important to remind the reader that all information systems applications share a common development cycle.

2.7 Evaluation in the information systems development cycle.

The types of information systems used in manufacturing organisations can be classified in two major groups: In-house development of systems using Rapid Application Development (RAD) and purchase of systems commonly known as Commercial off-the-shelf applications (COTS).

RAD, rapid application development, is a concept saying that products can be developed faster and of higher quality through:
- Gathering requirements using workshops or focus groups,
- Prototyping and early, reiterative user testing of designs,
- The re-use of software components,
- A rigidly paced schedule that defers design improvements to the next product version,
- Less formality in reviews and other team communication.

Some software development firms offer products that provide some or all of the tools for RAD software development. These products may include requirements gathering tools, computer-aided software engineering tools, tools for prototyping, tools for communication among development members, language development environments such as those for the Java platform and XML and testing and debugging tools.

Certainly many organisations may avoid the development of their own information systems applications, turning themselves to commercial applications offered by different software vendors. COTS, commercial off-the-shelf, applications describe ready-made products that can easily be purchased and implemented.

Whatever the type of application used by an organisation, RAD or COTS, information systems development consists of a cycle of seven stages that usually include process workflows, business modeling, requirements, analysis and design, implementation, test and deployment. Other academics have proposed six stages that include requirements, analysis, design, implementation, testing and utilisation, Kelleher (1995). The use of measures for this development cycle has been widely documented in the software engineering literature (Fenton 1991, Chulani et al. 1999, Pavur et al. 1999). Figure 2.8 depicts the IS development cycle.

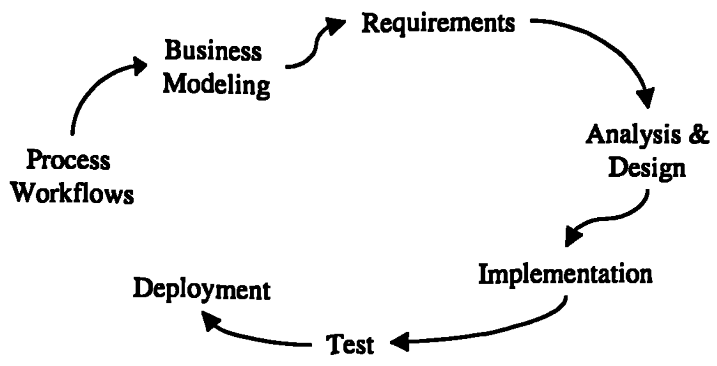

Figure 2.8 IS development cycle.

Based on the information systems development cycle, Beynon-Davies et al. (2000) developed a model linking assessment failure of information systems with the development process of IS. According to them, such a model constitutes a strategy for stimulating organisational learning in relation to information systems development. Remenyi et al. (1997) have indicated that there is a growing belief that there is a major misfit between information systems development and the expectations and requirements of business. However, conducting research based on the development cycles of information systems of large and complex applications is extremely difficult because of the amount of resources required. Development cycles for large and complex applications may take several months and in some cases developers may be distributed across geographical units.

2.8 Comments and remarks.

The importance of information systems in manufacturing will continue to grow in the years to come. It is expected that more and more manufacturing organisations will be involved in the integration of all their business units and in the formation of closer relationships with customer and suppliers using the latest developments in IT.

The growing utilisation of information systems applications like Internet based e-commerce solutions will give manufacturing enterprises the opportunity to experience new ways of working with their suppliers and customers and possibly enabling alliances with other companies. The continuous development of technology and the adequate management of information resources will enable the success of collaboration schemes such as the virtual enterprise. The easy access to sophisticated information systems applications in manufacturing comes with the added responsibility of understanding the value of IS to the business.

Agility has been related to the use of sophisticated IT/IS. The survey of the available literature on agile manufacturing suggests that agility may be supported by using some of the prototype-experimental IS applications reviewed in this chapter. However, researchers have not investigated in detail the achievement of agility in business processes in manufacturing organisations using traditional IS applications such as MRP or MRP_{II} systems or basic configurations of IT infrastructure and IS.

Investments in information technology should have the objective of improving current business models and not merely replacing existing ones. The next chapter presents a set of hypotheses intended to answer the linkage between the contribution of IS to the agility of business processes, especially manufacturing operations.

Chapter 3

Research methodology to determine the contribution of IS to manufacturing agility and factors affecting it.

3.1 Introduction.

The introduction to this work presented the convergence of two research fields. The first field is the wide recognition in the academic literature of information systems support of agility. The second field is the need for evaluation and the difficulty to realise benefits from information systems. This chapter presents the research hypotheses formulated from the literature review, aimed at identifying agility as a contribution from IS.

This research demanded a detailed literature survey of the field of information systems evaluation. As stated earlier in chapter two, different methodologies and frameworks have been defined to facilitate the identification of benefits from IT/IS. Evaluation of IT/IS is relevant because researchers have identified IT as a source of change (Davenport 1993) and also as a potential constraint or inhibitor (Broadbent and Butler 1995).

Information technology is central to business initiatives such as re-engineering, knowledge management, the creation of electronic channels of distribution, and the development of digital business strategies (DiRomualdo and Gurbaxani 1998). The concept of agile manufacturing is no exception and IT/IS have kept the attention of many researchers and practitioners.

The development of evaluation procedures of IT/IS might be seen as a consequence of the extensive use of IT/IS. However, because the evaluation of information systems has been labelled as a thorny problem (Smithson and Hirscheim 1998), it may not be a straightforward process to relate agility as a contribution of IS. Moreover, after an extensive review of the literature available on agile manufacturing it would be possible to find the use of information systems somewhat overemphasised. This research intends to identify the role of information systems in supporting agile manufacturing. This work is aimed at testing information systems as a principal contributor of agility in manufacturing enterprises. Knowing the potential benefits of the use of IT/IS, managers will be capable of better decision-making when planning and developing company's business processes, specially during the present time when business transformation has put pressure for a radical change on how IT is organised and managed (Earl and Sampler 1998). The detailed research methodology developed for this work is presented next.

3.2 Information systems in agile manufacturing.

The most renowned works on agile manufacturing have dedicated entire sections to the use of IS in agile manufacturing. Goldman et al. (1995) in *agile competitors and virtual organisations* described ubiquitous communication and information as the technical elements which are bringing and becoming part of the next industrial revolution. According to them, these elements are the central, critical, and fundamental part of the change to agility. Information is increasingly not only computer text data, but multimedia pictures and voice data as well. Goldman et al. provided examples of information systems in organisations like FedEX or UPS. In fact, these companies register each transaction involving a package on a nationally distributed networked computer system, enabling immediate tracking of each package. Other examples of manufacturing companies using IS include organisations that have implemented Computer-Aided Logistics Systems (CALS), requiring all technical specifications, drawings, manuals and other documents relating to products, be computerised. Finally, the researchers highlighted that distributed computer systems have become the lifeblood of the modern business, small or large.

Gunneson (1997) stated that information technology is important and high-level information systems will ultimately be required for the agile enterprise, but that does not happen overnight. Gunneson described that there will be need of ubiquitous email systems, information systems, expert systems, modelling and simulation systems, and decision support systems. Organisations will be sharing data and files world-wide with the same security they have in their own organisation. The researcher concluded that the biggest problem is still not technology, it is clearly cultural and organisational.

Another classic within the agile manufacturing literature is Kidd (1994). The researcher presented the concept of agile manufacturing built around the synthesis of a number of enterprises that each have some core skills or competencies brought to a joint venturing operation, based on using each partner's facilities and resources. For this reason, these joint venture enterprises are called virtual organisations because they do not own significant capital resources. Central to the ability to form these joint ventures is the deployment of advanced information technologies and the development of highly nimble organisations structures to support highly skilled, knowledgeable and empowered people. Finally, Kidd highlighted the need of advanced computer based technologies by agile manufacturing enterprises.

Noori and Mavadatt (1998) described that information technology is providing the means for companies to integrate better their internal and external activities. Such integration is related to the necessity of maintaining lean operations and becoming an "agile enterprise" in which the speed and flexibility at which a company functions matches that of its technology.

Gunasekaran (1999) proposed that information systems for agile manufacturing should include mostly software/decision support systems for various planning and control operations including materials requirements planning, design, manufacturing resource planning, scheduling and production planning and control. The researcher identified several computer-integrated systems that could be used for agile manufacturing, these include MRP, MRP_{II}, Internet, CAD/CAE, ERP, Multimedia and Electronic Commerce.

Zhang and Sharifi (2000) developed a conceptual model for implementing agility. They described agility providers, means by which agility capabilities could be obtained, as the need to be fully integrated with the support of information systems/technology.

Agile manufacturing is not the first improvement programme for manufacturing to recognise the importance of information technology. Gunasekaran and Nath (1997) described the role of IT in re-engineering viewed from two perspectives: (i) the role of the IT function (e.g. Internet, Multimedia, EDI, CAD/CAM, ISDN), and (ii) the role of the technologies themselves (e.g. CD-ROM, ATM, fibre optics). Information management throughout the company should encourage the development of skills in computer-aided systems engineering. The researchers recognised information systems as a major element of business process re-engineering. Also, they provided a list of advanced information technologies that can be used to support business process re-engineering. Some examples included the use of EDI to eliminate all non-value adding activities by avoiding congestion in different functional areas. Finally, the researchers concluded their paper by presenting a list of problems in BPR, the role of IT in solving them and a list of information technologies used in the integration of functional areas from process perspectives. Their work emphasised that re-engineering design is enabled by IT, but the implementation might be initiated without much of the assumed IT capability. According to them, an information system incorporating various types of technologies will act as a manager for the business processes, eliminating any sort of congestion or non-value adding activities, and achieving a dramatic improvement in overall performance of the company.

The concept of agile manufacturing was coined in the early nineties and currently manufacturing organisations have recognised the importance of being agile in order to respond to customer needs. Manufacturing organisations have identified information systems as one of the elements to be considered in the planning and achievement of agility. Some organisations may think that the use of Internet based applications is the next step they need to take in order to ensure their competitiveness (Kettinger and Hackbarth 1999).

Information systems importance to agile manufacturing has been recognised since the first works on the topic were published. But few works have addressed the capabilities of information systems to support the needs of an agile company. As presented earlier in chapter 2, the literature on agile manufacturing contains many examples on the design of advanced applications addressing the concept of agility. However, the success of such applications in the real world is arguable. Many manufacturing organisations have in common the use of commercial off-the-shelf applications to support their business processes and only a reduced number may use proprietary or prototypes, beta-versions, of information systems.

3.3 Influence of a dynamic business environment.

The influence of the business environment has been investigated in the literature of agile manufacturing. The business environment is the source of turbulence and changes impose pressure on the business activities of a company (Preiss 1997). These changes taking place urge companies to search for appropriate ways to maintain their competitive advantage. A dynamic business environment has been identified in some of the works on agile manufacturing of the early nineties (Dove 1994, Goldman 1994, Goldman and Nagel 1993, Youssef 1992) and in other works developed by the end of the decade (Kasarda and Rodinelli 1998).

The literature on agile manufacturing has highlighted the changing business conditions affecting the operation of the organisation. Success has been related to those companies who are able to respond quickly to unpredictable changes in the business environment (Hoyt 1996). Studying that situation, Hoyt (1996) included five characteristics of a dynamic business environment when investigating the allegation that agile companies thrive in hostile environments. The five elements presented in his work include:

a) A dynamic business environment has high potential for continual growth.
b) In a dynamic business environment it is difficult to develop accurate forecasts for medium and long periods of time.
c) In a dynamic business environment it is difficult to develop long range plans.
d) Organisations in a dynamic business environment have to constantly introduce new products.
e) Organisations thriving in a competitive business environment must be technology leaders to be successful.

The five elements presented in the work of Hoyt have been considered in the research of Dove (1994), Goldman (1994), Goldman and Nagel (1993), Kumar et al. (1993), Maidique and Zirger (1984), Maital (1994), Porter and Millar (1985), Swamidass and Newell (1987), Voss (1994) and Youssef (1992). The above elements were important to determine that agile companies appear to cluster slightly below the top financial performers in their industry.

Zhang and Sharifi (2000) described the degree of agility required by a company as a direct function of various factors including the degrees of turbulence of the company's business environment and the levels of sophistication of the company's operational business and internal conditions.

3.4 Obtaining benefits from information systems in manufacturing.

Few academics have studied the failure of information systems to deliver expected benefits in manufacturing organisations. Among them, Kathuria and Igbaria (1997) highlighted that the selection of the right type of IT application seems to have eluded most managers. According to them, numerous instances have reported a system or IT application not measuring up to the expectations or not meeting the needs of the company. Previously, the work done by Huff and Beattie (1985) observed that the mere introduction of IT, does not create competitive advantage; however, the use of the "right type" of IT application for a given company may grant competitive edge. Moreover, Kathuria and Igbaria recognised the lack of research focusing on manufacturing industries in the area of information technology and competitive advantage.

In the early nineties Cooper and Zmud (1990) considered the importance of matching IT applications with the "work context". According to them, matching IT applications to competitive priorities involves the identification of the tasks corresponding to competitive priorities (cost, quality, dependability) and the compatible process structures (job, batch, line, continuous). Studies in the area may adequately account for the "fit" between the technology being examined and the work context within which the technology is being introduced.

After highlighting the problems associated to the use of IT/IS in manufacturing, Kathuria and Igbaria (1997) defined a framework that matches manufacturing strategy, competitive priorities and IT applications in manufacturing, ranging from product design to distribution. In that framework, the process of matching IT applications to competitive priorities involves the identification of the tasks corresponding to competitive priorities (cost, quality, dependability, flexibility, etc.) and the compatible process structures (job, batch, line, continuous).

Despite the significant number of frameworks available for information systems evaluation, industrialists and practitioners appear sceptical about the utility of those methods. Cane (2000) suggested that it is difficult or impossible to quantify the precise value of any benefits delivered. According to him, high-level cost comparisons are meaningless, the financial data companies provide are frequently inaccurate, incomplete or cannot be used for sensible comparisons.

No manufacturing manager is unaware of the burgeoning impact that information technology has had on productive and distributive processes over the last quarter century, Randall (1999). However, the literature on information systems is full of examples of systems failure to deliver expected benefits. According to Randall (1999), for years the usually quoted proportion of MRP_{II} systems that failed to meet what was expected of them has been 80 per cent. Therefore, the development of suitable frameworks for IT evaluation grows in importance by the fact that the worldwide expenditure in IT will reach 1 Trillion USD (Cane 2000) by 2001 and an important amount of it will be spent by manufacturing organisations. On the other hand, according to Randall (1999), manufacturing businesses have no choice about adopting information technology, customers insist on IT, and competitors are unrelenting in squeezing every drop of advantage IT gives them. Also competitive pressures have forced management to take a grip on IT budgets (Farbey et al. 1999).

An extensive review of the literature on agile manufacturing has enabled the identification of labels given to information systems to support agility, these include:

- Being called critical for the achievement of attributes of next generation manufacturing (NGM 1997),
- Key to the agility of many manufacturing systems (O'Connor 1994),
- Important and ultimately required for the agile enterprise (Gunneson 1997),
- Form virtual enterprises that agilely respond to changing market demands (Song and Nagi 1997),

- Support means by which agility capabilities could be obtained (Zhang and Sharifi 2000),
- Support information which is central, critical, and fundamental part of the change to agility (Goldman et al. 1995),
- Contribute to responsiveness as well as to overall corporate and organisational aims (Thoburn et al. 1999).

Other researchers have defined IT/IS as essential for developing Agile Manufacturing Systems, Gunasekaran (1999) and in some cases IS have been defined as applications to support agility in manufacturing, Bocks (1995). IT in virtual enterprises acts as an integrator and virtual enterprises are inherent to agile manufacturing, Jagdev and Browne (1998). The literature on agile manufacturing refers to information systems as a set of applications that covers MRP, MRP_{II}, ERP, Internet enabled EDI, CAD/CAM, Quality Control, Shopfloor systems and other systems. Kathuria and Igbaria (1997) described that companies frequently tend to use integrated IT applications but there are instances when they also use stand-alone applications. This means that it is possible to find manufacturing organisations using integrated packages that include MRP, capacity planning, shopfloor control systems, etc., and other groups of companies running *stand-alone applications like MRP.*

The numerous examples citing the use of information systems in agile manufacturing have motivated the generation of the following research questions:

a) What is the contribution of information systems within the concept of agile manufacturing?
b) Are information systems critical to the achievement of agility?
c) What is the role of information systems among other enablers of agility?
d) Are low performing IS applications impediments to the achievement of agility?

The review of the current literature has provided sufficient elements to outline the first research hypothesis of this work:

H1: *The agility of manufacturing, seen as a contribution of Information Systems, is in part dependent on the support received from IS and on IS's condition of being critical, important and key in the support of agility.*

The identification of manufacturing agility represents a good opportunity to appreciate the contribution of information systems. Three fields have been considered to answer the first hypothesis: agility of manufacturing operations (Dove et al. 1996), IS support of manufacturing operations (Kathuria and Igbaria 1997) and agility as an improvement programme (Gunasekaran 1998). Various factors have been associated with the three fields proposed to answer Hypothesis 1:

- Characteristics of the applications/information systems being studied,
- The impact such applications may have on manufacturing related activities (Cooper and Zmud 1990, Kathuria and Igbaria 1997),
- Impact in terms of operational, strategic and tactical benefits (Ezingeard 1996),
- Flexibility of manufacturing operations (Gupta and Somers 1996, Kathuria 1998, Shewchuk and Moodie 1997).

Also the list includes:

- Identification of the characteristics of the manufacturing systems used (Hayes and Wheelwright 1984, Edwards et al. 1999),
- Implementation of improvement programmes for manufacturing that preceded agile manufacturing like Total Quality Management (Oakland 1995), Business Process Re-engineering (Hammer and Champy 1993), Lean Manufacturing (Womack and Jones 1996).

This research falls within the organisation's dimension defined in the IS evaluation models proposed by DeLone and McLean (1992) and Myers et al. (1997) and it is in terms of the effectiveness of the utilisation of IS described by Smithson and Hirsheim (1998).

3.5 Elements affecting the contribution of IS: alignment to business strategies.

The perceived value of information systems for any organisation is depicted in figure 3.1. Basically, for any manufacturing organisation, the business strategy is responsible for determining a set of objectives and steps that affects business processes with the final purpose of ensuring the growth and prosperity of the firm. These processes are supported by the IS function which provides the infrastructure and IS applications to support the realisation of business processes. Furthermore, these processes are responsible for creating and increasing revenue to the organisation.

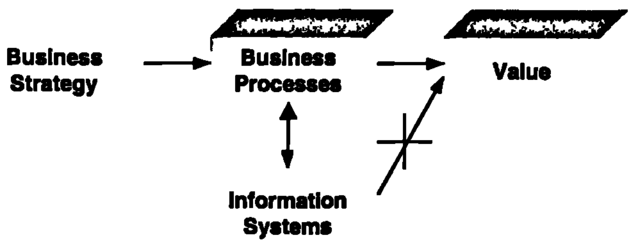

Figure 3.1 IS contribution and value.

The difficulty in relating information systems to the value achieved in the firm is of main concern in the management of information technology, Subrahmanian (1998). The broken link between information systems and value blocks represents the difficulty managers face to identify benefits from information systems. This issue has become more relevant, if not critical, with the rapid changes experienced in the business environment and in the implementation of new technologies in the development of information systems.

Practitioners and researchers have investigated the reasons why information systems fail to deliver expected benefits (Ewusi-Mensah 1997). Henderson and Venkatraman (1999) proposed that the inability to realise value from IT investments is, in part, due to the lack of alignment between the business and IT strategies of the organisations. According to them no single IT application, however sophisticated and state of the art it may be, could deliver a sustained competitive advantage. Advantage is obtained through the capability of an organisation to exploit IT functionality on a continuous basis. Gupta et al. (1997) highlighted that the alignment of IT management with a firm's competitive strategy has been cited as a critical issue for information systems executives and general managers. Strategy is seen as involving both formulation, decisions pertaining to competitive, product-market choices, and implementation, choices that pertain to the structure and capabilities of the firm to execute its product-market choices. IT has been regarded as a key strategic tool for competitive and profitable performance (Johnson and Scholes 1993).

The strategic alignment model defined by Henderson and Venkatraman (1999) identified the need to specify two types of integration between business and IT domains. Strategic integration is the link between business strategy and IT strategy reflecting the external components. The second type, termed operational integration, deals with the corresponding internal domains, the link between organisational infrastructure and processes. Henderson and Venkatraman (1999) provided a thorough description of internal and external domains in IT strategy.

An IT strategy involves three sets of choices, in terms of an external domain:

a) Information technology scope, those specific information technologies that support current business strategy initiatives or could shape new business strategy initiatives for the firm e.g. electronic imaging, expert systems, LAN, WAN, etc.
b) System competencies, those attributes of IT strategy that could contribute positively to the creation of new business strategies e.g. system reliability, cost-performance levels, flexibility.
c) IT governance, selection of use of mechanisms for obtaining the required IT competencies e.g. joint ventures with vendors, strategic alliances, joint research and development for new IT capabilities.

An external domain refers to the position of the firm in the IT marketplace. It is the business arena in which the firm competes and is concerned with decisions such as the distinctive strategy attributes that differentiate the firm from its competitors and product-market offering.

An internal domain is concerned with choices pertaining to the logic of the administrative structure, design of critical business processes, as well as the acquisition and development of human resources skills. These include:

a) IS architecture scope, choices that define the portfolio of applications, the configuration of hardware and software, and communication, and the data architecture that collectively define the technical infrastructure.

b) IS processes, choices that define the work processes central to the operations of the IS infrastructure such as systems development, maintenance, monitoring and control systems.

c) IS skills, choices pertaining to the acquisition, training, and development of the knowledge and capabilities of the individuals required to effectively manage and operate the IS infrastructure within the organisation.

Henderson and Venkatraman emphasised that IT strategy should be elevated from its traditional internal focus to address external issues of how well the firm is positioned in the fast-changing IT marketplace. Inadequate fit between external and internal domains of IT is a major reason for failure to derive benefits from IT investments. Earl (1999) highlighted that IT considerations should be included in business strategy-making enabled by the creation of an information business strategy.

Henderson and Venkatraman (1999) proposed four dominant alignment perspectives whose drivers include business and IT strategies. Two of them are lead by a business strategy and two of them are lead by an IT strategy. A brief description of each perspective is provided next.

3.5.1 Strategy execution (business strategy leadership).

This perspective is based on the notion that a business strategy has been articulated and is the driver of both organisational design choices and the design of IS infrastructure. This relationship is depicted in figure 3.2.

Figure 3.2 Strategy Execution.

3.5.2 Technology transformation (business strategy leadership).

Technology transformation is a perspective that involves the assessment of implementing the chosen business strategy through appropriate IT strategy and the articulation of the required IS infrastructure and business processes. This relationship is depicted in figure 3.3.

Figure 3.3 Technology transformation.

3.5.3 Competitive potential.

This alignment perspective is concerned with the exploitation of IT/IS capabilities to impact new products and services (business scope), influence the key attributes of strategy (distinctive competencies), and develop new forms of relationships (business governance). It allows the adaptation of business strategy via emerging IT capabilities. This relationship is depicted in figure 3.4.

Figure 3.4 Competitive potential.

3.5.4 Service level.

This alignment perspective focuses on how to build a world-class IS service organisation. This requires an understanding of the external dimensions of IT strategy with corresponding internal design of the IS infrastructure and processes. This strategic fit for IT creates the capacity to meet the needs of IS customers. This perspective is viewed as necessary to ensure the effective use of IT. This relationship is depicted in figure 3.5.

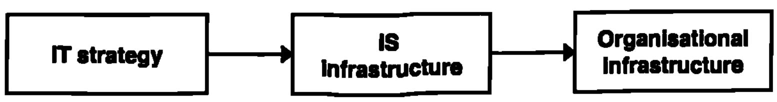

Figure 3.5 Service level.

Two of the alignment strategies proposed by Henderson and Venkatraman (1999) contemplate IT as the driver of an organisation, including its business strategy and its own IT and organisation infrastructure. It would be interesting to find-out if such approaches are suitable for the development of agility in manufacturing organisations.

Kathuria and Igbaria (1997) showed that the need for aligning systems with business strategy has been constantly emphasised in the information sciences as well as the manufacturing strategy literature. The need for aligning IT applications in various functional areas with the generic strategies of firms has been emphasised since the early eighties (Parsons 1983). Skinner (1969) was perhaps the first researcher to recognise the need for aligning decisions in the "infrastructural areas" with the manufacturing strategy of a firm.

Linking manufacturing strategies and IT strategies, Wu and Ellis (2000) proposed a structural approach to help a company identify the key manufacturing information systems requirements that are needed to effectively support the company's future manufacturing strategic aims. The researchers showed that purely technical oriented manufacturing information systems (e.g. ERP) implementation is one of the main reasons of failure.

The definition of strategic priorities based on the identification of critical processes has been studied in manufacturing. Despite the fact that software vendors provide standard IS applications, Wu and Chang (2000) identified that users were unable to define their strategic systems requirements. Very often, companies lack a structured, strategically driven approach to assist them in mapping a function-oriented software into business-oriented systems (Wu and Ellis 2000).

The literature has shown the potential of IT/IS, transcending from its traditional "back office" role and evolving towards a strategic role, not only to support chosen business strategies, but also to shape new business strategies (Henderson and Venkatraman 1999, Keen 1991, Konsynski and McFarlan 1990, Morton 1991).

The review of the literature presented in this section has provided enough elements to outline the second hypothesis of this research:

H2: *IT-business strategy alignment determines the impact information systems may have on the agility of manufacturing.*

3.6 Non-technical enablers of agility and their relationship to IS.

As stated earlier, personnel skills and expertise have been identified as part of the internal domain of an IT strategy. In fact, personnel skills and expertise maintain an important role within the concept of agile manufacturing. Gunasekaran (1998) identified people as an area where strategies for agile manufacturing should be knowledgeable, skilled, empowered and entrepeneurial. Also Gunasekaran recognised IT skills and knowledge as elements supporting enablers of agile manufacturing such as the virtual enterprise. Moreover, the level of IT/IS skills has been considered in the formation of strategic partnerships. When investigating the importance of some enablers of agility, Zhang and Sharifi (2000) identified that practices regarding Organisation and People were more important for manufacturers than concepts like virtual organisations, mass-customisation, and using the Internet as an information tool.

In their work, Dove et al. (1996) presented the existence of a growing recognition that ubiquitous electronic communications capabilities can enhance the productivity of all employees and result in a highly responsive and self-coordinating business unit. The importance of personnel skills in the use of information systems has been covered in the software engineering field as well. Edwards et al. (1999) emphasised the importance of the culture, working practices, expectations, expertise and experience, to make informed decisions about the company's needs for software systems.

Goldman et al. (1995) defined people, what they know, the skills they possess, the initiative they display, and information as the differentiators between companies in an agile competitive environment. They showed knowledge-based products as those that offer the greatest potential for individualisation, continuous work force education and training which are integral to agile company operations. Gunneson (1997) described that organisations in the future will not value employees by their job or position, but by their skill sets and competencies. In fact, multifunctional skills enable the agile enterprise.

People's skills and expertise are considered elements that affect the operation of agile enterprises. Valuing human knowledge and skills is one of the underlying principles of agility (Gunasekaran 1998). Skills and expertise have been recognised as elements affecting organisational change as well. According to Gunasekaran (1998) the organisational structure of agile manufacturing should encourage the integration of partner-organisations by knowledgeable workers with adequate skills in computers.

In the literature of information systems, evaluation of IT has been associated with organisational learning (Symons 1990). Experience and learning from past mistakes have been documented in the current literature (Armstrong 1988).

According to Serafeimidis and Smithson (1999) evaluation can serve multiple roles in addition to ensuring the cost-efficient use of resources. Evaluation of IT/IS acts as a feedback mechanism, applying a critical spirit to actions taken and results achieved (Hirscheim and Smithson 1988). Furthermore, IT/IS evaluation potentially contributes to organisational learning and understanding (Farbey et al. 1999). Organisations learn not only when an evaluation procedure is applied or training is provided to employees but also learning is achieved during the operation of a particular IS application, the so called learning curve.

Feeny and Willcocks (1998) found that as managers experience more volatile marketplaces, global competition, shortened product life cycles, customer pressures for tailored offerings and tighter performance standards, they increasingly depend on new information systems. A series of recommendations by these researchers included building a strong IT staff, a reusable technology base and a partnership between IT and business management.

The literature on agile manufacturing has presented people's skills and expertise in the agile organisation. Employees' IT skills and expertise have been recognised as elements for team work and integration (Goldman et al. 1995). The approach presented in this work recognises personnel skills and expertise as elements involved in the operation of information systems and the achievement of agility.

The following hypothesis has been outlined based on the high relevance given to personnel skills in the literature of information systems and agile manufacturing.

H3: *Information systems contribution to agility of manufacturing is dependent on the skills and expertise of employees.*

The contribution of information systems has been studied by academics in different environments and industries. One of the benefits of evaluation of IT/IS is the possibility of improving a system and the design of better systems in the future (De and Ferrat 1998). One of the reasons for low levels of contribution experienced with IT investments is that information systems have been largely seen as an expenditure rather than an investment by management.

3.7 Characteristics that encompass IT/IS capabilities to support agility.

Agility is a new perspective about the relationship between manufacturers and customers, a relationship of enrichment (Goldman et al. 1995). Agility compromises responding to changes (anticipated or unexpected) in proper ways and due time, exploring and taking advantage of those changes as opportunities (Dove 1996, Kidd 1994). This means that providers of capabilities of agility need to be fully integrated with the support of information systems/technology (Zhang and Sharifi 2000). Capabilities of agility may include responsiveness, competency, flexibility and speed, which the company needs to positively respond to changes/pressures from the business environment.

Dove et al. (1996) were among the first researchers to study the importance of information systems to agility. In the framework defined by these researchers, information systems are one of twenty-four critical business practices for agility. Dove et al. defined information systems unit relationships as the stimulation of the environment and the embodiment in the corporation for acquiring and using information technology components that solve unique business needs, yet fit into an overall corporate structure. However, according to Dove et al., this produces a dichotomy that in one hand a company wants to provide a great degree of freedom and autonomy to the business units to operate, while on the other hand a company wants solutions to fit into a corporate structure in order to share data, knowledge, and solutions across the business units. The researchers defined a template by which a company can provide this degree of flexibility, predicated on some strong standards which are part of the architecture that deems a component or systems function to be of no value added to the business or competitive value.

The outcome of the study provided a list of proficiency characteristics classified as proactive proficiency characteristics and reactive proficiency characteristics. A description is provided in table 3.1.

	Proactive Change Proficiency Characteristics
Creation	Designing an infrastructure of global interaction standards that permits unique local solutions
Augmentation	Improving the standards without impacting operational applications
Migration	Anticipating future electronic interactions with customers and suppliers
Modification	Adding new standards to the infrastructure without wreaking havoc on existing unique implementations
	Reactive Change Proficiency Characteristics
Correction	Fixing an infrastructure that is overly restrictive
Variation	Accommodating variations to the infrastructure standards for unique requirements
Expansion	Expanding the internal user community and number of supported business units
Reconfiguration	Moving unique solutions from one business unit to another

Table 3.1 Proficiency Characteristics for Information Systems.

According to the Agility Forum (Dove et al. 1996), the IT/IS proficiency characteristics represent the interactive relationships among individual units of information automation equipment and software. The report of the Agility Forum specified that information technology in support of an agile enterprise is the agility of the information technology infrastructure itself.

These group of researchers were the first indeed to approach non-technical problems of information systems within the context of agile manufacturing. They highlighted that too often the motivating force for new information technology systems is the lure of the latest technology itself, rather than the need to solve specific business problems.

The characteristics presented in table 3.1 are based on a detailed case-study developed at Remmele Manufacturing based in Minnesota, USA. A detailed justification for each of the characteristics presented in table 3.1 is provided next:

a) Designing an infrastructure of global interaction standards that permits unique local solutions. A company can create an information system base that enables independent business units or departmental functions to implement custom point solutions that provide them with a competitive edge. Enabling technologies include Intranets, client/server environments with object-oriented architectures and applications.

b) Improving the standards without impacting operational applications. At any point in time, the rules and standards of the information technology architecture need to be stable and implementation of new IS applications need time to mature and become fully functional in the business.

c) Anticipating future electronic interactions with customers and suppliers. This is, having an extensible architecture that allows unanticipated application and data requirements for collaboration with customers and suppliers.

There is also another characteristic associated to *migration* called *comparison*. *Comparison* has been defined as the organisation who constantly monitors developments in IT/IS in its industry and benchmarks it against other industries.

d) Adding new standards to the infrastructure without wreaking havoc on existing unique implementations. As business needs change or industries embrace new standards or practices, layers of standards must be able to be expanded and/or contracted (e.g. remove a standard from the corporate set and move it to the industry).

e) Fixing an infrastructure that is overly restrictive. As information systems applications evolve, there are inevitable requirements that cannot be serviced by the existing infrastructure standards.

f) Accommodating variations to the infrastructure standards for unique requirements. This is when applications and system functions cannot meet the "letter of the law" of the infrastructure standards, caused because purchased packages have been created independently of the current architecture of the company.

g) Expanding the internal user community and number of supported business units. Ubiquitous electronic communications capabilities can enhance the productivity of all employees and result in a highly responsive and self-coordinating business unit. This requires companies to define their infrastructure and the interaction of IT/IS applications in advance of implementation.

h) Moving unique solutions from one business unit to another. The utilisation of cross-divisional applications built around an IS package enables portability, so a single application can be exported across enterprise divisions.

The IT/IS proficiency characteristics of agility identified in the study by Dove et al. and the Agility Forum followed by the work accomplished by the Next Generation Manufacturing Project (1997) motivated the generation of two propositions. The first one is the association of those IT/IS proficiency characteristics to the attributes of a dynamic business environment already presented in this work:

1) IT/IS proficiency characteristics of agility are associated to the characteristics of a highly dynamic business environment.

During the development of this chapter, the influence of a dynamic business environment has been covered in the works of many researchers. The first proposition is influenced by the work done by Hoyt (1996). Also Noori and Mavaddat (1997) described the importance of information systems to provide the organisation with the ability to respond to its environment in real time.

The second proposition associates IT/IS proficiency characteristics and a set of different types of IS applications for manufacturing.

2) IT/IS proficiency characteristics of agility are associated to the utilisation of a specific type of information systems application.

The influence to elaborate the second proposition comes from the fact that several computer-integrated systems could be used to support agile manufacturing and these include MRP_{II}, Internet, CAD/CAE, ERP, Multimedia and Electronic Commerce. The classification employed to distinguish the use of different applications is based on the technology evolution of IS reported by the NGM project (1997). The above propositions have been generated with the idea of generating a broader understanding of the support of IS to agility in manufacturing organisations.

3.8 Overview of the nature of information systems research.

Doing research in information systems has typically implied the use of a positivistic approach. However, some researchers have started to encourage the use of an interpretative approach. Smithson and Hirscheim (1998) have encouraged the need for a paradigm shift within the academic community towards interpretivism and away from positivism. Bharadawj (1996) has discussed the use of positivist and interpretative approaches in information systems research. The researcher provided a series of arguments that stated that the positivist philosophy suffers from several limitations when applied to an issue like research in information systems. According to him, the strict inductionist approach is often inappropriate because speculation and creation of an a priory hypotheses are essential for a systematic procedure of theory building. The empiricist approach is based on the notion of pure observation, which is difficult because observations are always subject to measurement errors. And the assumption that knowledge is derived from an objective interpretation of assumptions, without any of the subjective biases or a priori knowledge of the scientist coming into play.

Bharadawj justified the use of an interpretative approach in IS. According to him, the interpretative philosophy is based on the belief that science is subjective and therefore allows alternative models of reality. The researcher listed a series of reasons why an interpretative view is pertinent to IS research. First, since the human element is inextricably linked with the technological aspect of IS research, it is only appropriate that the underlying philosophical perspective mirrors the links. Second, it effectively overcomes the problems associated with the pure empirical paradigm which views the construction of information systems as merely technical artifacts. The interpretative view has led to the development of several research programmes in IS.

Finally, Bharadawj analysed and commented the sophisticated methodological falsification model (SMF) proposed by Lakatos (Bharadawj 1996). According to him, this model is somewhere in between positivism and interpretativism. This approach introduced the notion of a research programme consisting of the hard core of fundamental assumptions and theoretical propositions accepted as absolute truth by the scientists within that research programme. Surrounding, the hard core is a protective belt of auxiliary hypotheses and mid-range theories. This protective belt has to bear the brunt of tests and get re-adjusted or completely replaced. The Lakatosian model has emphasised that every research programme needs a positive heuristic and a negative heuristic. The positive heuristic is a set of partially articulated methodological rules or hints on how to change or develop the research programme, while the negative heuristic suggests paths of research that should be avoided and is generally used to defend the hard core.

3.9 Research methodology employed.

Following the arguments provided in the previous section, the research hypotheses developed in this work could be classified as derivations of three propositions widely accepted by researchers and scientists in the fields of agile manufacturing and information systems. These include: the recognition of information systems as principal enablers of agility, the misalignment between business and IT strategies as being in part responsible of the failure to realise benefits from IS, and the importance of employees' expertise and skills in the operation of the agile enterprise and in the realisation of benefits from IS.

The answer to the two propositions involving the influence of a dynamic business environment and the use of a specific type of IS application and IT/IS proficiency characteristics of agility required the design of a survey research. The development of the survey involved collecting data from companies in various industry sectors. The questions developed for the survey were taken from the IT/IS proficiency characteristics of agility defined by Dove et al. (1996).

This research does not deny the "enablers of agility" label granted to information systems and the importance of the development-implementation of new information systems to support business processes. Instead, this work is focused on finding existing relationships between the agility of business processes, especially manufacturing operations, in a manufacturing organisation and the use of information systems. Moreover, this study does challenge information systems counted as principal enablers of agility. The following section presents the characteristics of the research methods reviewed during the development of this work.

3.10 Qualitative methods to gather data.

Qualitative data describe, explain and characterise the subject of investigation using words rather than numbers. The strength of qualitative research is that it is best for exploratory and descriptive analysis which stresses the importance of context, setting frames of reference, Marshall and Rossman (1994). Qualitative data are data represented as words and pictures, not numbers, Gilgun (1992). According to Taylor and Bodgan (1984), qualitative research methods were designed, mostly by educational researchers and other social scientists to study the complexities of human behaviour.

The use of qualitative measures for evaluation is not exclusive of the Management Information Systems field. Seaman and Basili (1998) described that recent work in empirical software engineering research groups has focused on the human aspects of communication among developers, and on the elicitation processes used to build systems based on commercial-off-the-shelf components, Parra et al. (1998). A number of different techniques used to gather qualitative data are reviewed in the following sub-sections.

3.10.1 Interviewing.

Interviews are conducted to collect historical data from the memories of interviewees. There are different types of interviews. In a structured interview, the questions are in the hands of the interviewer and the response rests with the interviewee. The extreme of a structured interview is one in which no qualitative information is gained at all, i.e. all responses can be quantified (e.g., yes/no, good/fair/poor, etc.). A qualitative study must be flexible enough to allow unforeseen types of information to be recorded. In an unstructured interview, the interviewee is the source of both questions and answers. Semi-structured interviews include a mixture of open-ended and specific questions, designed to elicit not only the information foreseen, but unexpected types of information, Seaman (1999). Personal interviewing is recognised as allowing a degree of flexibility and providing a richness of data for exploratory research (Fearon and Philip 1998).

3.10.2 Triangulation to confirm conclusions and extend theory building.

Triangulation is a tool used to confirm the validity of conclusions and closely associated to qualitative studies. According to Seaman (1999), qualitative methods to gather data should be aimed at theory generation and theory confirmation.

Applied to the particular characteristics of this research, triangulation gives the opportunity to gather additional data to support statistical results. Moreover, triangulation enables expanding statistical results through the use of research techniques such as structured and unstructured interviews. The scheme applied to this research is depicted in figure 3.6.

The development of a multiple case study that includes interviewing personnel directly involved in the operation of the business processes and information systems will give the opportunity to confirm the results of the survey research and support or refute the three research hypotheses generated in this study.

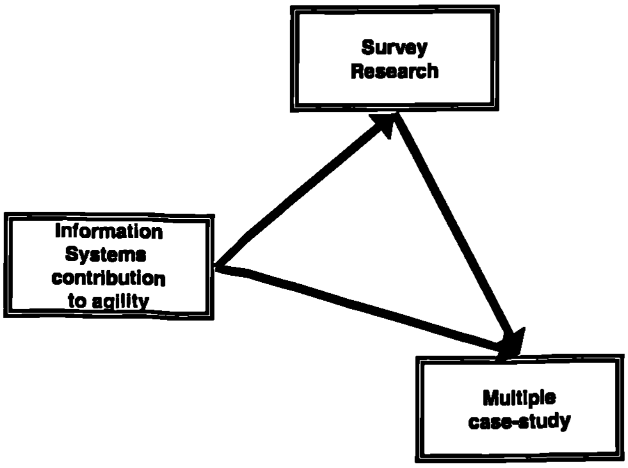

Figure 3.6 Triangulation scheme.

3.10.3 Theory generation.

Theory generation methods are generally used to extract, from a set of field notes, a statement or proposition that is supported in multiple ways by the data. The statement or proposition is first constructed from some passage in the notes, and then refined, modified, and elaborated upon as other passages are found and incorporated, Seaman (1999).

3.10.4 Theory confirmation.

Most qualitative data analysis methods are aimed at generating theory, but there are a number of methods and approaches to strengthening, or "confirming" a proposition after it has been generated from the data. Seaman (1999) described that the goal is to build up the "weight of evidence" in support of a particular proposition, not to prove it. Although quantitative hypothesis testing methods seem more conclusive than qualitative methods, these methods really do not provide any stronger evidence of a proposition's truth. According to Seaman, a hypothesis cannot be proven, it can only be supported or refuted, and this is true using either quantitative evidence or both.

3.10.5 Development of semistructured interviews.

The proposed framework of semistructured interviews for this research encompasses three main sections: organisation management, manufacturing operations and information systems. Figure 3.7 depicts this framework.

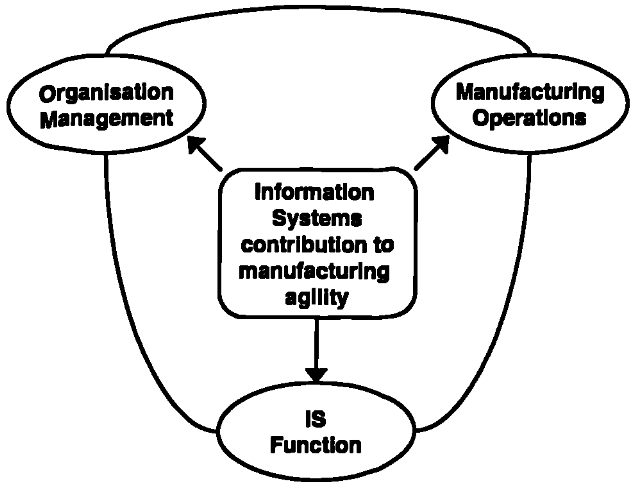

Figure 3.7 Semistructured interviews proposed framework.

The organisation management section is focused on identifying strategy and overall performance of the organisation, the manufacturing operations section is focused on identifying manufacturing performance and support received from IS. The IS section is focused on the performance and management of information technology in the organisation. The semistructured interviews took place in the multiple case-study developed for this research. The interview data was collected based on the qualitative methods recommended by Seaman (1999). During the interviews, the information of the open-ended questions was used in conjunction with a self-assessment benefit rating instrument administered through a questionnaire, mostly closed-ended questions, to participating companies. As a protection against bias, the self-assessment data was interpreted and justified in the light of the interviewee responses. According to Fearon and Philip (1998) this has the advantage of placing the benefit measurements from the self-assessment ratings in context and increasing the instrumental validity of final results.

3.10.6 Other techniques influencing the research.

The critical incident technique influenced the preparation stages of this research. John Flanagan (American Institutes for Research 2000) developed the critical incident technique (CIT) to identify behaviours that contribute to the success or failure of individuals or organisations in specific situations. Under this technique, a researcher first asks people familiar with the situation for a recent example of effective or ineffective behaviour, that is a critical incident. A critical incident is determined from the answers to the following questions:

- Describe what led up to the situation.
- Exactly what did the person do or not do that was especially effective or ineffective?
- What was the outcome or result of this action?
- Why was this action effective, or what more effective action might have been expected?

The critical incident technique has been applied in studies of numerous occupations, including aircraft pilots and dentists (American Institutes for Research 2000).

The critical incident technique may be used in an interview or in a survey. Once the respondent describes a specific experience or incident, the investigator may probe it in an interview or ask a standard list of exploratory questions using a survey. For example, the utilisation of this technique in this research will require identifying the specific information system used to support manufacturing operations in participating manufacturing organisations.

3.11 Research map of the strategies implemented.

The work path developed for this research is represented by eight main stages, as it is depicted in figure 3.8. Details on each of the eight stages are given in the following paragraphs.

The first stage represents an introduction to this research, literature review covering the need of manufacturing organisations to become agile, the recognition of information systems as principal enablers of agility, the identification of current problems associated to the use of IT/IS and the need to evaluate information systems.

The second stage of this research represents the identification of suitable research problems after an extensive literature review. This review covers the evolution of manufacturing operations towards agility, the evolution of information systems in manufacturing, a summary of the most representative examples of evaluation of information systems in manufacturing enterprises and models/frameworks developed in academia to evaluate information systems. This stage is a primer of the research hypotheses generated in the next stage.

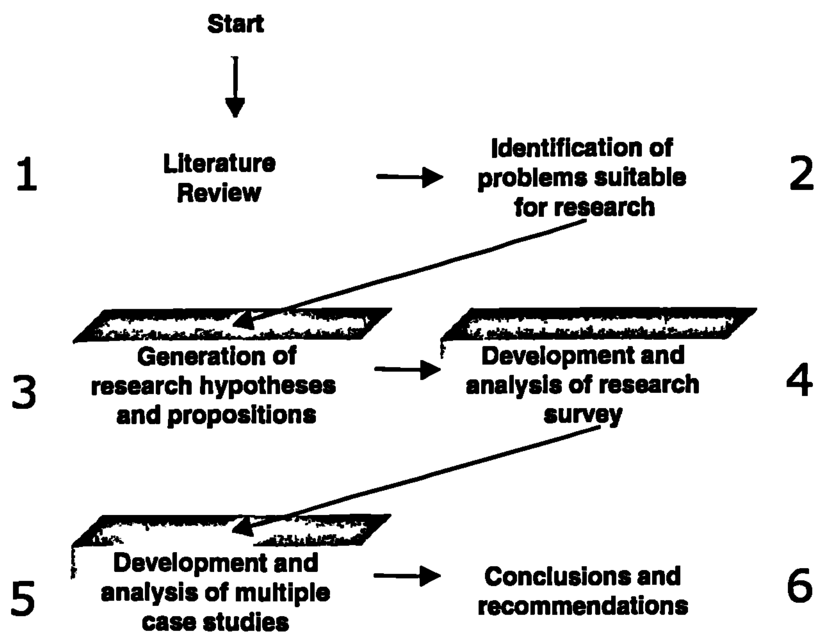

Figure 3.8 Research Map employed.

Covered aspects in the third stage include: the identification of IT/IS proficiency characteristics of information systems to support the concept of agility, information systems as enablers of agility, a dynamic business environment affecting information systems, defined IT/business strategies and skills and expertise of employees affecting the contribution of information systems. All of them have been used to generate the research hypotheses and propositions presented in this work. Also this stage covers the selection of the methodology that best fits the defined research objectives and hypotheses. A survey research scenario followed by a multiple case-study will provide the data required to validate the research hypotheses and propositions generated for this work.

The fourth stage of this research is represented by the accomplishment of a survey research to test two research propositions covering the association between IT/IS proficiency characteristics of agility, the influence of a dynamic business environment and the type of IS applications used in manufacturing organisations. The results of the survey will be further expanded.

Stage number five of this research is represented by the multiple case-study. This stage involves the use of a questionnaire instrument and the accomplishment of semi-structured interviews with manufacturing organisations. The questionnaire instrument covers three sections in terms of information systems, manufacturing operations and company management. A detailed analysis of the multiple case-study will enable the identification of elements supporting information systems contribution to manufacturing agility and to expand the results of the survey research.

The methodology employed to answer the research hypotheses involved comparing the perceptions of realised benefits of information systems with the characteristics of manufacturing operations and other business processes in participating companies. Also, included were the benefits (operational, strategic and tactical) expectations the companies have on the adoption of information systems. The above methodology can serve as a surrogate measure in determining the contribution of information systems to manufacturing agility, as well as identifying IT and business strategies, and skills and expertise of employees affecting such contribution.

The last stage of this research covers detailed comments and recommendations based on the results of this work. Final comments will focus on the role of information systems as an enabler of agility, information systems contribution to manufacturing agility and the interrelation with factors like IT-business strategy alignment, employee skills/expertise, dynamic business environment influence and types of information systems used.

3.12 Comments and remarks.

An extensive literature review provided enough elements to support the definition of each of the hypotheses presented in this work. This study amalgamates the recognition of IS as principals enablers of agile manufacturing with the need to identify agility as a contribution of IS.

Given the high profile of IS in the literature of agile manufacturing, investigating the first hypothesis will provide an answer to information systems assumption as principal enablers of agility. The second hypothesis relates agility to the alignment of IT and business strategies. As discussed earlier, the misalignment between IT and business strategies is in part responsible for the failure to realise benefits from IS. The last hypothesis presents the agility of business processes, especially manufacturing operations, dependent on IT skills and expertise of employees to operate information systems.

The proposed research methodology will facilitate the collection of data that can be analysed to support or refute the hypotheses and propositions presented in this work. The reviewed literature showed that the research techniques considered in this work have been widely employed in the information systems and software engineering fields. Apart from clarifying the importance of information systems within the concept of agile manufacturing, the findings of this study should enable organisations to acquire sufficient knowledge for a better management of IT and the definition of sound plans for the improvement of their business processes.

Chapter 4

Testing proficiency characteristics of IT/IS of agility in manufacturing organisations.

4.1 Introduction.

The previous chapter provided two research propositions involving characteristics that encompass capabilities of IT/IS to support the concept of agile manufacturing, a set of characteristics of dynamic business environments and the type of IS applications commonly found in manufacturing organisations.

The need to investigate the above issues is because in today's business environment, manufacturing organisations are subject to increasing competition, in terms of reduced product life cycle and constant changes in customer demands. In order to meet those demands, manufacturing organisations rely on technology that can provide them with wide benefits, not only in terms of cost savings, but also with the potential for revenue generation (Kidd 1994).

According to the NGM project (1997) the use of computers in manufacturing is represented by different technology trends. The origins of the use of IT in manufacturing can be traced back to the 50's, but it was not until the beginning of the 70's when IT started to be widely adopted in manufacturing, being represented by applications such as CAM (Computer Aided Manufacturing) and Materials Transformation. The progress of the 70's saw applications and technologies such as SPC (Statistical Process Control), Data Management, CAD (Computer Aided Design)-CAM, MRP (Material Resource Planning), CNC (Computer Numerical Control) and JIT (Just-In-Time) being developed and widely implemented in manufacturing enterprises. The 80's saw the development and implementation of technologies such as Intelligent Scheduling, Supplier Partnerships, CIM (Computer Integrated Manufacturing), MRP_{II} (Manufacturing Resource Planning) Automation (use of Programmable Logic Controllers), Robotics, EDI (Electronic Data

Interchange) and CAE (Computer Aided Engineering). The 90's and present times have witnessed the development of software based on Object Technology, and the widespread use of applications and technologies related to Operational Modelling, Enterprise Integration, Intelligent Sensors, Active Agents, Virtual Reality, APC (Advanced Process Control), E-commerce using the Internet and b2b (business to business). Other researchers have come across with different ways of classifying the use of IT in manufacturing. For example, Kathuria and Igbaria (1997) provided a classification consisting on seven major groups including product design, demand management, capacity planning, inventory management, shopfloor systems, quality management and distribution. Randall (1999) suggested that investments and use of IT/IS in manufacturing organisations can be classified in three major groups:

- *Infrastructure* covering the Internet, Intranet, databases and operating systems. According to Broadbent et al. (1999) Infrastructure is the enabling base of shared IT capabilities which provide the foundation for other business systems.
- *Planning* covering MRP, ERP Enterprise Resource Planning, APS Advanced Planning and Scheduling. These are information systems applications for the assessment of materials and plant resources, business processes modelling and real time decision support. This group covers applications used in design (e.g. CAD).
- *Execution* covering workflow and data warehousing among other functions. It is technology that facilitates minute by minute transactions; a central transaction resource linking other data streams within manufacturing operations, both internal (e.g. ERP systems) and external (e.g. customers, suppliers and service providers). This group covers applications such as CAM and CNC used from the design of components to the final inspection and signoff.

The development of agility in manufacturing organisations is closely related to information systems. Different types of technology, representing various stages in the evolution of information systems, are responsible for supporting critical business activities in manufacturing organisations. Despite the different range of applications used to support business operations, most manufacturing organisations share common needs and require basic IT/IS characteristics to fulfil them. This requirement is examined in relation to IT/IS proficiency characteristics identified in the literature of agile manufacturing.

This chapter explains the growing importance of information systems in manufacturing organisations, IS evolution, the conditions of the business environment affecting the manufacturing industry and information systems characteristics identified in the literature of agile manufacturing. All these elements were covered in a questionnaire instrument and used in a survey to explore possible associations among them. Surveyed manufacturing companies prioritised each of the above elements.

4.2 The growing importance of information systems in manufacturing.

In different improvement programmes for manufacturing organisations, information systems play a very important role. For example, in Total Quality Management the utilisation of MRP systems is fundamental to reducing inventories and cycle time. JIT (Just-In-Time) emphasises minimising (if not eliminating) waste in the form of inventories in order to reduce costs. JIT empowers employees to check quality at the source and ensuring that products are consistently made to standards. Some IS applications have been classified as JIT. However, some researchers argue that JIT is more of a philosophy than just another computerised planning system intended for repetitive environment, stable schedule, narrow product range and standard items (Kathuria and Igbaria 1997). In the early 90's Business Process Re-engineering (BPR) was the focus of attention in the manufacturing industry, BPR is essentially supported by IT. Then, lean manufacturing gained the attention of manufacturing managers, lean means doing more with less resources; banishing waste (Womack and Jones 1996). Since the early-nineties agility has been proposed as the main improvement programme for manufacturing organisations. Information systems have been identified as key enablers of concepts such as the extended and virtual enterprise (Jagdev and Browne 1998, Gunasekaran 1998) and hence, they are considered to be important components of agility. According to the originators of the concept of agility (Goldman et al. 1995), agile manufacturing organisations operate in dynamic business environments. Success in a dynamic business environment requires information systems that enable the organisation to react quickly to emerging customer opportunities.

A dynamic business environment is typified by rapidly emerging customer opportunities. Researchers in the fields of industrial engineering and operations management have remarked upon the importance of a dynamic business environment in shaping all the activities of manufacturing organisations (Kidd 1994, Goldman et al. 1995). Therefore, manufacturing organisations need to grasp to those emerging customer opportunities to their advantage.

4.2.1 Development of information systems in manufacturing.

The adoption of IT/IS in manufacturing has been through an evolution process that started more than three decades ago. The latest developments in information systems for manufacturing represent the utilisation of Internet based e-commerce applications, virtual enterprise and integration not only at the company level but with other organisations. However, IS applications that were originally developed some years ago are still widely used in the industry. Examples include the use of MRP, MRP_{II}, CAD/CAM, CNC, SPC, Data Management, extensive automation using PLCs, robots and AGVs, CIM and EDI.

The literature review presented in chapter 2 made possible to identify different prototypes of information systems and models intended to support agile manufacturing. Bullinger et al. (1998) developed an integration concept for heterogeneous legacy systems in manufacturing companies. Herrman et al. (1995) introduced an information model that describes the systems, process capabilities, and performance of a manufacturing firm, taking into account pre-qualifying partners, product design with respect to potential partners and selection of optimal partners for manufacture. Song and Nagi (1996, 1997) designed a very detailed application that enabled organisations to work in a virtual enterprise. Moreover, Mowshowitz (1998) provided some characteristics of the operation of virtual organisations. The development and use of sophisticated IT/IS applications like the examples shown above confirms the importance of technology in the future of manufacturing. However, in order to ensure the success of new IT tools/IS applications, those have first to meet the needs of manufacturing organisations facing dynamic business environments as means to ensure the success and positive contribution to business processes.

Given the high profile of IT in the agile manufacturing literature, this work identified the traditional support of the IT function in manufacturing enterprises, as shown in figure 4.1. In this simplified model, the information systems department is responsible for providing the applications/solutions in terms of infrastructure, planning and execution available to the organisation. The organisation reacts to customer opportunities by providing the required services/products and ordering materials from suppliers. IS applications/solutions used to support business processes link the IT function to the organisation. Certainly, the adoption of the agile manufacturing paradigm may require the IT function to impact not only the organisation alone but the interrelation between the organisation and its suppliers and customers.

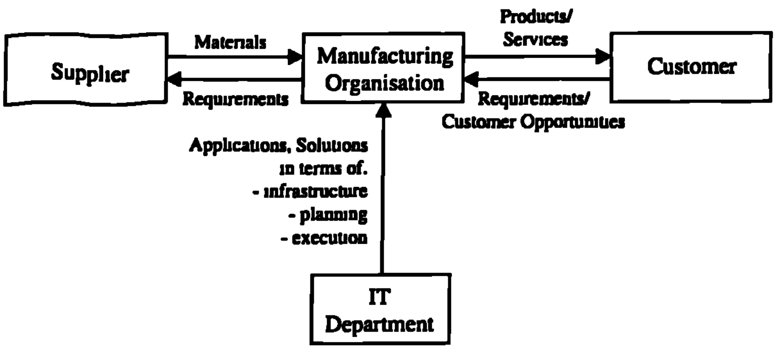

Figure 4.1 Use of IT applications/solutions in manufacturing organisations.

The study of the impact a dynamic business environment has on IT, the identification of characteristics of IT/IS suitable to the concept of agility and their interrelation with the use of commercial IS applications used in manufacturing enterprises are elements investigated in the following sections.

4.3 Dynamic business environment.

A dynamic business environment is being faced by many manufacturing organisations. Constant changes in the business environment can be manifest in ever customer needs changing, entailing new roles in industry. The business environment is the source of turbulence and changes impose pressure on the business activities of a company (Preiss 1997).

Manufacturing organisations in dynamic business environments need to be aware of new customer opportunities all the time. A very long list of items can be associated with a dynamic business environment. For the purposes of this work, three characteristics of a dynamic business environment presented during the generation of research propositions in chapter 3 have been considered. These include:

- A market that offers a high potential for continual growth.
- Difficulty in developing long range plans in the industry.
- Survival in the industry requires the introduction of new products.

The association of business environment characteristics to seven IT/IS proficiency characteristics identified by Dove et al (1996) and the Agility Forum is one of the propositions generated in chapter 3. An explanation for choosing these three characteristics is provided in Appendix C, titled "Survey Development Notes" and is mainly based upon a pilot survey.

4.4 Proficiency characteristics that encompass the capabilities of IT/IS to support agility.

During the presentation of the research hypotheses and propositions in chapter 3 it was possible to identify a set of IT/IS characteristics for the competitiveness of manufacturing organisations. These IT/IS proficiency characteristics identified by Dove et al (1996) and people from the Agility Forum represent the interactive relationships among individual units of information automation equipment and software. In fact, Dove et al. (1996) were the first researchers to address the specific needs of IT/IS of manufacturing organisations in terms of agility. The following statements already presented in chapter 3 represent each of the IT/IS proficiency characteristics as used in this research:

- *Augmentation.* The IT/IS infrastructure ensures continued viability as components are improved, added or removed.

- *Creation.* IT/IS in the enterprise provides an environment that promotes the development of customised solutions based on unique business needs.
- *Migration.* The IT/IS infrastructure anticipates future electronic interactions with suppliers and customers.
- *Comparison.* The organisation constantly monitors developments in IT/IS in our industry and benchmarks it against other industries.
- *Modification.* New standards can be upgraded to the IT/IS infrastructure without breaking other applications.
- *Variation.* It is possible to accommodate variations to the IT/IS standards in order to accommodate unique requirements.
- *Correction.* Fixings to the IT/IS infrastructure are in short periods of time when problems arise.

A brief justification of these characteristics is given below. Also, Appendix C provides arguments explaining the use of the above IT/IS characteristics.

The proficiency characteristic of *augmentation* is strongly related to flexibility of an IT/IS infrastructure. Researchers have claimed that information systems are inhibitors if there is an inappropriate or inflexible infrastructure (Saaksjarvi 1998). According to them IT/IS infrastructure is the enabling base of shared capabilities that provide the foundation for other business systems (Fitzgerald 1998). *Creation* is related to the capability for development of customised solutions to meet the business needs of the organisation. This means that organisations are required to be pro-active and innovative, so developing customised information systems solutions constitute a source of competitive advantage. In fact, some researchers (Song and Nagi 1997, Boar 1994) identified the importance of information systems to enable new ways of work not experienced before like the virtual enterprise, where *migration* has been identified and electronic interactions between suppliers and customers are extremely important for the competitiveness of an organisation. On the other hand, organisations need to be aware of the developments of IT/IS in the manufacturing sector, this is *comparison,* to acquire and manage the technology in such a way that delivers competitive advantage. Other characteristics such as *modification* are related to reliability and transparency of upgrading applications.

Correction and *variation*, are reactive characteristics related to the capacity of problem solving of standards and applications. For example, as an information system environment evolves, inevitably there are requirements that cannot be serviced by the existing infrastructure standards, thus organisations need to respond to it in reasonable periods of time to make all necessary changes. Reactive characteristics may involve purchased IS packages which have been created independently of the available infrastructure, hence changes may be required in terms of standards and infrastructure (Dove et al. 1996).

The three characteristics of a dynamic business environment proposed in this work are investigated based on the association they may have with the seven IT/IS proficiency characteristics of agility. For example, *a market that offers a high potential for continual growth* is attractive to new competitors seeking entry into that market, increasing the pressure of signing new and retaining current customers and forcing organisations to adopt new interrelation schemes with customers and suppliers. This could be associated to proficiency characteristics that anticipate future electronic interaction with customers and suppliers. Another example is given by the *difficulty in developing long range plans in the industry.* This case may include the association to characteristics that cover an IT/IS infrastructure that ensures continued viability as components are improved, added or removed. The same approach will apply to the business characteristic of *survival in the industry requires the introduction of new products* and the possibility of being associated to one or more IT/IS proficiency characteristics.

4.4.1 Infrastructure as an element of IT/IS proficiency characteristics of agility.

Infrastructure is an important component of IT/IS proficiency characteristics. Farbey et al. (1999_{II}) in their benefits evaluation ladder identified the importance of infrastructure as a separate rung. They explained that investments in infrastructure are intended to provide the foundation upon which subsequent value adding applications can be built. Infrastructure investments provide a general capability but may not be targeted at any specific application. Because investments of this type do not provide direct benefits to the business, they may therefore not figure prominently in the senior management's value systems. They recall that evaluation needs to demonstrate the link between the infrastructure and subsequent projects whose value to the business can be demonstrated. Moreover, investments in IT infrastructure are seen as necessary in order for the company in question to respond rapidly to any moves by competitors. They can be regarded as buying an option on the future profitability of the firm (Saaksjarvi 1998).

According to Saaksjarvi (2000) investments in infrastructure are long-term commitments accounting for a considerable share of the total IT budget. Infrastructure helps the company to integrate and accumulate earlier developments in transaction processing e.g. Decision Support Systems and strategic information systems. Furthermore, a flexible infrastructure may reduce time to market. A set of resources that makes feasible both innovation and continuous improvement of information systems is not single IS applications but the infrastructure's flexibility.

Broadbent et al. (1999_{II}) defined IT/IS infrastructure as the base foundation of budgeted-for IT capability (both human and technical), shared throughout the organisation in the form of reliable services. The focus of evaluation turns from specific applications to the capability of an infrastructure to support a range of future activities. However, information technology infrastructure can be a constraint where systems are not compatible, or where inconsistent data models have been used in different parts of the business. The same researchers concluded that knowledge of the role of IT infrastructure capabilities remains largely "in the realms of conjecture and anecdote". The importance of IT/IS infrastructure has been continuously developed in their work (Broadbent and Butler 1995, Broadbent et al. 1999_{II}). Flexibility for information systems infrastructure is an important issue as well. In fact, evaluation turns from specific applications to the capability of an infrastructure to support a range of future developments. According to Hanseth and Braa (1998) benefits from IT infrastructure only accrue through business applications, infrastructure cannot be designed and managed in the same way as information systems, as it is created by several actors and can thus be changed only gradually. However, the contribution of information technology can be directly measured through the support different applications yield to business processes.

A number of questions have been motivated by the elements presented above:

- According to the evolution of IS in manufacturing presented in chapter 2, what are the types of information systems associated to a dynamic business environment?
- What are the more relevant IT/IS proficiency characteristics identified by participating companies?
- What is the association between IS agility characteristics and a dynamic business environment?
- Are agility characteristics of IS associated to specific types of IS?

The proposed research questions are linked to the propositions, already presented during the generation of the research hypotheses. These are:

1) IT/IS proficiency characteristics of agility are associated to the characteristics of a highly dynamic business environment.

2) IT/IS proficiency characteristics of agility are associated to the utilisation of a specific type of information systems application.

4.5 Research methodology.

The best way to find an answer to the questions that motivated this research work is through the design of a research survey targeted at manufacturing organisations. The companies chosen to participate in this research work come from sectors identified by the British Trade and Industry Department (DTI 1997) as being in dynamic and competitive business environments. The identified industrial sectors include: aerospace, automotive and electronic-semiconductors. Automotive and electronic-semiconductors are characterised by short cycle times. The aerospace sector is characterised by long-cycle product development and lean manufacturing operations and is working to reduce its development cycles for new products. In fact, the pressure of the business environment on each of these sectors has become evident, for example: electronics-semiconductors release a new family of products every six months, the aerospace industry is a pioneer in the integration of business units and global co-operation. The automotive sector is very dynamic and is subject to constant mergers and take-overs. The main reason for targeting these sectors is to test the relationship of a dynamic business environment to IT/IS proficiency characteristics of agility. The identification of the level of agility of surveyed companies is not part of this research, for more details see Appendix C.

Respondents to the questionnaire were asked to answer the questions using a five-point Likert scale. The values utilised were 5 for completely agree, 4 for agree, 3 for not agree or disagree, 2 for disagree and 1 for completely disagree. Six companies agreed to give their comments on the draft questionnaire to clarify its contents. All these comments were taken on board and were implemented before wider circulation. Appendix B shows a sample of the questionnaire sent to surveyed companies.

IT directors, managing directors and manufacturing/operations managers participated in answering the questionnaire. Statistical tests (mean and variance) were applied to identify the presence of significant differences between the answers given by the three groups of people. The results of mean and variance tests showed no statistical difference. The next section presents findings and analysis of results.

4.5.1 Survey results within participating companies.

Manufacturing organisations from the aerospace, automotive and electronics-semiconductors were asked to identify the current type of systems used in their workplace and to rate the statements for a dynamic business environment and IT/IS characteristics for agility. The total number of questionnaires posted were 1000. Forty-seven questionnaires were completely filled and three more were incomplete. Six more questionnaires were relegated as not useful at all. Some researchers and practitioners (Grover 1997, Yu and Cooper 1983) have suggested that it 's highly undesirable to have response rates below 20% when doing research survey. However, there is one point to be considered, the number of variables defined in the questionnaire instrument are linked to the number of valid responses required, for example, multivariate analysis requires five times the number of variables in the model. The control indexes obtained during the application of statistical tools to the data collected meet the allowed limits. The percentages of participating companies were 17% from the aerospace, 55% from the automotive and 28% from the electronics-semiconductors sectors. The level of development of the systems in surveyed companies is presented in figure 4.2.

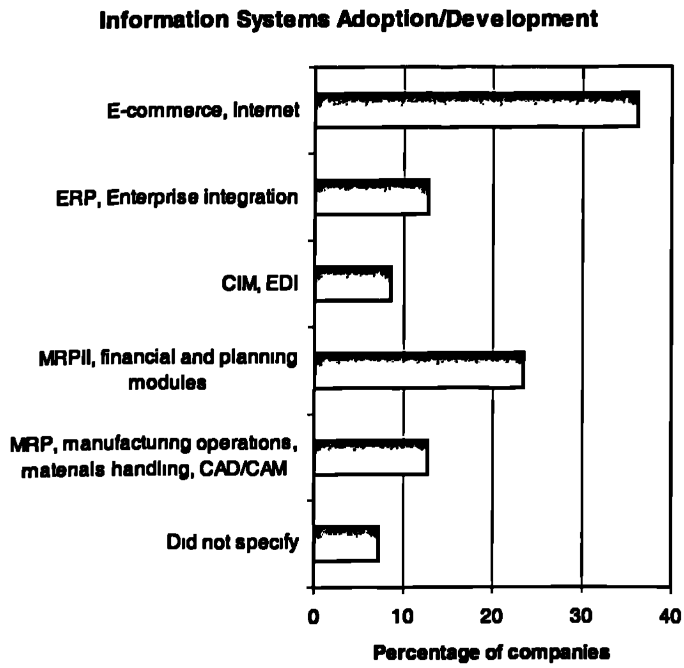

Figure 4.2 Information systems development identified by surveyed companies.

These organisations' turnovers range from £5 million to £250 million and have a workforce between 25 to 2500 employees. Surveyed companies have a wide range of implemented information systems. Their systems range from basic MRP applications to the implementation of Internet and b2b.

From the companies that participated in the survey more than a third of them have already implemented Internet solutions within their organisation and represent their most developed applications in use; thirteen percent of companies have already implemented ERP systems as their most developed IS application. CIM and EDI represent the most advanced stage of information systems for nine percent of surveyed companies. Twenty-three percent of companies use MRP_{II} and planning modules as their maximum development of their manufacturing information systems. Applications such as MRP and CAD/CAM are used by less than fifteen percent of surveyed companies, supporting their manufacturing operations and representing their most advanced applications. Also 6.4% of surveyed companies did not specify the type of systems they use. The results show the presence of heterogeneous information systems in participating companies which tends to suggest that the utilisation of the most advanced IT is not necessarily associated with any given sector within a dynamic business environment.

4.5.2 Dynamic business environment characteristics in participating companies.

Participating companies were asked to rate three statements related to the characteristics of their business environment. The following statements represent the three characteristics of a dynamic business environment identified from the literature:

- The potential for continual growth in our market is high.
- To survive in this industry we must constantly introduce new products.
- Long range plans (two years) are extremely difficult to develop in our industry.

The results of the answers to these issues are presented in table 4.1.

Business characteristic	mean	Agree or C agree	mode
High potential for market growth (BE1)	3.83	66%	4
Introduction of new products for survival (BE5)	3.87	66%	4
Difficulty to develop long rage plans (BE3)	3.17	40%	4

Table 4.1 Scores for business environment characteristics.

The results show that sixty-six percent of surveyed companies perceive themselves in a market growth with high potential growth (answered agree or completely agree), sixty-six percent confirmed that they have the need to constantly introduce new products to survive (answered agree or completely agree). Forty percent of surveyed companies agreed that it is extremely difficult to develop long range plans (answered agree or completely agree). These findings suggest that many of the surveyed firms operate in a dynamic business environment.

As the literature on agile manufacturing has associated a dynamic business environment to the development of agility and further on recognised information systems as key, critical and important to support the concept, it was decided to test (use of t-test) the association between a dynamic business environment with a specific type of IS application. Again, no relationship was found between these two issues. For example, there is no evidence to suggest that companies with a high market growth, and those constantly introducing new products are using systems represented by MRP nor that companies in a market with high potential growth are running Internet based applications.

4.5.3 Identification of IT/IS proficiency characteristics.

Seven questions were included to cover various aspects of proficiency characteristics of information systems. A series of t-tests were undertaken to check whether respondents' answers to these questions were influenced by the business environment within which they operated in. To do this, answers to the three business environment questions were reduced from a five point scale to a two point one by combining agree and completely agree against the other three possible answers (not agree or disagree, disagree and completely disagree). The scores given to each proficiency characteristic and the results of the application of t-tests are presented in table 4.2.

None of the scores on the seven characteristics differed significantly over the three business environment questions. This suggests that the business environment of the firm did not influence the characteristics of the information systems adopted. For example, those respondents reporting that their firm operated in an environment characterised by potential for high market growth were no more likely (or no more unlikely) to have adopted an IT system identified by any of the seven proficiency characteristics. This is also true for the other two business environment questions – difficulty to develop long range plans and introduction of new products.

To further test whether the business environment had an influence on the proficiency characteristics a simple three-factor model was constructed based on these seven characteristics as show in table 4.3. Included also in this table are Cronbach's alpha values for each of the factors identified.

Items identifying IT/IS proficiency characteristics of agile manufacturing

Augmentation: IT/IS in the enterprise provides an environment that promotes the development of customised solutions base on unique based needs.
Creation: The IT/IS infrastructure ensures continued viability as components are improved, added or removed.
Comparison: The organisation constantly monitors developments in IT/IS in our industry and benchmarks it against other industries.
Migration: Our IT/IS infrastructure anticipates future electronic interactions with customers and suppliers.
Modification: New standards can be upgraded or modified to the IT/IS infrastructure without breaking other applications.
Variation: It is possible to accommodate variations to the IT/IS standards in order to accommodate unique requirements.
Correction: In case of problem, fixings to the IT/IS infrastructure are in short periods of time.
It is possible to make variations to the IT/IS standards in order to accommodate unique requirements.

Business environment and IT/IS proficiency characteristics

BE1 - High Potential for Market Growth
BE3 - Difficulty to develop long range plans
BE5 - Introduction of new products for survival

P. Characteristic		Mean	BE1	BE3	BE5
Augmentation	IS1	3.64	-0.859	0.860	-1.288
Creation	IS2	3.72	0.479	1.845	0.479
Comparison	IS3	3.04	-0.130	-0.044	0.516
Migration	IS4	3.66	1.385	-1.264	-0.245
Modification	IS5	3.32	0.157	0.145	0.839
Correction	IS6	3.49	-0.049	0.372	0.282
Variation	IS7	3.43	-1.141	1.212	-0.386

t-critical = 2.01

Table 4.2 T-test for business environment and IT/IS proficiency characteristics.

Three clear factors emerged from the analysis. The first consisted of the correction and variation characteristics, the second of augmentation and creation and the third one of migration and comparison. Factor analysis attempts to identify underlying variables, or factors, that explain the pattern of correlations within a set of observed variables. The validity of the test was confirmed by the Kaiser-Meyer-Olkin index (.538) and Bartlett's test of sphericity index (.000).

Factor Loadings for IT/IS proficiency characteristics

P. Characteristic	**Mean**	**Factor 1**	**Factor 2**	**Factor 3**
Correction	3.49	**0.865**		0.132
Variation	3.43	**0.852**	0.126	
Augmentation	3.64		**0.913**	
Creation	3.72	0.264	**0.857**	
Migration	3.66	0.204		**0.888**
Comparison	3.04			**0.854**
Modification	3.32	0.630	0.355	0.311
Eigenvalue		2.431	1.613	1.329

Extraction Method: Principal Component Analysis

Rotation Method: Varimax

Cronbach's alpha for IT/IS proficiency characteristics for each factor

	Factor 1	**Factor 2**	**Factor3**
Cronbach's alpha	0.7425	0.7683	0.7163

Table 4.3 Factor Analysis table for IT/IS characteristics.

Each factor was tested against the business environment questions and, again, no significant differences emerged. It appears then that the business environment does not exert great influence on the IT/IS proficiency characteristics. The results showing the application of t-test to identified factors are presented in table 4.4.

The next step was to investigate the extent to which these characteristics were associated with different types of information systems identified in the survey. T-tests were undertaken to identify any variation of answers to IT/IS proficiency characteristics based on the type of systems employed by participating firms. For each proficiency characteristic, the answers given for a specific type of IS were compared against the answers given to the rest of the other types of systems present in the survey.

Business environment and three major factors identified

BE1 - High Potential for Market Growth

Alpha 95%

	Factor 1	Factor 2	Factor 3
t-stat	-0.626	-0.217	0.701
t-critical	2.014	2.014	2.014

BE3 - Difficulty to develop long range plans

Alpha 95%

	Factor 1	Factor 2	Factor 3
t-stat	0.857	1.489	-0.685
t-critical	2.014	2.014	2.014

BE5 - Introduction of new products for survival

Alpha 95%

	Factor 1	Factor 2	Factor 3
t-stat	-0.037	-0.450	0.151
t-critical	2.014	2.014	2.014

Table 4.4 T-test for business environment and factors identified for IT/IS characteristics.

Based on the results of the analysis shown in table 4.5 it was possible to identify variation only between companies working with the group represented by ERP and other types of systems in terms of *correction*. A possible explanation for this result is that companies which have implemented ERP systems consider variation to standards and repairs to infrastructure as critical. ERP is the integration of manufacturing resource planning, human resources modules and financial modules under one package and infrastructure is the backbone for integration of systems. However, given the size of the sample of the study, the outcome may be coincidental rather than truly representative. For all the other types of information systems used and the seven proficiency IT/IS characteristics of agility no significant differences were found.

T-test for IT/IS proficiency characteristics and specific types of technology used

Types of IS groups	**MRP vs. OTHERS**	**MRPII vs. OTHERS**	**CIM vs. OTHERS**	**ERP vs. OTHERS**	**Internet vs. OTHERS**
Augmentation	-0.470	-1.375	0.302	-0.358	1.259
Creation	-0.785	-1.884	0.774	-0.088	1.534
Comparison	-1.474	-0.163	-1.732	0.777	1.671
Migration	0.018	-0.786	-1.416	1.841	1.172
Modification	0.039	-1.695	0.962	1.459	0.184
Correction	-0.425	-2.010	0.567	**2.446***	0.214
Variation	0.226	-1.084	0.791	0.737	-0.082

t-critical = 2.014

* Mean for ERP = 4.33

Mean for OTHERS = 3.36

Table 4.5 T-test between IT/IS proficiency characteristics and type of IS.

The results of the analysis support the agile manufacturing literature, in the sense that different IT/IS characteristics are required to provide manufacturing organisations with the capabilities required to survive in a competitive business environment and these are independent of a particular type of IS application.

The study identified that infrastructure-related IT/IS proficiency characteristics, *augmentation*, *correction* and *migration*, are of principal importance. *Augmentation* received the highest score followed by its other factor component *creation.*

Each factor for IT/IS proficiency characteristics was tested against the types of information systems used by these surveyed companies, see table 4.6. No significant differences emerged from this analysis. It appears that the type of information system used does not have great influence on the proficiency characteristics for information systems sought by surveyed companies.

Types of IS groups	MRP vs. OTHERS	MRPII vs. OTHERS	CIM vs. OTHERS	ERP vs. OTHERS	Internet vs. OTHERS
Factor 1 (t-stat)	-0.131	-1.761	0.754	1.807	0.083
Factor 2 (t-stat)	-0.694	-1.813	0.593	-0.373	1.554
Factor 3 (t-stat)	-0.808	-0.537	-1.1796	1.480	1.617
t-critical	2.014	2.014	2.014	2.014	2.014

Table 4.6 T-test between factors for proficiency characteristics and type of IS.

Note: an explanation of the statistical tests employed in the analysis of this data is presented in Appendix C. Explanations presented include factor analysis, Cronbach's alpha and t-test.

4.6 Implications of results findings.

The results of the survey show a weak relationship between the three characteristics of a dynamic business environment and seven proficiency characteristics of IT/IS of agility. These results reveal that a one way arrow linking the IT department to the organisation is widespread in surveyed manufacturing companies and may not be adequate for responding quickly to changes in dynamic business environments.

The results are significant in showing that only one IT/IS characteristic of agility (*correction*) is related to a specific type of IS, namely ERP. This means that the achievement of agility does not necessarily depend upon the implementation of sophisticated information systems.

One aspect that requires further consideration is splitting the E-commerce/Internet category into two separate groups. One group for IT applications in manufacturing represented by b2b and the other for the Internet, containing browser technology, web pages, etc. Having two separate groups may have produced data resulting in an analysis leading to slightly different conclusions. There is a possibility that such analysis could have shown the association between technology represented by b2b and at least one of the characteristics of a dynamic business environment used in this work. Also, the analysis could have shown the association of b2b with one or more proficiency characteristics of IT/IS of agility as well.

IT/IS related characteristics of agility containing infrastructure appeared to have an extremely important role in participating organisations. In fact, the value of infrastructure lies in the support of subsequent value-adding applications, however infrastructure may not be perceived to be important in adding value to an organisation's processes.

The importance of *augmentation* is explained by respondents' preferences for a flexible infrastructure that enables a rapid response to a variety of information needs. Authors like Reich et al (1999) identified inflexibility and insufficient openness as main causes for information systems dissatisfaction. The characteristics that received the highest scores for each factor (*augmentation*, *migration* and *correction*) are linked to flexibility of IS, and that is what participating companies appear to be more interested in achieving, rather than the development or implementation of sophisticated IS. Indeed, the results of the study confirmed the importance of flexibility of IT/IS infrastructure given by manufacturing enterprises.

Finally, the findings of the survey can be summarised as follows:

- IT/IS proficiency characteristics of agility are not associated to a highly dynamic business environment.
- IT/IS proficiency characteristics of agility are independent from the utilisation of a specific type of information systems application.
- Three major factors underlie IT/IS proficiency characteristics of agility. These are *augmentation*, *migration* and *correction*.

4.7 Comments and remarks.

The results have shown that in surveyed companies the IT/IS proficiency characteristics of agility are not associated to the characteristics of a dynamic business environment presented in this work. This can represent a problem, in the sense that manufacturing organisations may not be able to respond rapidly to changes in the business environment.

The statistical tests have shown that no specific type of IS can be associated with the proficiency characteristics of IT/IS of agility. In terms of information systems, manufacturing organisations should pay more attention to the infrastructure-related IS characteristics identified in this work.

Given the high degree of competitiveness in some manufacturing sectors and the introduction of sophisticated information systems, the results of the study are indicative of the importance attributed to IT/IS infrastructure by manufacturing organisations. Careful consideration of *augmentation*, *migration* and *correction* may enhance the value of information systems and help to improve the planning of, and investment in, information systems that meet the future needs of manufacturing companies.

The findings of this survey have been treated as suitable for further testing. The development of a multiple case-study will make possible to further test these results and identify the contribution of IS to agility in manufacturing organisations.

Chapter 5

Agility and information requirements in companies facing dynamic business environments.

5.1 Introduction.

The previous chapter tested seven IT/IS proficiency characteristics of agility, their relationship with three characteristics of a dynamic business environment and the types of IS applications commonly used in manufacturing organisations. The development of a multiple case-study will enable the possibility to further investigate the findings of the survey and to support or refute the three hypotheses generated.

In information systems evaluation, the wide availability of different types of manufacturing information systems makes the identification of benefits to business processes even more complex and difficult. In fact, information systems have a wider impact which may vary according to the circumstances and the context in question, Serafeimidis and Smithson (1999).

In this research, the study of the contribution of information systems to the agility of manufacturing organisations required the use of qualitative methods. According to Seaman and Vasili (1998), and Seaman (1999), the principal advantage of using qualitative methods is that these methods force the researcher to delve into the complexity of the problem. Thus, results are richer and more informative. The researchers warned that qualitative analysis is generally more labour-intensive and exhausting than quantitative analysis, and can be considered "fuzzy" or "soft" in technical research communities. According to McClure (1999) qualitative analysis is widely used in the IS field, and it is often required when doing research on the identification of benefits of information systems. The use of a mix of qualitative and quantitative methods may provide a richer perspective in research problems where purely qualitative methods are not widespread. The combination of both, quantitative and qualitative methods represents a powerful research approach.

Seaman (1999) has provided an extensive review on the utilisation of qualitative methods for doing research on IS and software engineering. Most qualitative data analysis methods are aimed at generating theory, but there are a number of methods and approaches used to strengthen a proposition generated from quantitative data. Sophisticated qualitative methods are employed in purely qualitative studies, Judd et al. (1991). Qualitative data can be used to go beyond the statistics and help identify the reasons behind the hypotheses and relationships like the triangulation approach presented in chapter 3.

The methodology of case-study has been thoroughly explained by Yin (1994) and it is a technique commonly utilised in IS research. Generally, case-study has some longitudinal dimension since it is conducted over a period of time. A ramification of case-study is the site visit. Seaman (1999) has provided a detailed description of the use of case-study and site visit. According to her, a site visit is planned to obtain first-hand information from tours of specific facilities and services, interviews with individuals or groups, or observations of specific activities at the site. In addition, the site can be used to obtain reports, brochures, and examples of products or services made available at the site. Site visits enable the opportunity to obtain first-hand information about users or activities in a particular setting. Another benefit is the ability to evolve the data collection strategies on site, depending on the topics the evaluator determines are important to probe for obtaining additional information.

5.2 Development of multiple case-study.

Two stages have been completed during the development of this research: an exhaustive literature review generating three hypotheses and the accomplishment of a research survey.

The reason to undertake a multiple case-study is to gain a deep understanding of the contribution of information systems to manufacturing agility in manufacturing organisations. With the accomplishment of a research survey it has been possible to identify three major factors underlying the proficiency characteristics of IT/IS of agility. The three IT/IS characteristics associated to those three factors are: ***augmentation*, *migration*** and ***correction*.** Two testable propositions that are indicative of IT/IS proficiency characteristics of agility are not affected by a dynamic business environment and that they are not related to the use of a specific type of information system were generated during the survey. The multiple case-study has enabled further testing of the results obtained from the survey.

Data collected for the case study is associated to information systems support of business processes, agility of manufacturing operations and the development of agile manufacturing as an improvement programme in participating companies. Special emphasis has been put on the significance of information systems among other enablers of agility, the performance of IS applications used in the participating companies, business and IT strategies present in participating organisations and the skills/expertise of personnel to achieve agility and to obtain benefits from IT/IS.

The companies presented in this chapter agreed to participate in this research, on promise to deliver them a summary of the results of the study, including a taxonomy of enablers of agility as well as guidelines for the use of information systems and their role within manufacturing agility. The purpose of targeting SMEs in this study has been to facilitate the process of data collection and data analysis, rather than targeting large organisations with several departments, with complex and bureaucratic organisational structures. Marri (2000) described that the importance of SMEs has been widely acknowledged, since it is a fact that these firms are increasing in number, are creating most of the new jobs and are often key contributors to the economic growth of many regions. Some of the characteristics of SMEs include: lack of bureaucracy, agility to react quickly to keep abreast of changing market requirements, efficient and informal internal communication networks and rapid adaptation to change.

Participating companies in the multiple case-study come from the same three manufacturing sectors targeted during the survey research, these are: automotive, aerospace and electronics (computer, semiconductors). All companies are profitable with three of them growing at annual rates of over 20% in recent years.

5.3 Information intensive manufacturing sectors.

Manufacturing organisations have become more information intensive in recent years. Part of this information intensity is more notorious in some industries than in others. In 1997, the UK's Department of Trade and Industry (DTI 1997) identified some industry sectors as being in competitive business environments. This study included the automotive and electronics-semiconductors sectors. Also the aerospace sector has been included in this study because is a sector that has embraced lean operations and requires high technology investments. Figure 5.1 illustrates some industry sectors as being more information intensive and subject to a dynamic business environment. Chosen companies in this work are in the right upper corner. Traditional manufacturing sectors are located in the lower left corner.

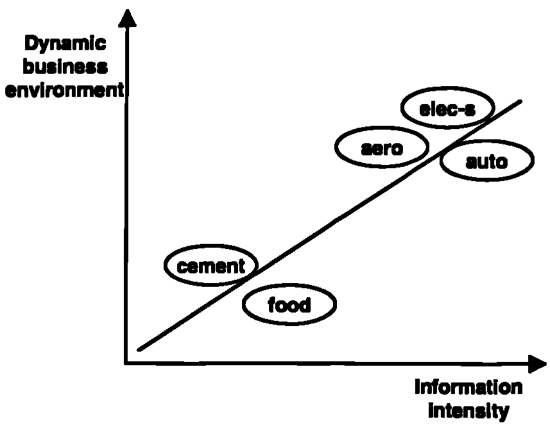

Figure 5.1 Increase of information intensity of manufacturing companies.

Gunneson (1997) emphasised that change is now a permanent part of the global business landscape. Kidd (1994) identified a business scenario for agile manufacturing characterised by short product life cycles, increasing competition and decrease in sales revenue, pushing companies to develop the capabilities of rapidly responding to and accurately assessing every commercial opportunity. Goldman et al. (1995) described agility as a comprehensive response to a new competitive environment. According to them, agility reflects a competitive environment that links customers and suppliers far more closely.

Companies participating in this research can be related to the company matrix presented in table 5.1. Usually small enterprises are those with less than 250-300 employees and medium enterprises are those with more than 250-300 but less than 1000.

Company size	AERO	AUTO	ELEC-SEMI
Small	1	1	1
Medium	1	0	0
Large	0	0	0

Table 5.1 Company Matrix.

From the beginning of the development of the multiple case-study there has been consensus among participating companies about the importance of responding quickly to changes in the business environment. Agility is an ongoing process and some business processes may be more agile than others within a company. The study of information systems support to manufacturing operations is essential to fulfil the research aims of this work.

5.4 Background of participating companies.

The collection of data regarding the background of participating companies is an important stage of the multiple case-study. Indeed, this stage is required to draw acceptable conclusions to answer the research hypotheses of this work. Basic details identified and registered include: annual turnover, registered annual growth for the past four years, number of employees in the site, main business operations and area of expertise.

Participating companies in the multiple case-study provided a detailed description of the conditions that are making their business environments dynamic. Also, presented here is the impact of such conditions on manufacturing operations.

5.4.1 Background of company A: an organisation in the aerospace sector.

This company has been in the business for fifty-five years and last year it had a turnover of £11 million. The company has been growing at an annual rate of 20% in recent years and it has 130 employees. Main operations in the company include machining and assembly of aerospace components. Currently the company has a wide knowledge base of machining complex components. The aerospace sector is behind the automotive industry in terms of developing cycle times but it has been working to cut developing cycles up to 18 months.

The business environment is indeed very dynamic and hence companies in this sector have to meet changing customer needs to remain competitive. The company identified a number of issues behind the increase in competition. These included: threats from manufacturing companies in countries with developing economies that can manufacture the same type of components at lower prices, pressure to invest heavily in new manufacturing machining equipment and the reduction of development cycles. The company has identified scheduling and capacity planning as major operations to sustain continued growth in the near future.

5.4.1.1 Manufacturing operations at company A.

Company *A* provided details of its manufacturing operations. Six issues were taken into account and these are:
Key manufacturing processes: machining and assembly.
Type of manufacturing system: jobbing and batch
End of product variety: 100
Number of components: 30
Number of suppliers of raw material: 10
Number of customers: 10
Company *A* stated that there are high entry costs and high switching costs for this sector. Despite this, the aerospace sector is very dynamic.

5.4.2 Background of company B: an organisation in the electronics-computer sector.

Company *B* is the only company participating from the electronics-computer sector. This is a small company dedicated to the manufacture of bespoke power servers and computer systems. The company has been operating in the electronics-computer sector since 1992. In the view of its founder, the company has been kept to a small size with special emphasis on maintaining profitability and ability to respond to customer needs:

> *"It was a conscious decision not to have the business become a multi-million pound organisation, it is a family business"*,

the current management of the organisation is based more on longevity in the market place.

The company operates in a competitive business environment and provided a series of issues supporting that. The organisation has to re-invent itself every three months mainly motivated by new processes being introduced in the sector by big industry players. Technology is changing at a very fast pace and new computer systems with new configurations are released in periods of few months. The operation of the company demands a high degree of flexibility and therefore the implementation of processes like ISO9000 in this particular sector is extremely difficult. In this particular sector, it should be noted that the distinction between manufacturers and service providers is constantly changing.

The following statements reflect the current situation experienced by this company:

- Profitable with constant annual growth in the business in recent years.
- The company has been successful in adapting itself to changes introduced by new processes in industry.
- The business environment is very flexible and moving very quickly.
- The company has become a service provider as well as a manufacturer.

The situation faced by company *B* is different to what other companies from the other sectors have been experiencing. The manufacture of computer servers is characterised by low entry costs and low switching costs. This means that it is extremely easy for a customer to find new suppliers and to switch suppliers without major problems.

5.4.2.1 Manufacturing operations at company B.

Company *B* provided details of its manufacturing operations. Six issues considered include:
Key manufacturing processes: assembly of power servers, electronic components
Type of manufacturing system: jobbing
End of product variety: 1-10
Number of components: 10
Number of suppliers of raw material: 3
Number of customers: 150

5.4.3 Background of company C: an organisation in the automotive sector.

This company is based in the West Midlands and is the British subsidiary of a multinational company which is a global-player in the manufacture of automotive and aircraft seating systems. The number of employees in the UK site is 200 and last year's turnover for the company was £25 million. The company has been experiencing a continuous and firm growth since 1994 with annual growth rates of over 20%. Some of its main customers include big car manufacturing companies (Land Rover, Toyota, Saab) and automotive part manufacturers (Lear American and Johnson Controls).

The organisation identified several factors as evidence of the dynamism of the business environment, these include:

- Despite being in an industry characterised by high entry costs and high switching costs, there is pressure on industry players to react quickly to changes in the business environment.
- High annual growth in terms of turnover for the past years (over 20%).

- The introduction of new production methods like flexible working hours and bank hours affects the operations of the organisation. Since production schedules are provided by the customers, interpretation and execution of such schedules are main tasks for company *C*. However, it is not possible for company *C* to know if a customer will stop operations because of bank hours until it receives the production schedules on due-date. Only after those events take place, company *C* is in a position to make its own decisions and balance its own labour hours against demand.
- The business demands keeping a constant cost per unit.

According to the manufacturing director of the company, the automotive industry is more about cost and innovation. The industry grew for some years but now it has stabilised for the last couple of years, also the global supply is great. However, for the companies participating in the business, there are pressures and constant changes in customer requirements.

The manufacturing of seating systems is very special. A car manufacturer approaches a seat provider, spending together a lot of time on design, crash tests and reliability. All these steps are important because a seating system is considered a critical safety part of a car. The whole issue forges long-term relationships between companies that can last from five to seven years.

5.4.3.1 Manufacturing operations at company C.

Each company that participated in this research provided the main characteristics of its manufacturing operations. For the particular case of company *C*, the following issues were identified:

Key manufacturing processes: rivetting and semi-automated assembly of seating systems

Type of manufacturing system: batch and JIT

End of product variety: 11-50

Number of components: 100

Number of suppliers of raw material: 80

Number of customers: 6

This particular line of business within the automotive sector is characterised by high entry costs and high switching costs.

5.4.4 Background of company D: an organisation in the aerospace sector.

During the visit to this company, it was possible to identify a company with great expertise in the implementation of improvement programmes in manufacturing. The company explained that they have implemented lean manufacturing policies and the utilisation of six metrics widely used in the aerospace industry (customer acceptance/reject rate, delivery schedule achievement, value added, employee training and development, stock turns and floor space utilisation).

This enterprise is one of two companies from the aerospace sector that participated in the study. The company has a wide customer base. Components manufactured on this site are for new aircraft as well as spare parts for models not built anymore and flown in remote regions of Australia. The company is based in northern England and is one of four manufacturing sites of the British subsidiary of a large multinational company leader in the production of aerospace and automotive components. The company's turnover is £27 million and it has a staff of 300 employees.

The company has been taken-over twice in the last four years. The company is also moving to a high volume and high variety production mode as much as is possible in the aerospace sector. Components that were generally made outside the company are now manufactured in-house, reducing the number of suppliers and enabling the company to participate in large aerospace programmes. The total quality counsellor of the company enumerated certain characteristics showing the dynamism experienced in the sector:

- The company has experienced high annual growth rates in recent years (over 20%).
- The industry is extremely competitive.
- Customer needs change all the time.
- Supply chain is very volatile.

A dozen companies form the customer base of company *D*, some of them are very large companies involved in large projects like Airbus Industrie and its new A380 plane. This company participates in 20 different programmes per year.

Another characteristic of the aerospace sector turning it into a dynamic sector is the reduction of cycle times for new products. For company *D*, three months is the period (cycle time) to deliver a prototype. Without drawings the development period is about five months. The production volumes per week are between 40 to 50 and that is quite high for the aerospace industry.

5.4.4.1 Manufacturing operations at company D.

Company *D* provided details of its manufacturing operations. The following issues were considered:
Key manufacturing processes: engineering component manufacturing followed by heat treatment.
Type of manufacturing system: batch + flow line
End of product variety: 3000
Number of components: 43
Number of suppliers of raw material: 600
Number of customers: 12

Like the automotive industry, the aerospace sector is characterised by high entry costs and high switching costs. The companies from the three sectors that participated in this research agreed that their business environment is very dynamic and there is pressure to meet changing customer needs.

5.5 Importance of agility in participating companies.

The multiple case-study required investigating the common understanding of the concept of agile manufacturing among participating companies. The four companies were presented the definition of agility proposed by Goldman et al. (1995) and all of them said that they have heard about the concept. The interviewees were invited to explain why agility is important for their organisations. Several arguments supporting the adoption of agility in participating companies were provided by the interviewees which include:

- Customers are demanding ever higher standards of flexibility.
- Customer needs keep changing all the time. Meet customers needs otherwise they will find someone else who can.
- The company has to re-invent itself almost every three months. Roles keep changing in the industry.
- New processes are introduced by big industry players.
- Highly flexible and moving very quickly.
- Relevant to respond to customer demands while keeping costs per unit constant.
- Big auto companies introduce flexible working hours and bank hours making difficult to balance labour against demand.
- Able to respond to variation in customer requirements.

From all the above statements, the ability to respond to changing customer needs appeared as a main concern for participating companies and it was seen as a justification to embrace agility. During the case-study, companies expressed interest in becoming agile. Also, interviewees identified some agile processes in their organisations. These will be discussed in detail in the following chapter.

One of many advantages of undertaking multiple case-study for this research is the possibility of identifying the role of information systems in achieving agility in business processes like manufacturing in the participating companies. Further, it provides the means of assessing the significance of information systems among other enablers of agility.

5.6 Description of manufacturing operations in participating companies.

The details of manufacturing operations for the four companies that participated in the multiple case-study are presented in table 5.2.

Company	Type of manufacturing system	End product variety	No. of components in the product with largest sales	No. of suppliers	No. of customers
A	Batch and jobbing	>100	30	10	10
B	Jobbing	10	10	3	150
C	Batch and JIT	50	100	80	6
D	Batch and flow line	>100	43	600	12

Table 5.2 Manufacturing details of participating companies.

Batch and jobbing appeared as the main types of manufacturing systems employed by participating companies. Jobbing is the type of system that revolves around made to-order, low volume, high value, products (Edwards et al. 1999). Jobshops are often considered as having an inherent advantage in pursuing flexibility/quality whereas continuous type of structures were associated with cost/dependability, with other type of structures (batch and line) falling in between, Hayes and Wheelwright (1992). The data collected show different types of manufacturing systems currently being used in participating companies and each system has the potential to be linked to the development of agility in manufacturing operations.

5.7 Development of improvement programmes in participating companies.

The identification of the development of improvement programmes for manufacturing in participating companies has been in the interest of this research. Different improvement programmes have been adopted by the industry and widely described in the literature (Oakland 1995, Womack and Jones 1996). The assessment of the development of improvement programmes for manufacturing will enable the identification of the expertise of each company, which can be viewed as a foundation for the development of agility.

During the development of the case-study eight improvement programmes for manufacturing were considered. The improvement programmes presented to participating companies are TQM, JIT, BPR, Lean Manufacturing, Concurrent Engineering, Cellular Manufacturing, Benchmarking and ISO9000 accreditation. The respondents were asked to rate each of the above programmes using a 5-point Likert scale, with values ranging from 5 for successful to 1 for dissatisfied, specifying if such programme has been undertaken or considered in future plans as well. The results on the assessment of those improvement programmes are presented in table 5.3.

Improvement programme	Company A	Company A rate	Company B	Company B rate	Company C	Company C rate	Company D	Company D rate
TQM	*UT*	*3*	*UT*	*3*	*UT/FP*	*4*	*UT*	*4*
JIT	*FP*		*UT*	*5*	*UT/FP*	*4*	*UT*	*4*
BPR	*UT*	*3*	*UT*	*5*	*UT/FP*	*4*	*UT*	*5*
Lean Manuf.	*FP*		*UT*	*4*	*UT/FP*	*4*	*UT*	*4*
Concurrent Engineering	*UT*	*4*	*UT*	*5*	*UT/FP*	*4*	*UT*	*4*
Cellular Manufacturing.					*UT/FP*	*4*	*UT*	*5*
Benchmarking	*UT/FP*	*4*	*UT*	*2*			*UT*	*4*
ISO9000 accred	*UT*	*5*	*FP*		*UT/FP*	*5*	*UT*	*5*

UT: undertaken
FP: future plans

Table 5.3 Level of adoption of improvement programmes by participating companies.

The results shown in table 5.3 reveal that most of the improvement programmes for manufacturing have already been implemented, disclosing an adequate level of awareness among this group of companies.

Specifically, company *C* stated that it has already implemented all the above listed improvement programmes, with the exception of benchmarking. Moreover, the company believes in the continuous development of all improvement programmes and not just implementing and storing them for good. Also, company *C* declared itself to be satisfied with the outcome of the above improvement programmes.

Also, company *D* presented great expertise in the implementation of all the above improvement programmes with high levels of satisfaction experienced. Programmes that were rated as successful include BPR, Cellular Manufacturing and ISO9000 accreditation. In this company, none of the above programmes outcome was rated as medium or dissatisfied.

A review of the results of company *A* showed that it has already implemented TQM, BPR, Concurrent Engineering, ISO9000 and Benchmarking. Company *A* did not experience a successful outcome with the improvement programmes of TQM and BPR. Improvement programmes considered in future plans include JIT, Lean Manufacturing and Cellular Manufacturing. Benchmarking has been undertaken but it still forms part of the future plans of the organisation.

Company *B* has already implemented all listed improvement programmes with the exception of cellular manufacturing and ISO9000. However, the company showed low levels of satisfaction with benchmarking. The company has stated that it is considering an ISO9000 accreditation in the forthcoming future. However, the problem faced by the company is that compliance with ISO9000 methods does not support the level of flexibility required by the company to respond quickly to changing customer needs.

Further analysis of the results revealed that those companies that are subsidiaries of large multinational corporations have the largest number of implemented programmes with the highest levels of satisfaction experienced. The other two, local companies, have not implemented all listed programmes and stated their dissatisfaction with some of them. The results may seem trivial, however in many cases big corporations have entire departments committed to the introduction and implementation of improvement programmes in their business units.

5.8 Structure of the multiple case-study.

This research has introduced three hypotheses with the purpose of identifying agility as a contribution of information systems as well factors affecting it. The scheme proposed to support/reject the research hypotheses is depicted in figure 5.2.

In fact, figure 5.2 shows three major fields used to answer the proposed hypotheses. These fields include:

- IS support of manufacturing operations, covered in the IS function and manufacturing operations section of the open-ended questions and self-assessment questionnaire.

- Agility of manufacturing operations, covered in the manufacturing operations section of the open-ended questions and self-assessment questionnaire.
- Agility as an improvement programme, covered in the organisation management section of the open-ended questions and self-assessment questionnaire.

The three fields cover questions in terms of:

- IS support of principal manufacturing operations,
- Expected benefits from IS,
- IT, business and manufacturing strategies and the alignment between them,
- Difficulties experienced to measure the contribution of IS,
- Skills and expertise of employees in the operation of IS within the company

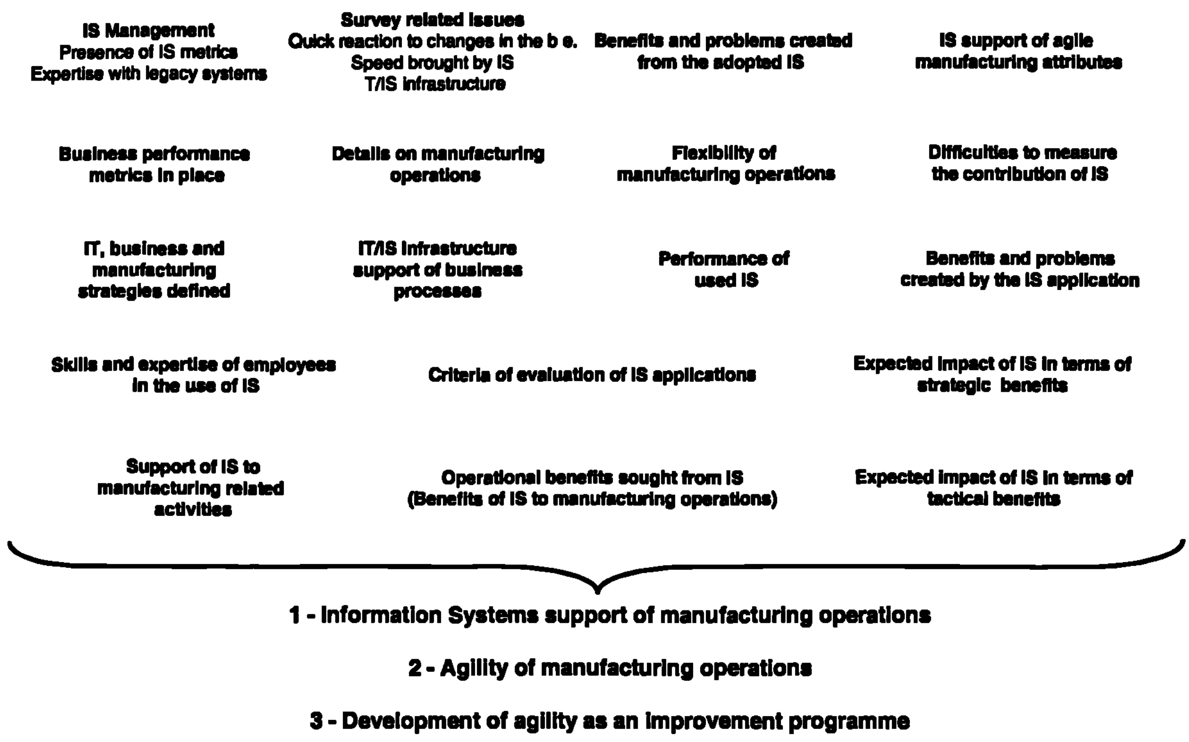

Figure 5.2 Structure developed for multiple case-study.

5.9 Comments and remarks.

The utilisation of quantitative and qualitative methods to gather data has proven to be an adequate methodology for the multiple case-study. A series of structured and open questions were asked to the interviewees of participating companies. Using this format it was possible to document several data sets that characterise the dynamism of the three sectors investigated. Examples include the introduction of new processes every three months in the electronics-computer sector; or the fact that customer needs keep changing all the time in the aerospace sector, an industry characterised by high entry costs and high switching costs. Also, companies recognised the increasing information needs of their processes.

Other key operations that have been possible to identify include the types of manufacturing systems used in participating companies, with jobbing and batch as common manufacturing systems in use.

All participating companies were aware of the improvement programmes that have preceded agile manufacturing. Companies were familiar with concepts like ISO9000, TQM, benchmarking, lean manufacturing, etc. Naturally, some of them showed more expertise than others. However, all four companies recognised their need for agility. In fact, none of the companies regarded agile manufacturing as just another buzzword, all of them recognised the importance of agility for the future of their businesses. Despite being in industry sectors characterised by different cycle times for product development, different entry costs and switching costs, the companies recognised that their customer needs keep changing all the time. For participating companies, the idea of being agile is the ability to respond quickly to changing customer needs.

The results of investigating the contribution of information systems to the agility of manufacturing operations in participating companies are presented in the next chapter. The findings will enable the development of a new taxonomy of enablers of agility, including information systems.

Chapter 6

Identifying the contribution of information systems in supporting agility in manufacturing organisations.

6.1 Introduction.

The previous chapter provided critical information regarding the background of participating companies, justifying them as suitable organisations to participate in a multiple case-study. The purpose of developing the multiple case-study is to gather evidence to support/reject the research hypotheses formulated in this work. This chapter is associated to the first hypothesis presented in this research and it shows the work done to determining manufacturing agility as a contribution of information systems.

Reich et al. (1999) pointed out that most companies turn to new technologies, in particular information systems that will provide them with a competitive edge, or that will allow them to become agile. According to them, the central contribution of the technology would be the acquisition, management, communication and re-use of information. Unfortunately, very often organisations realise that information systems simply do not deliver expected benefits, Strassman (1997).

The study of manufacturing organisations facing dynamic business environments represents an opportunity to appreciate the extent information systems support of manufacturing agility. The analysis used in this chapter required identifying at least one agile process in each company. Questions covering IS support of manufacturing operations, agility of manufacturing operations in the company and the development of agility in the organisation represent the backbone of the work presented in this chapter. Appendix **D** shows a sample of the questionnaire employed during the visits to the companies that participated in the case-study. Appendix **E** explains the purpose of using each section of questions. Some metrics used by participating companies are shown in the second half of Appendix **E**.

6.2 Understanding agility and IS contribution.

The possibility of associating the agility of business processes, specially manufacturing, as a contribution of the use of information systems, motivated the identification of three major fields used during the development of the case-study. These fields have their roots in the academic literature:

- Level of information systems development in support of manufacturing operations (Kathuria and Igbaria 1997, Ezingeard 1996, Ezingeard et al. 1998).
- Level of development of manufacturing operations agility (Dove et al. 1996).
- Level of development of agility as an improvement programme (Gunasekaran 1998).

In fact, the above fields can be evaluated using a five-point Likert scale, ranging from 5 for very developed to 1 for not developed at all. For the purpose of this study, each of the three fields is represented by one component of a triangle as shown in figure 6.1. In this particular case and for illustrative purposes, figure 6.1 represents a hypothetical condition where all fields are rated as very developed. Structured and open questions related to the above fields are used to evaluate the state of progress of agility with interviewees from participating companies. Additional data sets were collected as part of the visits and from company documentation.

The methodology employed in this multiple case-study required the participating companies conducting a self-assessment on how they perceived themselves in each of the above fields. There are relevant examples in the literature of agile manufacturing and information systems supporting the use of self-assessment (Goldman et al. 1995, Gunneson 1997, Fearon and Phillip 1998). In this multiple case-study, each participating company used the above five-point Likert scale for that purpose. Furthermore, during the analysis of the case-study, company specific manufacturing data sets were used to validate the ratings of the self-assessment. During the development of the multiple case-study a dictation machine was used to record the answers provided by the interviewees.

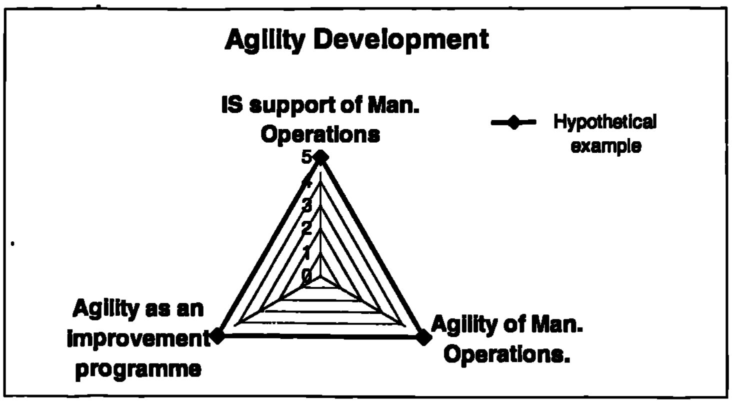

Figure 6.1 Ideal agility triangle.

6.3 Information systems used in participating companies.

Information systems have been considered critical to support business processes in manufacturing organisations. All different departments in a manufacturing organisation, design, finance, manufacturing operations, logistics, etc., need the support of IS. Table 6.1 shows details of information systems in participating companies. A general description of an MRP system and its similarities with the systems used by companies *A*, *B*, *C* and *D* is shown in Appendix **F**.

Company	Application	Description	Type	
A	JobShop	kind of ERP	COTS*	Specific package
B	No name	kind of ERP	RAD**	in-house software development
C	Tetra 3	MRP	COTS*	Specific package
D	CINCOM	MRP + FM	COTS*	Specific package

*COTS: Commercial-off-the-shelf.

**RAD: Rapid Application Development.

Table 6.1 Information systems found in participating companies.

Only one company uses an in-house developed RAD application. The other three companies use commercial-off-the-shelf applications. Also, data sets regarding expenditure on IT were investigated in each company. These include percentage of annual turnover invested in IT; percentage of the IT budget allocated to new IT investments; the number of people working in the IT department; percentage of IT budget allocated to infrastructure, planning and execution and other investments like training. The answers registered are shown in table 6.2.

Company	% Turnover	% N.I.	People IT	% Infra	% Planning	% Execution	% Others
A	2	10	1	20	20	20	40
B	3.7	20	5	65	5	25	5
C	0.6	4	2	50	40	0	10
D	4	20	3	50	25	0	25

Table 6.2 Results of general issues on information systems.

Participating companies showed different levels of expenditure on IT as a percentage of their annual turnovers. In the literature, some researchers identified that the top 150 companies in the UK spend more than 2% of turnover on IT (Spikes Cavell 1996, Farbey et al. 1999_I). The expenditure of two companies (*B* and *D*) is in the order of 4%. Company *A* has the industry average of two percent. Company *C* has the lowest expenditure in IT with less than one percent. From the results shown in table 6.2, most of the expenditure in participating companies is represented by infrastructure. In three companies (*B*, C and D) investments in infrastructure represent 50 percent or more of the IT budget. These findings can be linked to the importance of infrastructure as a principal component of IT/IS proficiency characteristics of agility. In three companies (*B*, *C* and *D*) investments in planning and execution lag well behind infrastructure. This information is compatible with the findings of Taudes et al. (2000). In their study the researchers found that approximately 35% to 40% of the total IT investment is dedicated to IT infrastructure.

6.4 Contribution of information systems to agility in participating companies.

This section presents the IS support for manufacturing operations and the steps taken to develop agility in participating companies.

6.4.1 Analysis of company A.

Company *A* was the first organisation to participate in this multiple case-study. A highly developed knowledge base in machining complex components was an agile process identified in this organisation. The participation of this organisation has provided elements for the identification of the role of information systems in supporting improvement programmes designed for the achievement of agility in business processes. Also, the analysis of this case revealed that being profitable and experiencing high levels of growth does not necessarily imply agility. The self-assessment given by the company to the development of agility of manufacturing operations, the support of IS to manufacturing operations and the development of agility as an improvement programme is presented in figure 6.2. The agility of manufacturing operations received a score of 2, which was the lowest score registered during the case-study. The support of IS to manufacturing operations and the development of agility were given a score of 3. The explanation for those scores is provided next.

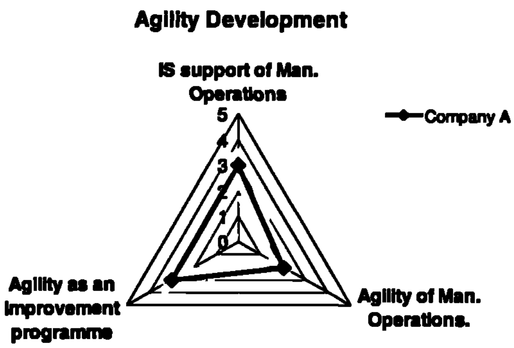

Figure 6.2 Agility development experienced for company A.

6.4.2 Agility of manufacturing operations in company A.

The company received a low score in this area. The managing director said that the company is working further to develop the agility of its manufacturing operations. The company's main problems have been in terms of production planning and scheduling and the development of flexibility in the shop floor which explains the low score given to agility of manufacturing operations. The company identified adjusting capacity rapidly and handling variation in customer delivery schedule as two very important issues of flexibility being pursued at the time.

An IS application called Jobshop which is a type of ERP-MRP system for SMEs is used by this company. This system was originally implemented to produce work lists of accurate scheduling for the job shop. The company was compelled to purchase that system because of the high growth rates been enjoyed in recent years.

Before the Jobshop system was implemented, the company was unable to respond to the growth rate it was enjoying with old fashion planning techniques used to establish a work order. Moreover, that situation was impeding the organisation to grow any further.

The company has been operating with the system for a year when this case-study took place. In the past six months the company has been able to improve its manufacturing operations and to start developing a flexible manufacturing base. The MD's view was that information systems (JobShop) are part of the reasons for the improvement experienced, however information systems cannot be considered as the overwhelming element to achieve agility.

6.4.3 Information systems performance at company A.

The company regards information systems critical for the operation of the company. For them, the purchase of JobShop has been a worthwhile investment, however according to the company, the system has not reached its full potential. Currently, it is in the interest of the company to get the most from IS. The company acknowledged information systems as not the main factor driving the company towards agility:

"Information systems by themselves are not the most important or the most difficult part of the equation".

In the company, information systems are important in providing the background information to support agile manufacturing initiatives.

On the other hand, the company does not have defined metrics to measure the contribution of IT. In fact, the managing director of the company declared that it is very difficult to quantify benefits when aims are simply not realised:

"It is easy to work out how much is going to be spent, but the actual value, figures are hard to credit if they are realistic".

Moreover, he added that no simple investment decision can be based solely on financial criteria, and additional activities are required elsewhere to support the introduction of a new system. Among the benefits from the system are lower WIP, better manipulation of stock figures and savings in purchasing costs.

6.4.4 Factors behind the development of agility in company A.

The MD said that agility is very important for them:

"Our customers demand ever higher standards of flexibility".

The company was rated 3 in the development of agility, the MD said that they have to develop further to meet the needs of their customers. In this company, organisational issues were regarded as very important, apart from having agile manufacturing operations.

The company has identified a series of issues related to the development of agility. These include:

- The capability to produce components in sufficiently low volumes that can reduce the WIP in the shop floor.
- Elimination of set-up costs.
- Flexible manufacturing systems enabling the possibility of having a wide-variety of choices permanently set on a relatively small number of machine tools.

The company's experience shows that the most difficult part in real life is actually in the shop-floor, getting the right attitude from employees. In terms of the use of information systems to support business processes of the company, the MD regarded training of personnel as the most important characteristic supporting the integrity of data entered into the JobShop system. The reason is because people in the shopfloor have to enter data and lack of training has been identified as one of the causes of mistakes in the operation of the system. The company is actively seeking to develop the full potential of its JobShop system and moving from a medium level of satisfaction to a full level of satisfaction. The study of this company revealed that being profitable and experiencing high levels of growth does not mean being agile.

6.4.5 Analysis of company B.

Company *B* was the only enterprise from the electronics-computer sector participating in this research. Also, it was the only company using a RAD system, developed in-house, for the past 3 years. As stated earlier, this company manufactures bespoke computer servers/systems and configurations not commercially available. Its main customers include software development firms.

The self-assessment given by the company to the development of agility of manufacturing operations, the support of IS to manufacturing operations and the development of agility as an improvement programme is presented in figure 6.3.

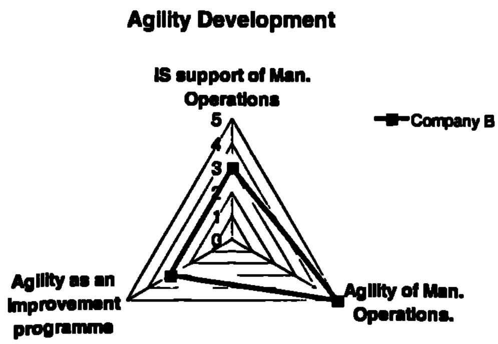

Figure 6.3 Agility development experienced for company B.

The agility of manufacturing operations received a score of 5, which was the highest score registered during the development of the case-study. The support of IS to manufacturing operations and the development of agility were given a score of 3. An explanation to these scores is provided next.

6.4.6 Agility of manufacturing operations in company B.

The information system used in this company is called the Central System and it does support the business processes of the organisation. The company is extremely agile in its manufacturing operations, being able to dispatch a new computer-server system in 24 hours. The integration/utilisation of electronic components to manufacture the bespoke systems is done on a JIT basis. In fact, the company carries very little stock. Moreover, the Central System is critical to support such performance in the organisation. Optimised delivery times, reduced finished stocks and reduced WIP inventory represent important benefits the company expects from the use of information systems.

The Central System provides detailed job orders, spreadsheets invoices, financial status, work status and stock details which are critical for the operation of the organisation. For example, generated spreadsheets enable the company to keep track of its performance and any employee can see what the level of profitability is within the whole firm in an ongoing basis. In fact, the MD stated:

> *"How we are doing, how we are going to do it, what standards are used, are some of the questions answered by the system".*

Interviewees identified that success of an IS application depends on ho v it meets the specific needs of the business, in the case of this organisation those needs include quoting quickly to clients and generating production job sheets. The reason for developing an IS application in house was because there was no suitable off-the-shelf IS applications the company could purchase.

People from the company noticed that IS support of manufacturing operations is limited. In fact, one of the difficulties highlighted is that the Central System has no direct link to real time operations in the shopfloor. Manufacturing operations depend on the individuals manufacturing and assembling the computers.

6.4.7 Information systems performance at company B.

The organisation is fully dependent on the Central System. The managing director defined the success of the application as:

"The right solution for the right problem".

Furthermore, the Central System has provided a list of benefits that include:

- The system makes possible taking responsibilities at different stages of the process (i.e. order needed components, register the names of people involved during the manufacture and assembly of each server).
- Merge data and represent it in a different manner.
- Produce complex quotations, job sheets and spreadsheets.
- Mechanism to control quality.
- Very simple application.
- Information is common across the sales and manufacturing, just presented in a different manner.

The company is very satisfied with the Central System because it meets the needs of the organisation. The time employed to produce detailed quotations to the customers has been reduced from half an hour to 5 minutes. Moreover, the system can be linked to ERP systems of other companies, and it allows customers to order and configure their computer systems on-line although some operations are done manually:

"It relies on the integrity of someone to manually transpose information from the invoices of the purchases into the job sheets".

Company *B* has plans to introduce a new system in the future to support its business:

"The company is planning to integrate all the information to one complete shared package that we can use".

In order to integrate all the information into one consolidated package, the company considered the acquisition of the Sage 50 system, which is an ERP-MRP type of system for small enterprises. During trials with the application it was discovered that it is very poor at doing the job and to efficiently produce job sheets and quotations. The MD explained that:

> *"We have not found a package flexible enough to handle the changes experienced in the business and those systems demands require us to take an accurate analysis of what our stock income is".*

6.4.8 Factors behind the development of agility in company B.

The Central System is integrated to all the operations taking place in the organisation. In fact, the system is able to support the company's business model. Such model is behind the organisation's profitability and ability to respond to customer needs. The Central System supports three operations demanded by the business: generation of spreadsheets to enable the analysis of sales on an ongoing basis, a database used for on-line processing and generation of jobsheets on a daily basis and accounts package, which is the analysis of cashflow and payments to suppliers. However, the company is moving towards being a service provider rather than continuing to develop its manufacturing capabilities.

6.4.9 Analysis of company C.

Company *C* was the only organisation from the automotive sector participating in this research and it was the only company that registered a developed level of agility in its manufacturing operations and a developed level of implementation of agility as an improvement programme.

The self-assessment given by company *C* to the development of agility of manufacturing operations, the support of IS to manufacturing operations and the development of agility as an improvement programme is depicted in figure 6.4.

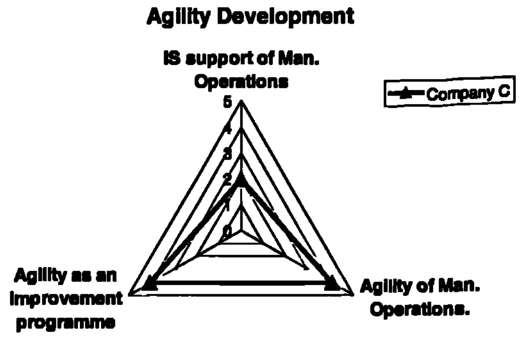

Figure 6.4 Agility development experienced for company C.

The agility present in manufacturing operations received a score of 4, the development of the implementation of agility as an improvement programme received a score of 4, but surprisingly information systems support of manufacturing operations received a score of 2. This result probably means that the manufacturing agility in the organisation has little to do with the use of information systems. A detailed explanation of these results is provided in the next sections.

6.4.10 Agility of manufacturing operations in company C.

In the manufacturing site, the company's main activities involve riveting and semi-automated assembly of seating systems. The company scored the highest level (4-developed) of agility as an improvement programme by all participating companies. Initiatives already taken to achieve this high score include:

- The company has been running a two-year programme focused on getting more flexibility out of manufacturing operations.
- The company works under a manifest with its customers, they provide the production schedules required by company *C*.
- The company keeps constant costs per unit.
- The organisation has been successful most of the time in balancing labour hours against demand, which is the biggest challenge facing in the automotive sector.
- The manufacturing system employed in the company can be switched between batch and JIT, depending on the customer.

The company highlighted three types of flexibility as very important for them: volume (adjusting capacity rapidly); mix/change (customisation of products to customer specifications); and delivery time (handling variation in customer delivery schedule). Also, this company scored the highest level (4-developed) of agility as an improvement programme by all participating companies.

6.4.11 Information systems performance at company C.

The company has been using a system called Tetra CS3 manufactured by Kalamazoo Inc. as its IS platform for the past three years. It is mainly used to support finance, stock control and manufacturing operations and it is a relatively complex application. This IS application has been useful at getting the stock better, aiming at better stock control and minimising stock loses. However, support for manufacturing is too slow to make a significant impact on operations. According to the interviewees the performance of the application has been fair, not good:

> *"We are getting it to work for us but it is hard work. It takes too long and too much effort. The biggest problem of the system is the ability to adapt with the usage of the product, it is not real time, it is delayed. The data that the system records is after the event, not as the event is happening. The company turnovers very quickly and needs to keep the system updated".*

The main difficulty encountered in identifying IS benefits to manufacturing operations, according to one manager, is that currently Tetra CS3 is not linked with the physical systems in the shopfloor. Once this linkage is made and information systems are able to drive the production operations, the benefits can be identified and measured if required. The Tetra CS3 system cannot react quickly enough to real time activity. Moreover, reflecting the current support IS provide to manufacturing operations, the engineering manager stated that information systems do not support the manufacturing site:

> *"Support is given to the finance and stock control of the company rather than manufacturing where it is required".*

Because the system has had a low performance supporting manufacturing operations the interviewees at the company stated the following:

> *"The manufacturing site is independent from IS, agility depends more on other factors".*

In company *C*, the performance of manufacturing operations contrasts with the low budget allocated to IT. This company registered scores below industry average as shown in table 6.2. For example, percentage of annual turnover invested in IT was only 0.6%.

The company experienced no significant problems in the introduction of Tetra CS3 but as yet, unresolved problems involve the use of the system to support manufacturing operations. According to the company, manufacturing has got no real benefits from the system. Benefits to manufacturing come from spreadsheets, jobsheets and deliveries. The company has been able to overcome the limitations of the system by the way it works with its customers. The company operates a cost implied process where the work is based on a customer schedule, on a manifest. That means, a schedule comes in, it is interpreted and a job-work schedule is produced. All this work is done without making use of the system:

> *"Task production to build is completely independent".*

The intervention of employees is an important issue when it comes to ensure the integrity of data entered into the system. The company does not have an established procedure for correct data entry into the system.

> *"If wrong data is input, you do not realise that until you check your stock or simply you run out of stock, you do not notice it".*

6.4.12 Factors behind the development of agility in company C.

In this organisation, the low performance of information systems contrasts with the flexibility of manufacturing operations. The following areas have been identified by the company for further development to enhance agility of its operations:

- High level of fluctuation, the company needs to be more responsive to changing customer requirements while continuing with the focus on cost effectiveness.
- Minimise waste, and more efficient stock control and time utilisation.
- Improved IS support for manufacturing, including real-time monitoring of manufacturing operations.
- Procedures in place to ensure the integrity of data entered into the system.
- Implement a new IS platform that will enable the company to become integrated to its customers, suppliers, the parent company and other production sites.

6.4.13 Analysis of company D.

Company *D* was the second organisation from the aerospace sector to participate in this multiple case-study. The company's self-assessment indicates a medium level of development of agility as an improvement programme (scored 3), a high level of information systems support of manufacturing operations (scored 4) and medium development of agility of manufacturing operations (scored 3). The scores of company *D* are presented in figure 6.5.

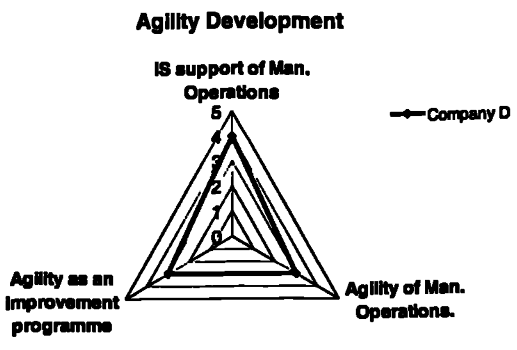

Figure 6.5 Agility development experienced for company D.

During the development of the case-study it was said that this company has already implemented lean manufacturing policies and according to those interviewed, the company has implemented some agile manufacturing processes. Regarding the high score registered for IS support of manufacturing operations, interviewees said that information systems are widely used to support manufacturing operations.

A dynamic characteristic of the aerospace sector is the reduction of cycle times for new products. For company *D*, the period to deliver a prototype, i.e. cycle time, is three months. Without drawings, the development period is about five months.

6.4.14 Agility of manufacturing operations in company D.

The company has implemented a range of business initiatives with the aim of becoming more agile. These include:

- Moving to high volume, high variety as much as possible in the aerospace industry.
- Manufacture of components made by competitors in-house at lower costs.
- Commitment to lean manufacturing.
- Kit parts to customers so they do not carry stock.
- Capacity monitoring of suppliers (measure them).
- Decrease of 5% in costs to their customers while increasing volumes of sales by 20%.
- Continuous development of Kanban and pulling systems.

In the organisation, the production volume per week is between 40 to 50, which is relatively high for the aerospace industry. Kanban and pulling systems are widely used in the shop floor. Kumar and Motwani (1995) identified pull systems as determinants of agility. According to Quintana (1998) the goal of the pull system is to pull the materials requirements while accumulating a minimum amount of inventory (lean), and with minimum advance notice of production requirements from the customer (agile).

Currently, the company is focusing on upgrading and improving its manufacturing operations. Adjusting capacity rapidly and handling variation are regarded as extremely important issues to survive in this sector.

6.4.15 Information systems performance at company D.

The company has been using CINCOM as its main IS application to support business processes. The system provides support mainly to manufacturing operations, however the company is disappointed with the performance of the application. The company has been using the system for more than three years and it has been experiencing problems with it:

> *"The company has got level schedules for production, however the MRP system does not reflect that. At the end of the day, the customers do not pull to that level of schedule".*

One of the advantages of the system is that it allows company's customers to check the capacity of its operations. So they can know if the company is telling the truth or not. Also, the system requires entering data manually, changes in schedules and specifying the numbers required:

> *"The systems requires manual inputs, so people have to go in and say yes, we need that part, order it".*

In this company, a low performance characterises IS support of manufacturing operations. The continuous mistakes made when operating the system, prompted the development of a series of procedures to ensure the right utilisation of the system:

> *"What was offered and what was needed were incompatible at the time, we struggled, the support provided by the system has been fairly poor, the IS has been like rubbish, we have to work it hard".*

Nowadays, the company has set an improvement steering committee to make sure the site uses CINCOM properly. According to the company, the main difficulty observed in identifying benefits from IS in manufacturing, is aligning the application (MRP system) with customer demand.

6.4.16 Factors behind the development of agility in company D.

The company highlighted during the interviews that they are probably using agile manufacturing processes in response to customer satisfaction/global requirements. Certainly, agility is very important in a business environment like the aerospace sector.

The company has created a steering committee to define procedures for all business processes, including manufacturing and information systems. One of the reasons for that is because CINCOM is a very complex application:

> *"If you want to go from* A *to* B *the system provides you with 100 different ways to achieve that. The company experimented with it, trying to find out how to get from* A *to* B *in the quickest route".*

The development of flexibility in manufacturing operations and the adoption of a lean policy have enabled the company to develop some agile processes. However, information systems were not identified as the main elements that have enabled the improvement of manufacturing operations in the company.

6.5 Particularities on information systems and manufacturing.

The results of the previous section showing the relegation of information systems behind other enablers in the achievement of agility in manufacturing, motivated the incorporation of the answers given to a series of questions closely related to the state of information systems in participating companies. The answers to a number of structured questions would be useful in providing additional facts and ultimately enable comparisons with the results of the analysis shown earlier. This section shows the assessment given to IS support of manufacturing-related activities, operational benefits of information systems, IS management guidelines and strategic and tactical benefits expected from IS.

6.5.1 Support of IS to manufacturing-related activities.

The view of the companies on the performance of their information systems is compared to the assessment given to IS support of seven manufacturing-related activities. The interviewees used a five-point Likert scale to assess these activities and during the interview they were encouraged to expand their written answers verbally. A first look into the answers shown in figure 6.6 revealed a poor support for *capacity planning* present in all companies.

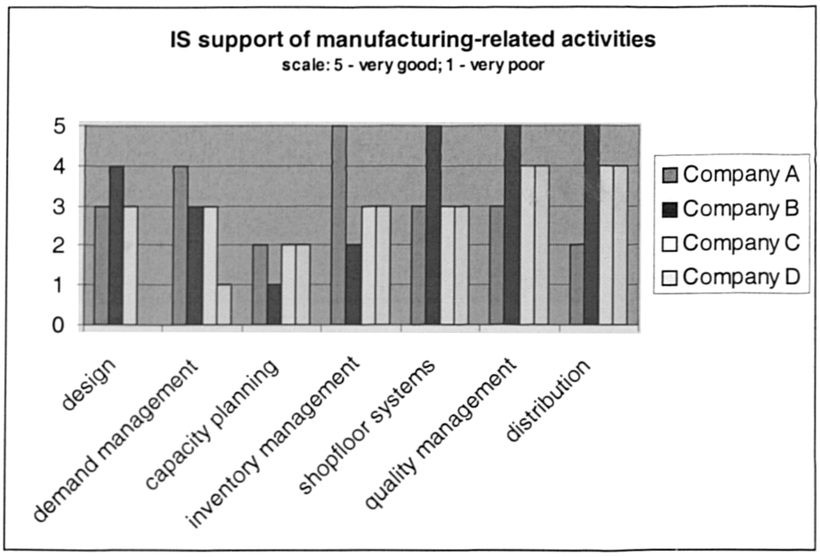

Figure 6.6 Assessment of IS support of manufacturing–related activities.

Company *D* specified that they do not do any design on their site and they said they were having problems with *capacity planning*. This is in part proof that participating companies are facing a dynamic business environment. For example, company *D* which is committed to a lean policy expressed that it is very difficult for them to define current capacity because flexibility and people skills are a main constraint for *capacity planning*. Indeed, this company said that a low performance characterises IS support of manufacturing operations. Company *A* stated that due to the high growth experienced, they were experiencing difficulty in identifying if the right job was being done at the right time and hence the low score for *capacity* *planning*. In company *A*, the level of IS support of manufacturing operations did not reach a high level of development.

Inventory management provided the highest rate of support by information systems in company *A*. In company *B* the maximum support of information systems was given to the *shopfloor*, *quality management* and *distribution*. In company *C* *quality management* and *distribution* received good support from information systems. Support given to *design*, *demand management*, *inventory management* and *shopfloor* systems was rated as medium (3), not good, not poor. The results show that IS provide poor support to principal activities in manufacturing such as *capacity planning*. However, that has not been an impediment to start developing agility in manufacturing. Activities that received good ratings in most companies include *quality management* and *distribution*.

6.5.2 Operational benefits of information systems.

A list of operating benefits sought from IS in manufacturing operations is presented in table 6.3.

	Benefits from IS
1	Automate processes
2	Eliminate bottlenecks
3	Optimise delivery times
4	Reduced overhead apportion
5	Reduced finished stock levels
6	Reduced WIP inventory
7	Reduced raw material inventory holdings
8	Reduced direct labour
9	Reduced indirect labour
10	Reduced scrap and rework
11	Reduced warranty claims
12	Increase throughput
13	Reduced manufacturing lead times
14	Reduce machine set-up/changeover
15	Reduced working capital
16	Reduce quality control
17	Sort out specification

Table 6.3 Benefits from IS to manufacturing operations.

In fact, it would be possible to identify hundreds of benefits to manufacturing operations. The list of benefits shown here, taken from the work developed by Maskell (1991) and widely used by Kidd (1994) and Irani (1998), was thought to be sufficient for this study. For illustrative purposes, the answers provided by the respondents were divided and presented in figure 6.7 and figure 6.8.

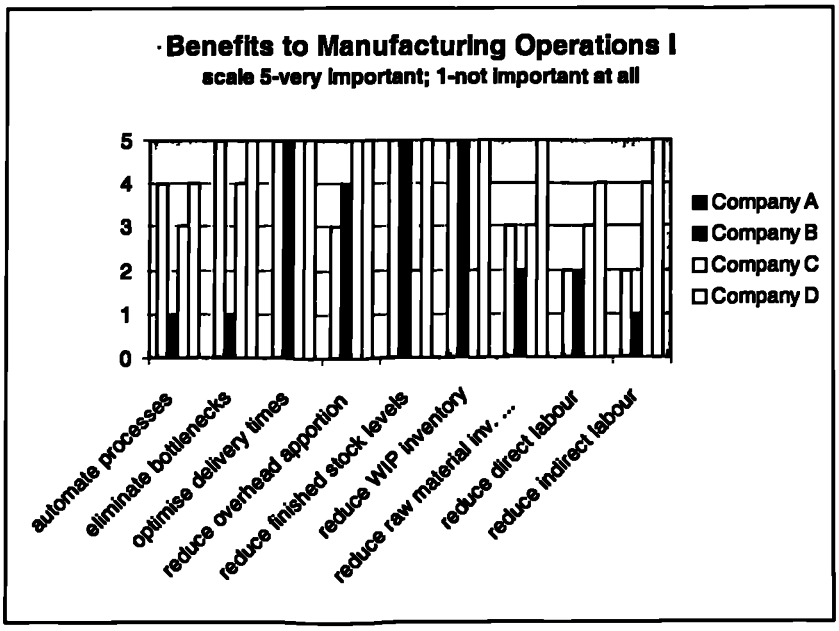

Figure 6.7 Assessment of IS benefits to manufacturing operations I.

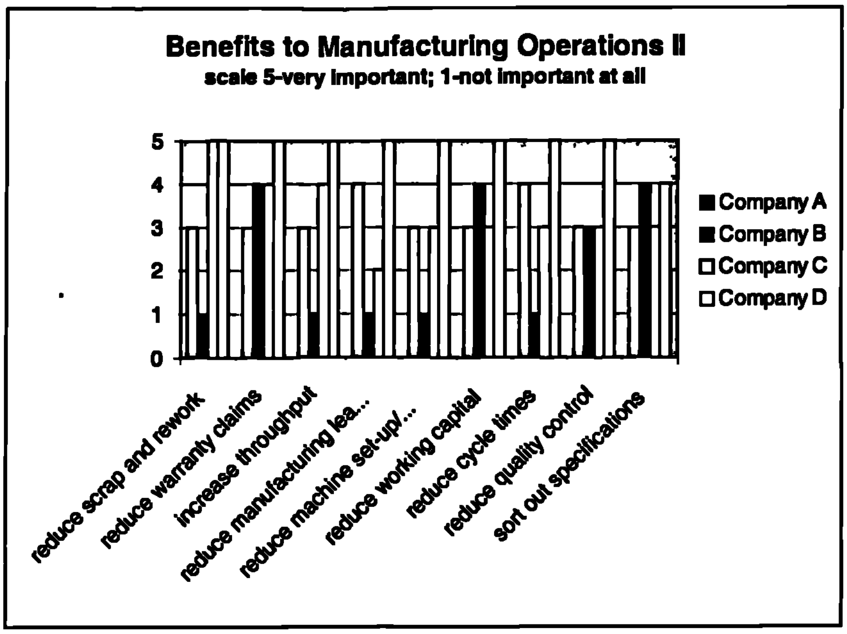

Figure 6.8 Assessment of IS benefits to manufacturing operations II.

The low scores given to certain benefits may suggest that these are not related to way the companies run their businesses, as explained next.

The results show that company *B* scored low in *automate processes, eliminate bottlenecks*, *reduction of raw material inventory holdings* and *increase throughput* because of the nature of the business of the company; the manufacture of bespoke computer systems using a jobbing manufacturing system. Company *A* considered as not important benefits *reduction of direct and indirect labour*; in fact, this organisation does not expect staff reductions because of the use of IS. In company *C* only three benefits were rated as not important, these include: *reduction of finished stock levels*, *reduction of WIP inventory* and *reduction of manufacturing lead times*. Indeed, company *C* declared that IS support for manufacturing is too slow to make any significant impact on operations. In company *C*, the limited expectations on IS contrast with the work done on getting more flexibility out of manufacturing operations. Company *D* showed great enthusiasm in identifying benefits sought from the adoption of information systems to support manufacturing operations. In fact, of the seventeen issues presented in table 6.3, fourteen issues were rated as very important and the rest of them, *automate processes*, *reduce direct labour* and *sort out specifications*, were rated as important.

During the assessment of operational benefits, interviewees stated their interest on the achievement of flexibility on manufacturing operations. Indeed, manufacturing flexibility can be a critical source of competitive advantage, yet is one of the most difficult goals to achieve (Nemetz 1990, Ritzman et al 1993, Gupta and Somers 1996, Shewchuk and Moodie 1997, Kathuria 1998).

6.5.3 Comparison of criteria used to evaluate information systems.

The study revealed that the use of formal procedures to measure IS contribution is not widespread. The identification of IS contribution is relevant because the impact of information systems can be perceived at different levels in the organisation (Li 1997 and Thoburn et al. 1999). A basic criteria for the evaluation of information systems has been identified by Boar (1994) and Randall (1999) and shown in table

6.4. Figure 6.9 shows the assessment done by the companies using a five-point Likert scale, ranging from 5 for very important to 1 for not important at all.

Criteria of Evaluation	
1	Simplicity and robustness
2	Ease of configuration
3	Rapid implementation
4	Ease of learning
5	Scalability
6	Distributed data with replication
7	Expandable across the enterprise
8	Capability for multi-site, multi-company, multi-enteprise
9	Adequate training for new/upgraded versions

Table 6.4 IS evaluation issues.

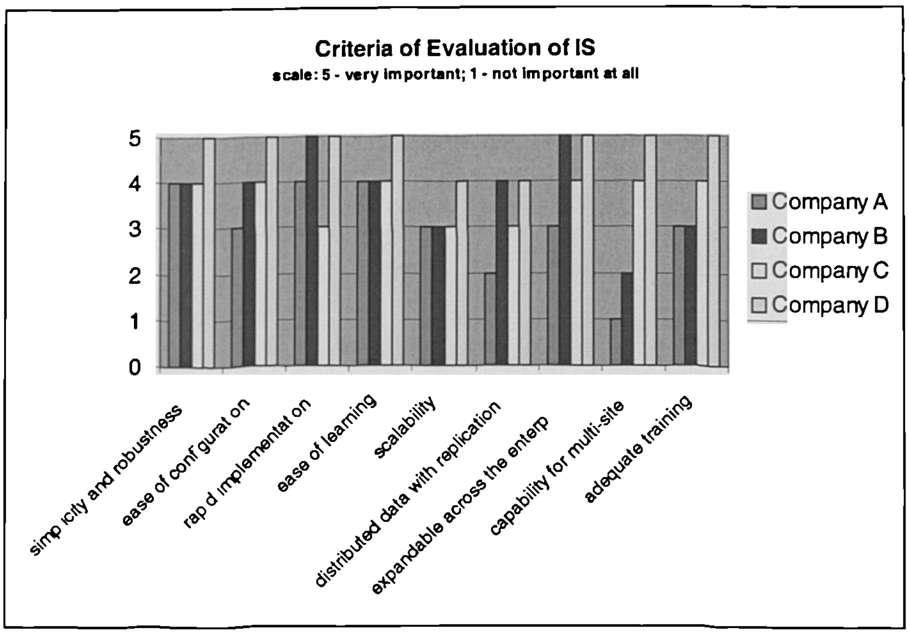

Figure 6.9 Assessment of evaluation criteria of IS.

The elements introduced in table 6.4 represent a set of characteristics used in the evaluation of information systems which can be compared to the performance of the IS used in the companies (the case study has already shown that companies *C* and *D* use low performing IS). Indeed, the ratings given by the interviewees to these IS characteristics reflect the priorities of their organisations. During the development of the study it seemed that the prioritisation of the elements presented here responded more to the characteristics of the manufacturing operations of participating companies than giving an assessment based on defined IS management guidelines. For example, in two companies (*A* and *B*) that do not have business units in different geographical locations the issues of *capability for multi-site, multi-company and multi-enterprise* received a low score.

Another issue that received a low score by one company, *B*, is *distributed data with replication.* In this particular company all data is centralised and access to it is only by the person who has to deal with it. Among the issues that received the highest scores it was possible to identify *rapid implementation.* In fact, the three companies that use COTS applications regard this issue as a very important. Company *A* implemented a type of ERP system for small manufacturing enterprises more than twelve months ago. Overrun in terms of budget and time were some of the problems the company suffered when implementing the system. The company that developed a RAD application, *B*, highlighted that *implementation time* was not really important.

Ease of learning is another characteristic that received a high score in all companies. During the development of the study interviewees said that the most employees can learn about the use of a system is important to deliver benefits to the organisation. In fact, in company *B*, *ease of learning* and *simplicity of use* were identified as two characteristics behind the success of the Central System. The complexity of the system used in company *D* made learning to use the system by all relevant employees extremely difficult. Other companies associated *ease of learning* to having training programmes in the use of IS. In company *C*, training of employees which is related to *adequate training* was regarded as critical to ensure the realisation of benefits from the use of information systems. Furthermore, skills and expertise of employees, a principal enabler of agility, is closely related to *adequate training*. The assessment of the IS evaluation criteria covered in this section is a detailed description of the requirements that best match the information needs of each company.

6.5.4 Identification of information systems management guidelines.

The literature on Management Information Systems is rich in providing numerous guidelines and recommendations for the administration of information resources. During the development of this section, interviewees were presented with a number of factors closely related to the policies that drive the management of information resources in their organisations. The first two factors presented include:

- How are current metrics utilised to measure the contribution of information systems in your organisation (Q1).
- Expertise to deal with legacy systems and rapid changes in operating systems and applications versions (Q2).

The interviewees assessment of the above statements was done using a five-point Likert scale with values ranging from 5 for very good to 1 for very poor. The answers given by the interviewees are shown in figure 6.10. The MD of company *B* considered that his organisation was in a good position regarding current metrics utilised to measure the contribution of information systems. By far, company *B* was identified as the enterprise with the most IT literate personnel and with having a policy of monitoring the extent IT/IS meet the needs of the organisation. Company *D* described that they have developed a balanced scorecard to register the contribution of information systems. Companies *A* and *C* said that they were in a poor situation regarding this issue. In fact, company *A* has no metrics at all and questioned the viability of measuring benefits from IT/IS.

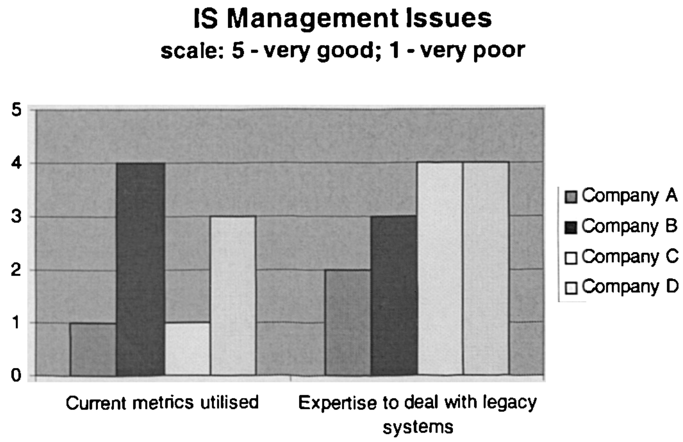

Figure 6.10 Assessment of IS Management Issues.

Expertise to deal with legacy applications is an issue that has been considered important in the management of information systems for agility. Researchers and practitioners that have addressed this issue included Subrahmanian (1998) from Carnegie Mellon University and Edwards et al. (1999). Regarding this issue two companies (*C* and *D*) answered having a good expertise with legacy systems. The reason for this answer is that both companies have been working in recent months towards the implementation of new applications to replace their current IS, Tetra CS3 for company *C* and CINCOM for company *D*. The implementation of these new applications will have an impact on the future operation of both organisations. Procedures expected to change with these new IS include: the relationships with customers and suppliers, partnerships with other companies, and closer ties with other geographically distributed business units.

Also, this section included two more factors of relevance to the future development and management of information systems (Subrahmanian 1998): business environment and IT/IS infrastructure. These factors were presented to the interviewees in the following statements:

- The business environment as a major driver in determining the management of the IS function within the organisation (*S1*).
- Awareness of the IS department in creating an agile and flexible IT/IS infrastructure according to the rate of change in technology (*S2*).

To answer these statements interviewees used a five-point Likert scale. The answers given to these two statements are presented in figure 6.11.

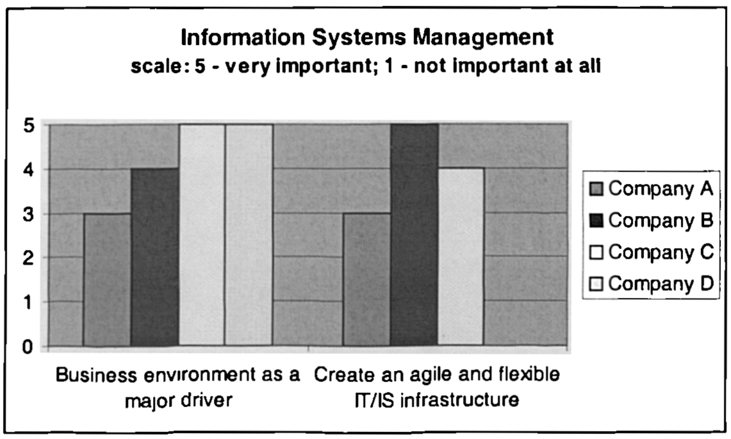

Figure 6.11 Assessment of IS Management Factors.

Companies *C* and *D* considered that the business environment was a major driver in determining the management of the IS function. However, in both companies the IS function has been struggling in recent times. Both companies have low performing IS applications supporting their business processes, especially manufacturing. The only company that showed a satisfactory result was company *B*, rating the business environment as important and having a good performing IS, the Central System.

Only one company showed full awareness in creating an agile and flexible infrastructure. Company *B* which has the highest IT literacy among interviewed companies gave the highest rating to this issue. Company *D* was unable to answer this question mainly because decisions related to major investments in terms of infrastructure and applications are taken at its UK headquarters in Birmingham.

The case study also investigated the use of financial techniques to measure any contribution from information systems. The use of financial techniques in the evaluation of information systems alongside with techniques that involve the identification of non-tangible IS benefits has been identified in the literature (Ezingeard et al. 1998). Indeed, a significant number of financial techniques can be applied to justify investments in manufacturing. To understand to what extent financial techniques have permeated the manufacturing enterprises that participated in this research a number of techniques were presented to the interviewees.

The study shows that companies are familiar with popular techniques such as Payback Period and others like Cost Benefit Analysis, Net Present Value and Internal Rate of Return. An explanation on these techniques can be found in any management accounting textbook (Atkinson et al. 1997).

The results show that although participating companies are familiar with many of the financial techniques presented in the study, they hardly use them to assess any contribution of information systems. During the study, the companies provided their view on the evaluation of IS. In company *A*, the MD revealed that they do not have procedures to measure the contribution of information systems. The MD said that he does not find it meaningful to trace back the benefits provided by information systems. The MD of company *B* said that the company does have in place few methods to measure the contribution of information systems to business processes. For example, the company is able to generate reports (account and management reports) about the performance of the company or register the time it takes to generate detailed quotations to customers. During the development of the interview, company *C* stated that it does have procedures to measure the contribution of information systems. However, the measures covered in those procedures are quite rudimentary. Basically in the company they generate monthly report accounts which provide analysis figures in terms of stock and financial control.

According to company *D*, different financial techniques to assess projects have been used in the past. Indeed, at least thirteen different techniques available have been used on a regular basis. The *Total Quality Counsellor* of the site mentioned that EVA (economic value added) is regarded as a powerful technique for performance measure. In the specific terms of information systems contribution, the interviewees explained that in the company they have developed a balanced scorecard to document benefits from information systems. However, financial techniques are used in the evaluation of investments involving CNC machinery to improve the flexibility on the shopfloor, but not in the assessment of IS. In company *D*, flexibility of manufacturing operations, a principal enabler of agility, is regarded critical in the development of the operations side of the business.

6.5.5 Strategic and tactical benefits expected from information systems.

During the development of this study, a number of information systems-related benefits were identified in the literature of agile manufacturing and presented to participating companies. An important number of attributes, linking agility to the use of IT, were identified by Goldman et al. (1995). Also other attributes were identified in Randall's (1999) work on benefits of information systems.

Given the need to invest in information systems and the unanimous perception that manufacturing companies need to become agile and satisfy customer needs, participating companies were asked to prioritise the following benefits using a 5-point Likert scale:

- Employees accessing company-wide data.
- Increase electronic links with customers and suppliers.
- Value of information content of products.
- Working teams with access-wide to all data.

The results to the above information systems-related attributes are presented in figure 6.12.

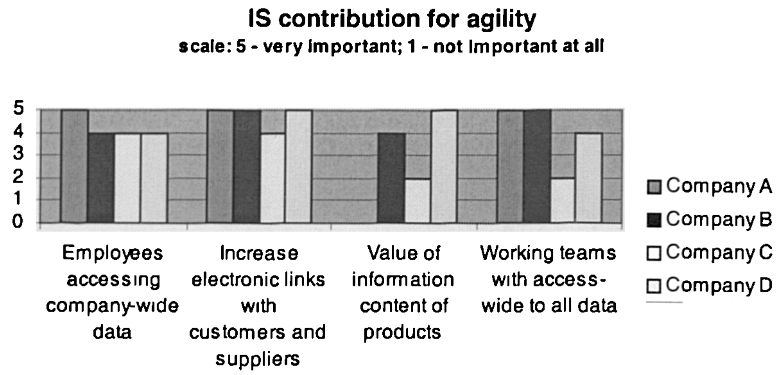

Figure 6.12 Responses given to the four factors of agility.

There are some significant differences between the answers given to the above attributes. One of them is *value of information content in products.* Company *B* and *D* perceived as important the value of information in its line of products but that was not the case for companies *A* and *C. Increase electronic links with customers and suppliers* received the highest scores by all companies, supporting the close link between this attribute and information systems. Also *employees accessing company-wide data* was rated high. Company *D* regarded all the above benefits as important and very important. Supporting the second benefit listed, company *D* described that it is in the process of developing a portal that will enable the integration of suppliers and customers. *Working teams with access wide to all data* was rated as not important in company *C*, this answer has an explanation on the way the company operates, under a manifest with customers providing the production schedules.

There are four more benefits, strategic benefits, that have been considered cornerstone in the development of assessment frameworks for information systems, these include:

- Achievement of competitive advantage.
- Tasks that could not be done before.
- IS applications seen as a distinctive proprietary advantage.
- IS are seen to maintain competitive position.

These expected benefits have been important in the adoption and evaluation of information systems. The identification of opportunities to deploy IT for competitive advantage has been highlighted by Segars and Grover (1998). The answers given by the interviewees to the above benefits are shown in figure 6.13.

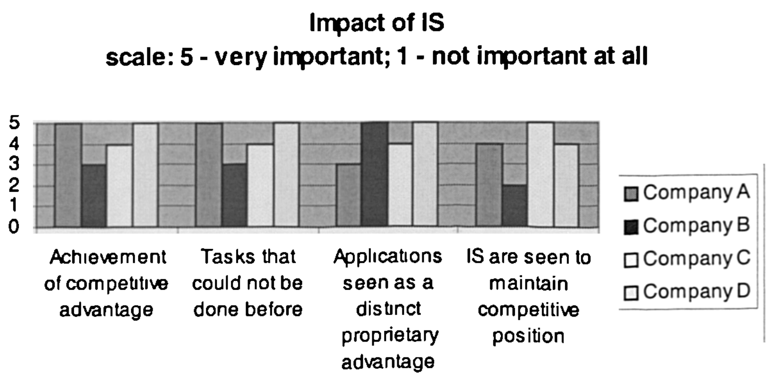

Figure 6.13 Impact of IS.

The results showed that in company *A*, information systems are seen in the achievement of *competitive advantage* and seen to *maintain competitive position.* The same opinion was shared with companies *C* and *D*. These three organisations believe that IS allow them to do *tasks that could not be done before. Applications seen as a distinct proprietary advantage* received a high score in companies *B*, *C* and *D*. Company *B* provided low scores to *achievement of competitive advantage*, *tasks that could not be done before* and *maintain competitive position.* The answers given by company *B* are interesting because in this organisation interviewees said they were satisfied with the performance of information systems and also reported a high development of agility in its manufacturing operations.

One more statement was evaluated as part of the management of information systems for agile manufacturing. The statement is: ***investments in IT/IS are intended to increase revenue through new business processes.*** This assertion was originally proposed by E. Subrahmanian (1998), as a consequence of the value of information systems in manufacturing organisations. Company *C* was the only organisation which did not see investing in IT as a way of increasing revenue through new business processes. Their idea of using information systems is to improve operations (e.g. flexibility of operations on the shopfloor) and through the improvement of operations improve the service to the customer. The same company reported that the manufacturing site is independent from IS. Companies *A*, *B* and *D* considered the statement important.

6.6 Similarities and differences between participating companies.

Figure 6.14 represents the highest and lowest values registered during the development of the multiple case-study. The analysis of the results revealed information systems as not principal enablers of agility. Certainly they are critical to supporting business processes but information systems, in themselves, are not sufficient to achieve manufacturing agility. This statement suggests that the hypothetical agility triangle presented at the beginning of this chapter may be unrealistic.

The results show that it is possible to achieve a high level of agility with low levels of information systems support to manufacturing operations and low performing IS applications. Agile manufacturing depends more on other factors like having the right attitude from people, providing training to employees, leanness, high variety with high volume, reduction of set-up time and costs and WIP, set of skills and expertise of people and having a flexible manufacturing base.

The study has provided some arguments on what constitutes agility, or rather what is not covered by it, for example:

- Being profitable does not mean being agile or growing at high annual rates does not mean being agile.
- Utilisation of simple or sophisticated IS has little or nothing to do with the achievement of agility in manufacturing operations.
- Company size is not related to the agility of its processes.
- Poor support of information systems to manufacturing operations does not determine the level of agility achieved.
- A poor level of satisfaction with information systems does not necessarily impede agility.

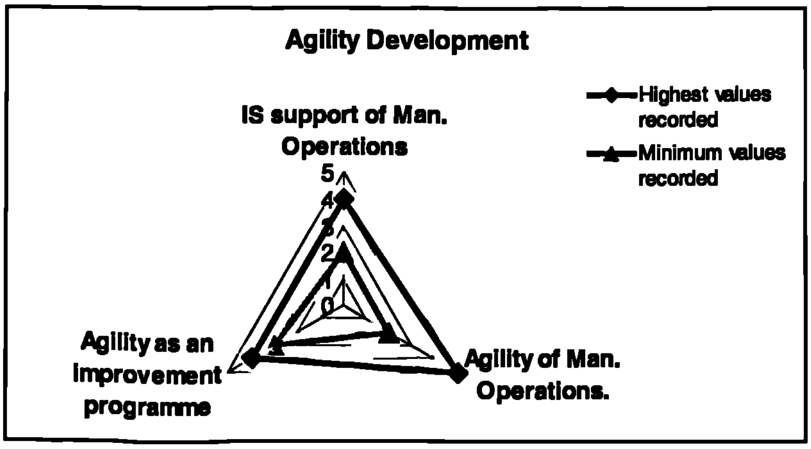

Figure 6.14 Maximum and minimum values registered.

6.7 Proficiency characteristics that encompass IT/IS capabilities for agility in studied companies.

Two testable propositions were generated from the statistical analysis of the survey. These are:

a) IT/IS proficiency characteristics of agility are independent of the characteristics of a dynamic business environment.

b) IT/IS proficiency characteristics of agility are independent of the types of IS applications used in manufacturing.

The purpose of this section is to further investigate these testable propositions with the four companies that participated in the case-study. All the data collected in terms of information systems have been arranged based on the three factors underlying the IT/IS proficiency characteristics of agility identified during the statistical analysis of the survey. Also, a detailed explanation of the impact of the business environment on information systems is provided for each company.

6.7.1 Proficiency characteristics and business environment in company A.

The proficiency characteristics related to the three factors identified in the analysis of the survey and the influence of the business environment in company *A* are presented in this subsection.

a) Factor 1: Correction and Variation.

Correction has been one of the problems faced by this organisation. Currently the company has only one person in the IT department and most of his time is invested in trouble solving rather than exploring ways on how to exploit the JobShop system to deliver benefits to the company. Indeed, this characteristic is particularly weak in the company.

b) Factor 2: Augmentation and Creation.

At present time the company has got an infrastructure consisting of PC's running Windows98, workstations running Windows NT and Novell Netware as the network platform plus a number of servers. The company has installed all the modules of the JobShop system enabling, for example, the future operation of web-based applications, if required, but currently those services are not available.

c) Factor 3: Migration and Comparison.

Migration was considered when the system Jobshop was installed. The organisation has no plans to update or replace the current system in the medium term. The addition of future modules or third-party applications to the system is fully supported by the IT/IS infrastructure of the company.

d) Dynamic business environment.

Customer's needs changing all the time and the need to respond to them reflect the dynamism of the business environment faced by this company. However, the business environment does not have any direct impact on IS. Information systems are directly affected by the decisions taken by the management of the company based on business needs at the time.

6.7.2 Proficiency characteristics and business environment in company B.

A description of the three factors with their associated IT/IS proficiency characteristics and the business environment in company *B* is provided next.

a) Factor 1: Correction and Variation.

The current IT/IS infrastructure and the Central System facilitate doing fixings to problems that may arise in the organisation. For example, restoration of corrupted tapes of the backups tables and databases of the company is relatively easy. Current IT/IS infrastructure was rated good in this company.

b) Factor 2: Augmentation and Creation.

The current system (Central System) used in this company is not modular, it is fixed. That means the impossibility to add or remove modules to it. It is possible to add external applications to interact with the system, but that does not guarantee a seamless integration and trouble-free operation. Moreover, the current system does not support more than 20 simultaneous users. This means that a replacement system must be purchased if the company decides to leave its policy of fixed size and decides to hire more employees and expand its business. If the company decides to grow in size, they will be in need to replace or develop a new system able to support a larger number of users, but that somehow contradicts the business policies of the company.

c) Factor 3: Migration and Comparison.

The current IT/IS infrastructure of the company supports the interaction with customers and suppliers through electronic channels. In fact, the company uses the web to allow customers configure their servers-systems online at the time of purchase, show suppliers current stock levels of components and link the company's IS to those of services providers (e.g. Barclays bank).

d) Dynamic business environment.

The business environment in the electronics-computer sector is extremely dynamic. So dynamic is that the company has to invent itself every three months, and the flexibility demanded by the business is not supported by methodologies that require exact documentation of procedures like ISO9000. Success in the company depends closely on the support provided by information systems, however the Central System is not affected by changes in the environment. Change come from management and not from the inherent capability of the IS function to adapt itself to the conditions of the business environment. In fact, people react to changing conditions in the business.

6.7.3 Proficiency characteristics and business environment in company C.

The conditions observed in company *C* for the three factors and their associated IT/IS proficiency characteristics and the influence of the business environment are presented in the next paragraphs.

a) Factor 1: Correction and Variation.

Correction was a characteristic highlighted in company *C*. In fact it was one of the IT/IS proficiency characteristics that received the highest scores in the survey. The company explained that it is the accumulated experience of people that has enabled the operation of the Tetra CS3 system and people are responsible from getting results from the system. Fixings to IT/S infrastructure and applications problems are not adequate and they rely entirely on employees' actions.

b) Factor 2: Augmentation and Creation.

The need to acquire the proficiency characteristics associated to this factor was highlighted during the study of company *C*. The Tetra CS3 system operates with a number of workstations using the AIX operating system. However, this application does not support the development of customised solutions and is not modular. The company has considered not worth fixing the current system. Instead of working to solve those limitations, it has contemplated the implementation in the forthcoming future of a new system that will cover not only the operations supported by Tetra CS3 (stock control and financial control), but EDI and real time monitoring of manufacturing operations. It will be a modular application customised to the specific needs of the company and it will support the development of customised solutions.

c) Factor 3: Migration and Comparison.

The characteristic of migration was also identified in this company. In company *C* IT/IS infrastructure is important, so future changes to it have been contemplated in order to implement and develop a new system that will enable the company to be part of a global organisation.

d) Dynamic business environment.

The characteristics of the business environment faced in company *C* included the perception of a medium to high *potential for continual growth* with customer needs changing all the time. However, changes or modifications to information systems depend on management's capacity to react to the business environment and not as an inherent characteristic of IT or the type of IS application used.

6.7.4 Proficiency characteristics and business environment in company D.

A description of the three factors with their associated IT/IS proficiency characteristics and the business environment observed in company *D* is provided next.

a) Factor 1: Correction and Variation.

In this company, fixings to IT/IS infrastructure and information systems received a high rate. In fact, Management has put emphasis on developing procedures to tackle problems as quick as possible. A number of procedures have been developed based on lessons learned from past mistakes. The motivation to document fixings and repairs to IT is the low performance of the CINCOM system. Moreover, the experience of people with the system has been critical in compiling manuals and procedures for the operation of the CINCOM system.

b) Factor 2: Augmentation and Creation.

The IT/IS infrastructure of the company has been able to support the operation of the CINCOM system. However, for the implementation of the new system, scheduled in the coming months, the IT/IS infrastructure will need to be upgraded. Its current condition will not support the operation of the new system. These changes will guarantee the modularity required to add or remove components.

c) Factor 3: Migration and Comparison.

Actions associated to the characteristics of migration and comparison include upgrading the current CINCOM system and the development of the company's portal. To support these tasks, the company has considered an upgrade plan for the current IT/IS infrastructure.

d) Dynamic Business Environment.

Company *D* explained that despite being in a business environment characterised by very high entry costs and with a limited number of players, there is pressure to reduce development cycles of new products. The study showed that changes to the IT function comes from the capacity of reaction of management of the company to changes in the business environment. In manufacturing organisations like those studied here, the IT function is a subordinated unit that cannot react to perceived changes by itself. However, that does not represent an impediment to develop manufacturing agility.

6.7.5 Issues supporting IT/IS proficiency characteristics for agility.

Three attributes identified by Subrahmanian (1998) and closely related to the outcome of the survey presented in chapter 4 were developed in the information systems management section of the case-study. The statements presented below include elements such as IT/IS infrastructure, IS department capability to react quickly to the business environment and adequate speed provided by the IT function to support processes under the pressures of the business environment:

1) The current IT/IS infrastructure and applications guarantee managing processes (e.g. order fulfilment, new product introduction, inter-organisational supply chain

management) that span beyond their business units and require integration with other companies.

2) The information systems department has the capability to react quickly to changes perceived in the business environment and make pertinent changes.
3) The speed brought by the IT function is adequate to support our processes under the demands of the business environment.

Figure 6.15 presents the answers given by participating companies using a five-point Likert scale.

During the analysis of the survey in chapter 4, IT/IS Infrastructure emerged as an element shared by the factors underlying IT/IS proficiency characteristics of agility. In the statement related to this factor, only company *B*, provided a satisfactory answer, that is good. The three other companies answer to the factor was medium (3), not good, not poor. No participating company admitted having a poor IT/IS infrastructure managing their business applications. In fact, all of them agreed that IT/IS infrastructure is important to support business processes.

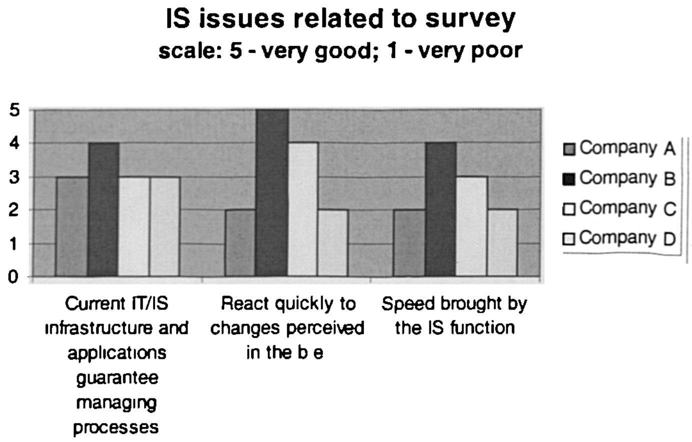

Figure 6.15. Assessment of proficiency characteristics of IT/IS.

The second factor investigated, *Information systems department's capability to react quickly to changes perceived in the business environment* was rated good by companies *B* and *C*, and received poor ratings from companies *A* and *D*. In the case of company *B*, the Central System was specifically designed to handle the changing needs of its customers. In the case of company *C*, IT people have developed the expertise required to face changes in the business environment. In fact, these companies are very responsive to the changing needs of their customers. On the other hand, companies *A* and *D* admitted to having a poor experience with this second attribute of study.

The last attribute investigated, *the speed brought by the IS function is adequate to support processes under the demands of the business environment*, has been related to the successful management of IT/IS. Only company *B* admitted to having a good experience with this particular attribute. In fact, this company is the most capable of the group to react to the particular needs of its customers, all its specific-built server-systems are bespoke and shipped to its customers in less than 24-hours. Also, this company showed great confidence in the support the Central System provides to the business.

6.7.6 Synthesis of results for testable propositions.

The development of the multiple case-study made it possible to further expand the propositions generated from the results of the survey. Despite the fact that three organisations recognised that the business environment is a major driver in the management of the IT function, in all companies it was noticeable that all decisions concerning IT were made first by the company's management. IT was not identified as an independent unit that can react on its own to changes in the business environment.

The results of the study also supported the idea that the use of a specific IT application is not associated to the achievement of agility. In fact, some organisations that use systems which are not considered to be either state of the art, or technologically advanced, have developed agility in manufacturing.

6.8 Information systems role as enablers of agile manufacturing.

The study showed that information systems are relegated behind other enablers of agility. Although information systems are often used to support agility, information systems in themselves are not sufficient to start developing agility in manufacturing operations.

The results of the study did not show strong evidence to associate the agility of manufacturing as a contribution of information systems. Rather, it revealed that the most significant enablers of agile manufacturing are: providing training to employees, right attitude of workforce towards change, having a flexible manufacturing base, including flexibility with reduced set-up times, constant costs per-unit and people's knowledge and skills. Indeed, in the course of the study, it was possible to find examples where lack of adequate operator training has been identified by the companies as key impediments for rapid progress towards agility.

None of the participating companies identified IS as an enabler required to start developing agility in their manufacturing operations, as it was the case of other enablers like training of employees or having a flexible manufacturing base. The study showed that information systems are not principal enablers of agility. In fact, information systems should be considered secondary, or second-order enablers of agility. Figure 6.16 shows a new taxonomy of enablers of agile manufacturing based on the development of agility of business processes, in this particular case, manufacturing operations. First-order enablers are used during the first phase of the development of agile business processes. Information systems are used in the second-phase which involves the enhancement of agile business processes.

The self-assessment on the fields of agility of manufacturing operations, IS support of manufacturing operations and agility as an improvement programme included in the case-study, has enabled the identification of the role of information systems in those organisations that scored "developed" levels in the above fields. For example, it has been possible to identify the role of information systems in the "developed" agility of manufacturing operations in companies *B* and *C*. Also the study has been useful in identifying the role information systems play in improving those fields that were rated as "not developed". For example, note the role of IS in improving manufacturing operations in company *A* discussed earlier.

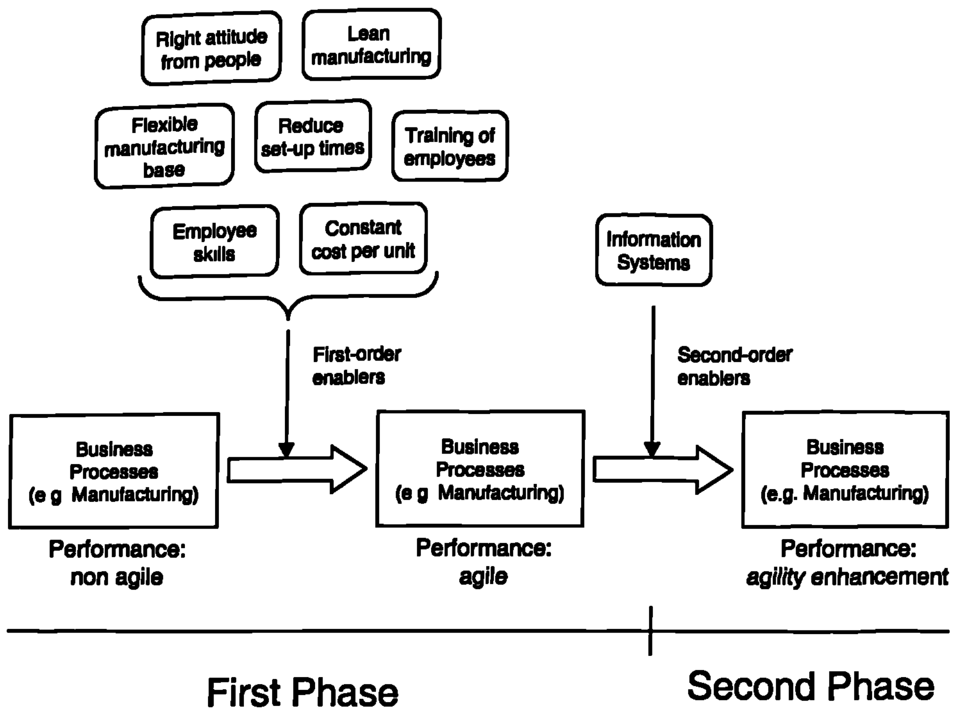

Figure 6.16 Information systems role within agility in manufacturing.

6.9 Comments and remarks.

The results of the study identified the role of information systems among other enablers of agile manufacturing. Some participating companies in the multiple case-study recognised the critical support of information systems to some business processes. However, that critical support was not related to the agility of manufacturing. In fact, the results shown in this chapter did not provide evidence to associate manufacturing agility as a contribution of information systems.

The available literature on agile manufacturing has probably failed to acknowledge the significance of the different enablers involved in the achievement and support of agility. The study further revealed that information systems are not principal enablers in the development of agile manufacturing, but that they should be considered second-order enablers for that purpose. The results of the multiple case study tend to indicate that information systems do not play a significant role in achieving agility, this means moving business processes, specially manufacturing, from a non-agile state to a state of agility or at least a state where significant progress towards agility has been made. The contribution of information systems may be at the later stage of the process, in enhancing agility, once principal enablers have been implemented. The next chapter provides further evidence on the use of IS to enhance agility based on defined business and IT strategies. Also it shows an example of using IS to enhance agility.

It is worth emphasising that the results of this study are applicable to SME's and further work will be required to determine if the same results apply to large manufacturing organisations.

This work confirms information systems as one of the agility enablers referred to in the literature of agile manufacturing. The results of the study show that when a company has agile processes in place, it is easier to identify the contribution of information systems. When the company has no agile processes in place, then, the potential benefits derived from introducing information systems may be open to speculation. Therefore it can be concluded that the introduction of agility in business processes starts with the implementation of the principal enablers identified in this study and is enhanced by the IT-based tools which have been extensively described in the literature of agile manufacturing like virtual enterprises, electronic marketplaces, or e-commerce. Denying any involvement of IS in the enhancement of agility will be equivalent to saying that IT-based tools such as e-commerce have absolutely no role to play within the concept of agility, and that is not true.

Chapter 7

Linking an IT strategy to IS contribution to manufacturing agility.

7.1 Introduction.

The previous chapter showed that the achievement of agility in manufacturing cannot be seen as a contribution of information systems. In participating companies, the move towards agility of business processes depended more on having implemented non-IT related enablers. Moreover, the results proved that the low performance of information systems is not an impediment for the achievement of manufacturing agility. This chapter develops the hypothesis of having an IT strategy aligned to a business strategy to realise benefits from IS and agility in manufacturing. It also investigates skills and expertise of employees to realise benefits from IS as well as to achieve agility in manufacturing.

Over the last two decades, the use of information technology to support the strategic objectives and strategies of business organisations has become quite prevalent (Cash et al. 1992, Luftman et al. 1993). Goldman et al. (1995) stated that strategic information and strategic planning processes have been recognised as critical enablers for the implementation and operation of the agile enterprise. Johnson and Reid (1997) described an information system as strategic if it supports the competitive position of the organisation, therefore providing competitive advantage. Furthermore, the academic literature provides numerous examples of organisations that have applied IT as a means of improving their competitive standing (Senn 1992). In fact, Behrsin et al. (1994) declared that the definition of IT strategies has received special attention during the nineties.

As stated earlier, one of the reasons of the failure to realise benefits from IT is the misalignment between business and IT strategies in the organisation. Therefore, there is a need to align IT to business strategies (Ma et al. 1998, Coleman et al. 1996).

In the concept of agile manufacturing, people's knowledge has a principal role. According to Kidd (1994), an agile enterprise needs highly skilled and knowledgeable people who are flexible, motivated and responsive to change. The researcher showed that the agile enterprise needs new forms of organisation, structures that engender non-hierarchical management styles, and stimulate and support individuals, as well as cooperation and team working. In fact, people skills and expertise have been considered in the internal information systems domain of any IT strategy (Henderson and Venkatraman 1999). The internal domain of an IT strategy defined by Henderson and Venkatraman (1999) says that the acquisition and development of human resources skills, necessary for achieving organisational competencies, is in the same level as the justification of the design and redesign of critical business processes (e.g. product delivery, product development, customer service and total quality). Other researchers have investigated the importance of people related factors in the concept of agility. For example, Zhang and Sharifi (2000) found that practices regarding organisation and people are regarded as effective and important by manufacturers.

7.2 Business and IT strategies in participating companies.

A description of the business strategy and IT strategy defined in each of the companies that participated in the case-study is presented in this section. The results will provide elements to support/refute the alignment of business/IT strategies behind the contribution of information systems to the agility of business processes, especially manufacturing operations.

7.2.1 Company A: Business strategy.

The company stated during the interviews that it is looking to sustain the 20% annual growth experienced in recent years. According to the MD the potential exists to do that, provided there is not major slowdown in the economy which is possible and if the growth pattern in the aerospace sector falls slightly below the line that is predicted to grow.

"We should be able to continue that length of growth. The key to develop agility in the organisation is to be able to produce components in sufficiently low volume that can reduce our WIP in the shop, but also produce components, larger quantities in order to absorb set-up costs associated with manufacturing. The key to agility is to reduce or in fact eliminate these set-up costs of running individual machines".

Actually in the shop floor the company has been implementing aerospace sector initiatives and having more of a Kanban approach to operate the shop.

"The company is still not there but that is the sort of approach more likely to yield results in the longer term".

7.2.2 Company A: Manufacturing strategy.

The current manufacturing strategy defined for the company is as follows:

"At this time the company is investing in flexible manufacturing systems, technically allowing the company to keep a wide-variety of choices permanently set, on a relatively small number of machine tools."

The company is looking to kit parts or individual items in precisely the volume its customers want and which is more appropriate for them.

7.2.3 Company A: IT strategy.

Company *A* revealed during the multiple case-study that it currently does not have a defined IT strategy for the present and future.

"The company is confused about the development of a future IT policy. There is no current policy as such, investments in IT are based on identifying the current needs of the business".

The justification provided by the company says:

"Our customers are sending us pretty confusing messages about what they want, we believe the WEB is the area more likely to coin a strategic change on what the company is doing at the moment".

In fact, the organisation found the design of an IT strategy rather difficult:

"It is very difficult for us to formulate a strategy for IT because we do not know what our customers want to do. If we have a clear idea of what they want, we will be more able to formulate a strategy to support it".

7.2.4 Company A: Metrics and measures to register the contribution of IS.

The company does not use metrics to measure the contribution of information systems. According to the MD of the company:

"It would be possible to trace back the benefits from IS but the company does not have the time and personnel to do that, and probably any attempt to do so would be meaningless".

7.2.5 Company B: Business strategy.

The company is seeking to develop further the range of services provided to its customers. In fact, that is the tendency being experienced in the industry. Also the company admitted that they lack a developed management expertise to go through a fine analysis when it comes to measure overall performance. The business strategy pursued by the company says:

"Keep the same size of the company and grow in terms of turnover and gross profit and look for longevity in the market place".

Also, the company identified the need to improve quality and the need to change as important factors in its business strategy.

7.2.6 Company B: Manufacturing strategy.

Sustain the current level of agility achieved in manufacturing operations, which is, manufacture and deliver bespoke server systems in less than 24 hours.

7.2.7 Company B: IT strategy.

The company enumerated the following factors as part of its IT strategy:

"Use the Internet to find solutions to customer problems, develop or purchase a centralised information system that can support the level of flexibility demanded by the company. Enable suppliers to view what are they supplying and display current stock levels on the Internet".

7.2.8 Company B: Metrics and measures to register the contribution of IS.

The only direct metric the company employs to measure the contribution of information systems is in terms of the time it takes for processing customer orders and the generation of detailed quotations to the customers. The generation of account and management reports and the generation of work orders for manufacturing are seen as a positive contribution of the system to the organisation.

7.2.9 Company C: Business strategy.

The business strategy of the company is focused on maintaining its current competitiveness and on being able to respond to customer requirements. It also covered, having enough flexibility to meet future demands, ensuring the profitability of the company and maintaining the annual growth rate experienced in recent years. In fact, six years ago the turnover of the company was £3 million now it is close to £25 million.

The company highlighted that they are not in a position to influence the industry. Indeed, the company is not a first-tier supplier, not a second-tier supplier either, and they are very remote from influencing customers main decisions.

7.2.10 Company C: Manufacturing strategy.

The company is committed to supporting the flexibility of its manufacturing operations developed over the past two years. Such flexibility has proven to be effective in facing new production schemes introduced in the automotive sector like working hours, bank hours and customised downturns.

7.2.11 Company C: IT strategy.

The IT director and the engineering manager of the company revealed the current IT strategy developed by the company:

> *"The strategy of the company is to migrate to a new IS platform that will link the company to a global organisation and become a member of it in the long term".*

The company had the opportunity to glance into the UK market, looking for suppliers and vendors who can service them. The company has chosen the *SAP* software as its future IS platform. Moreover, for the adoption/acquisition of information systems the company regards customisation as an important issue:

> *"If a company has to fit the ERP system, it simply does not work. Generally speaking you just cannot buy something off-the-shelf. A company has to buy something that can be made bespoke into the organisation".*

During the development of the study interviewees described that investments in information systems are used to improve operations and through operations improve services to the customer. Also, the company has envisaged possible benefits from the use of the *SAP* system:

> *"Minimise waste, stock control and time utilisation to make it more efficient and the company should be more agile".*

7.2.12 Company C: Metrics and measures to register the contribution of IS.

During the study, the company identified monthly reporting accounts as the only tangible way to show the contribution of information systems to the organisation. Furthermore, the company declared having low expertise in the utilisation of metrics to measure the contribution of information systems.

7.2.13 Company D: Business strategy.

Company *D* identified the following factors as key to sustaining the competitiveness of the organisation:

- Maintain our position as supplier of medium-complex parts to the European manufacturing and assembly sites of the parent company.
- Continue its active participation in the Airbus programme.
- Continue supplying spare parts to numerous airlines.

The business strategy of the company contemplated dividing the production site in five completely independent units. Each unit will be responsible for its own total supply chain, procurement of new material and parts to the customer house, meaning total ownership. The company is looking forward to reduce the number of suppliers to the site.

7.2.14 Company D: Manufacturing strategy.

The manufacturing strategy of the company covered: having high volume and high variety production as much as possible in the aerospace sector, kit parts to main customers and investing in new machining equipment to manufacture parts made by other companies with a reduction in costs up to 40%. The company has emphasised the adoption of metrics defined by the UK Lean Aerospace Initiative. The outcome of the manufacturing strategy envisaged for the company was described in the following terms:

"We've got through a year with a 5% decrease costs to our customers, as well 20% increase in volume of sales for the site in the last three years. 20%

year on year sales increase on sales volume, reduction to our customers of 5% year on year".

The company has been growing consistently in recent years:

"Two years ago the turnover was £22 million, last year it was £27 million and for this year it will be £35 million".

7.2.15 Company D: IT strategy.

Company *D* showed a detailed IT strategy envisaged for the present and the future of its operations. The IT strategy was described in the following terms:

"The IT strategy is defined by the design of a portal and the development of the second stage of CINCOM. The portal will give us a complete link from customer to supplier. Companies like Rolls-Royce or Airbus, can see directly into the supply chain, the portal right down to our suppliers. Small suppliers on the demand management, varying capacity products. It is a virtual open book to see the whole supply chain of the business. CINCOM will support manufacturing and financial operations. And our systems will be supported by the IS we have. How we cost, how we self bill".

The company emphasised the importance of information systems to support all its operations and described the priorities of the company in terms of IS:

"We don't do anything without IS. The main thing is the portal and the second stage of CINCOM. It does support the business strategy of the company".

Also the company has spent a lot of resources to create an implementation team for IT projects:

"That's because at the light of our projects we have operations people working hand in hand with IT people and demand management people.

There is no miscommunication between them to what the company tries to achieve, what operations can do and support from IT".

7.2.16 Company D: Metrics and measures to register the contribution of IS.

Further on, company *D* declared its commitment to the use of tools to register the contribution of IS. The company is using a balanced scorecard for that purpose. However, it was observed in this company that the IT function is subordinated to the operations side of the business (e.g. manufacturing):

"Measure of operation, the plan is get metrics for our operations first, that give us the biggest area for improvement, having got that right we want to go into all aspects of the business to measure. That is a goal but we need to get the operations side of the business before we move to the commercial side, IT included, of the business".

The company stated that is tackling the operating aspects of the business before moving to the IT side of it. A number of future dates have been set for this plan:

"Within the next three months every manager within the commercial area will have an improvement plan. Shopfloor, operation area, improvement plan. They've got one. That's what we are concentrated on and then we'll move into the commercial area, IT included. Implement an improvement plan, then we start measure them all".

The company revealed during the study that it has developed a plan for the forthcoming implementation of IS:

"Will be the stage implementation of CINCOM, once it has been implemented we have to evaluate how that has performed. There will be four consultants from CINCOM and four from the company. The total implementation time will take up to six months".

7.2.17 Summary of IT strategy and business strategy.

The results of the multiple case-study have shown that the low performance of information systems in two participating companies, *C* and *D*, was due to the misalignment between what was offered by the system and the needs of the business. In both organisations, manufacturing operations did not receive an adequate support from information systems. However, that condition was not identified as an impediment to moving towards agility in manufacturing operations. Further on, the study revealed that in both companies, the definition of a business strategy and an IT strategy has been contemplated in the acquisition of future information systems. Both companies highlighted that their current information systems, Tetra CS3 and CINCOM, were purchased without any consideration of their manufacturing needs.

A summary of the performance of IS, defined IT strategy and business strategy for the four participating companies is presented in table 7.1

Factors Studied	Company A	Company B	Company C	Company D
Information System	JobShop	Central System	Tetra CS3	CINCOM
Performance of information system	Good	Good	Low	Low
Defined business strategy	YES	YES	YES	YES
Defined IT strategy	NO	YES	YES	YES
Current Information Systems have been implemented as a result of the business and/or IT strategies defined in the company	YES, the application was purchased to meet their immediate needs of capacity planning and scheduling	YES, the application was developed to meet business needs	NO, a new system will be purchased according to the business and IT strategies of the organisation	NO, a new system will be purchased according to the business and IT strategies of the organisation

Table 7.1 IT and business strategies summary.

The results of the case-study showed that the definition and implementation of a sound business strategy is critical for moving towards the agility of business processes, especially manufacturing, as it has been the case of all participating companies. Having a business strategy aligned to an IT strategy ensures that the information system delivers benefits to business processes, although that cannot be considered as a principal condition for moving towards agility.

7.3 People skills and expertise.

According to company *A*, people play an important role in the achievement of agility:

> *"Agile manufacturing requires the enthusiasm of the entire workforce in order to be able to do it. The most difficult part in real life is getting the right attitude from employees".*

As stated earlier, training of employees has been acknowledged as an important enabler in the move towards agility. In the case of company *A*, the utilisation of a new information system required proper training of people. However, the company recognised that it has under-invested in training:

> *"We did not invest in training as we should have done. We made a fundamental mistake, we did too much of the project management internally. Manager knowledge of the business was extremely high but lacked computer knowledge".*

Moreover, the company does not have full-time personnel in the IT department:

> *"What we have is a man that specialises in CNC programming that spends most of his time dealing with aspects of the system network, operation aspects, hold everything together. Another person spends a lot of time managing the system as well".*

The MD declared that this is an area of the company they are going to review because it may be more appropriate to spend more time and money to get the problems solved.

Skills and expertise of people have been associated with the internal domain of information systems. The current performance of the JobShop system has been satisfactory but it has not reached its full potential yet.

Company *B* was the only organisation that was completely satisfied with the performance of its information system. It was developed in-house as a RAD application and it has been running for the last three years. The company highlighted the computer-literacy of its employees. Because the performance of the application has been good and it is the right solution for the right problem, skills and expertise of people did not appear as the principal success factor behind the operation of the Central System. The operation of the system did not require trial-error and learning from past mistakes to make it work for the needs of the organisation.

In companies *C* and *D* who have experienced low performing information systems, people skills and expertise emerged as a major enabler behind the support of information systems to their businesses processes, specially manufacturing operations. In fact, company *C* experienced a low support of IS to its manufacturing operations and company *D* mentioned that they have struggled:

"*Information systems support to manufacturing has been fairly poor*".

In this study, skills and expertise of employees emerged as a principal enabler to achieve agility in manufacturing operations. When it came to supporting manufacturing operations, skills and expertise of employees played a critical role in the use of low performing information systems. This enabler is closely related to the enabler of training of employees, which is also a first-order enabler of agility. Also, this enabler can be related to computer literacy of employees, which is one of the hiring policies of one participating company.

In fact, skills and expertise of employees emerged as a critical enabler in the operation of low performing information systems. Moreover, in these organisations any contribution from the use of information systems to manufacturing was directly associated to skills and expertise of people. However, the same affirmation did not become evident in organisations running information systems with an acceptable performance level. In those companies, skills and expertise of employees remained as a first-phase enabler of agility. Figure 7.1 depicts the impact of employee skills and expertise and its involvement with information systems.

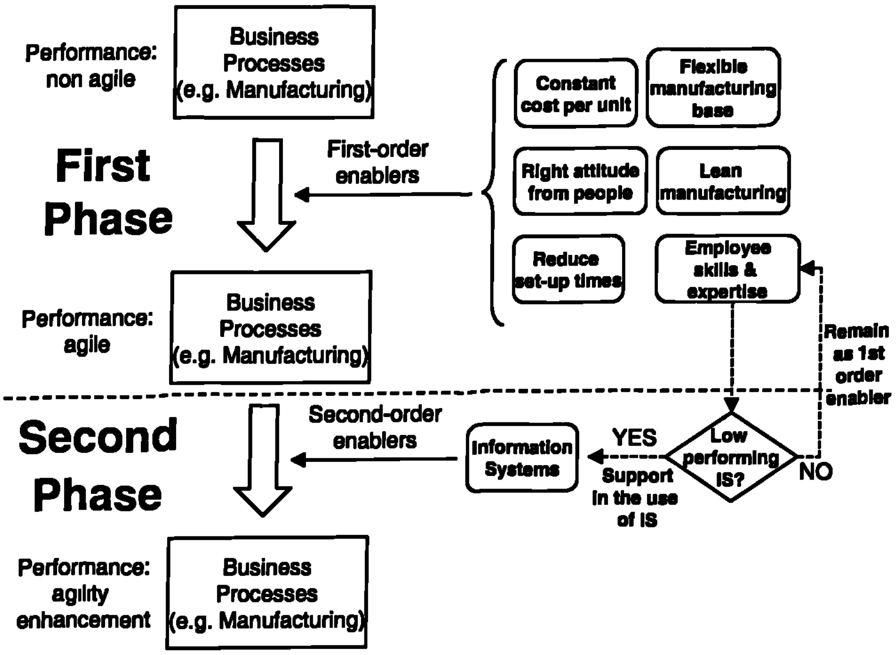

Figure 7.1 Impact of people skills and expertise.

7.3.1 Description of the processes used by people to attain knowledge in the company.

Interviewees in company *C* have expressed their dissatisfaction with the Tetra CS3 system used to support business process. For them, the performance of IS has not been good. They had to work it hard to make things happen with the system. People were investing long sessions with too much effort involved. On the other hand, employees expertise with the system was important to ensure the integrity of data entered into the system, for example, to validate production schedules based on previous numbers. However, mistakes may happen.

People working in company *D* have had to learn from past mistakes. This learning process was due to a system that was incompatible with the needs of the business. The implementation of a series of procedures and the creation of an improvement steering committee ensured that the system can be operated in the right way.

Based on the results of the analysis of the multiple case-study it appeared that organisations with agile manufacturing operations and low performing IS applications have employees that have accumulated enough expertise to operate IS based on trial and error and learning from past mistakes. In companies using information systems performing at an acceptable level, the role of people skills an expertise became less relevant, compared to the first case, in the operation of IS supporting manufacturing operations.

7.4 Differences between information systems and other enablers for agile manufacturing.

During the development of the case-study, the role of information systems among other enablers of manufacturing agility became evident. Information systems are not principal enablers of agility in manufacturing compared to others enablers like skills and expertise of people, having a flexible manufacturing base or training of personnel.

Moving manufacturing operations from non-agile to agile is the main contribution of principal enablers of agility. The results of the study suggest that the performance of manufacturing operations is dependent on the level of development of principal enablers of agility (e.g. shopfloor flexibility, employees skills and expertise) affecting manufacturing operations. This relationship is depicted in figure 7.2.

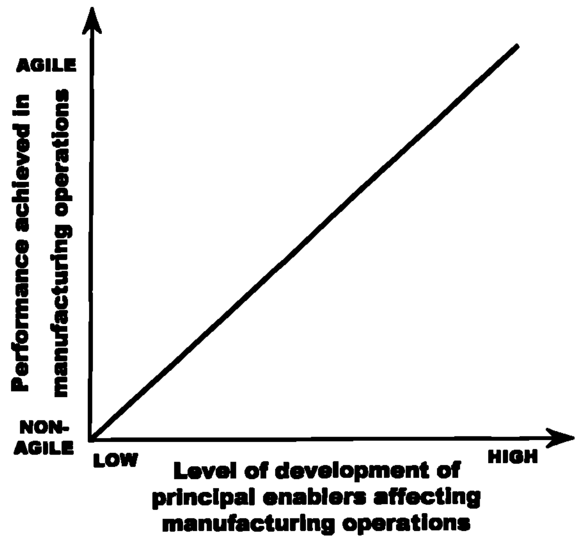

Figure 7.2 Impact of principal enablers on manufacturing operations.

The behaviour of second-order enablers like information systems is different from those identified as principal enablers. The results of the study showed that information systems are not principal enablers when moving towards agility of manufacturing operations. Interviewees stated that information systems are neither the most overwhelming factor, nor the most important part of the equation to become agile.

The results of the multiple case-study enabled the elaboration of the following statements:

- Not enough elements were found to support the assumption of having agile manufacturing operations as a direct contribution from information systems.
- Information technology/information systems might be used to support critical processes, however that does not make a process agile.
- Information systems and IT-based enabling technologies like the virtual enterprise, e-commerce, electronic marketplaces should be considered second-order enablers for agility rather than being considered as principal enablers.
- A high or low support of information systems to manufacturing operations may not have significant influence on the level of agility achieved in those operations.

7.5 Employees skills/expertise and IT/Business strategies.

During the visits to participating companies the misalignment between the needs of the organisation and what was offered by the systems (Henderson and Venkatraman 1999) was identified as the main reason why organisations have low performing information systems. The study revealed that the achievement of a developed level of agility in manufacturing does not require an organisation to be lead by an IT strategy. In fact, none of the participating companies have an IT strategy leading their organisations. In some organisations the development of an IT strategy was considered suitable only after a business strategy has already been implemented. Actually, not having a defined IT strategy was not an impediment to develop agile business processes, especially manufacturing.

Based on the results of the study, an IT-strategy is needed once an organisation has been making progress on the development of the agility of its business processes. The definition of an IT strategy may give the opportunity to enhance the agility of business processes. The next section presents a model that has been envisaged to enhance the agility of manufacturing organisations through the use of an IT strategy.

7.6 IT-strategy leadership to sustain and enhance agility.

The results of the study motivated the development of a path for the achievement of agility, and then enhanced by using an IT strategy. The proposed framework is based on the dominant alignment perspectives proposed by Henderson and Venkatraman (1999) and consists of three main stages. The first one is start developing agile manufacturing processes based on a sound business strategy. The second one consists of having a business strategy supported by an IT strategy. The last one contemplates implementing an IT strategy to lead the company once it has been possible to achieve agile manufacturing processes. Figure 7.3 depicts this framework. The following steps give details of the possibilities of enhancing agility by using an IT strategy.

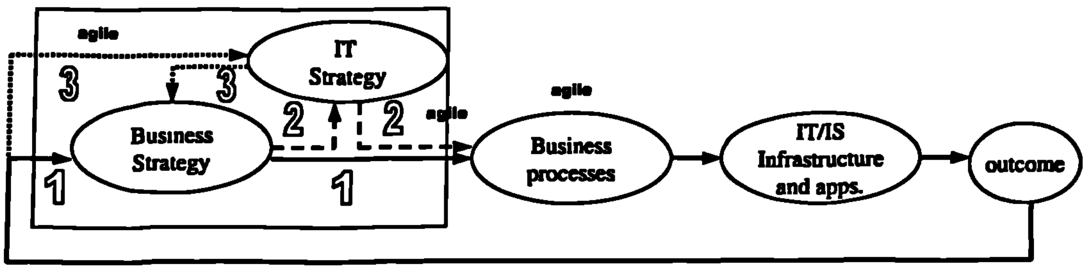

Figure 7.3 Business and IT strategies to ensure the adequate support from IS.

1. *Development of agile processes (e.g. manufacturing) based on a sound business strategy.*

This stage consists of defining a sound business strategy that is the driver of all changes to business processes (e.g manufacturing). Information systems at this stage are required only to support critical operations, IT strategy is absent at this first stage and has no influence in the organisation. The purpose of the business strategy is to start developing the operations side of the company towards the achievement of agility. For example, companies should develop the flexibility in the shopfloor (e.g. reduce of set-up costs, develop a flexible manufacturing base) where applicable.

2. *Definition of an IT strategy to support the business strategy.*

The feedback received from the outcome of the implementation of the business strategy targeting the agility of operations entails the definition of an IT strategy. Updates to the business strategy would involve the definition/utilisation of an IT strategy. An IT strategy is intended to support upgrades to the business strategy after changes have been introduced to business processes. For example, an organisation has finished or has made significant progress in developing flexibility in the shopfloor and it is ready to seek best IT competencies to further develop the business strategy.

3. *Implement an IT strategy to lead the company once it has been possible to achieve agility in business processes (e.g. manufacturing).*

Once it has been possible to achieve agility in the operations side of the business and an IT strategy has been used to make upgrades to the business strategy, the next step is the exploitation of emerging IT capabilities to impact new products and services. This would enable IT to influence the business strategy of the company and develop new forms of relationships (in terms of agile manufacturing this could mean the formation of virtual organisations). An organisation implementing an IT-lead strategy seems to be a sound method to ensuring competitiveness, once a company has achieved agility in manufacturing operations and other business activities. An IT strategy used to influencing the business strategy of the company not only ensures the sustainability of agile manufacturing but also it increases the contribution and support of information systems to the firm. This stage has been envisaged to show that it is possible to have an IT strategy leading a company, enhancing the level of agility in manufacturing and other business processes already achieved in the organisation.

7.7 An example of an organisation suitable for adopting an IT-leadership in the near future.

During the case-study two companies revealed their plans to start in a short period of time the implementation of new information systems. In the particular case of company *D*, plans were in place to upgrade its current MRP system plus the development of a new company portal. In order to move towards agility in manufacturing, the company has been working in the development of a flexible manufacturing base and the implementation of a business strategy that will split the site in five business units. As previously mentioned, the strategy is aimed at achieving ownership of the supply chain, providing better customer service, having better logistics, better planning and scheduling, more flexibility and providing a quicker response to customer needs. In the past months the company has made significant progress in achieving the goals of its business strategy.

Customisation of information systems has been regarded as important for the company. According to them, the main benefits from customisation would be in terms of purchase orders, raw material, reduced documentation and standardisation of information. Also, it will be possible to compress time from the research stage to the manufacturing stage. Another element of the IT strategy is the development of a portal that will enable the company to have an integrated supply chain. The portal will enable suppliers to log into the system and check quantities or check the production schedule. The development of the portal has been rated as vitally important for the future of the organisation. However, above any development in IT, the company regarded having a flexible manufacturing base and skills of personnel as principal enablers for the development of agility in manufacturing.

The development of the situation observed in company *D* is compatible with the future adoption of an IT-lead strategy. In the forthcoming future, once the company has achieved agility in the operations side of the business, especially manufacturing, and an IT strategy has been used to support upgrades to the business strategy of the company, the adoption of an IT-lead strategy will be adequate in sustaining and enhancing the agility achieved. This means for example that relying on the portal will make it possible to respond quicker to customer needs given the flexible manufacturing base already developed in the shopfloor or to expand the current base of customers. Certainly the overall level of agility of the company will be impacted by the introduction of this strategy. Figure 7.4 depicts the strategy scheme proposed for company *D*. The observations registered during the study suggest that company *D* is in stage 2, so the next step will be the use of an IT-strategy to influencing the business strategy of the organisation and to sustain and enhance agility.

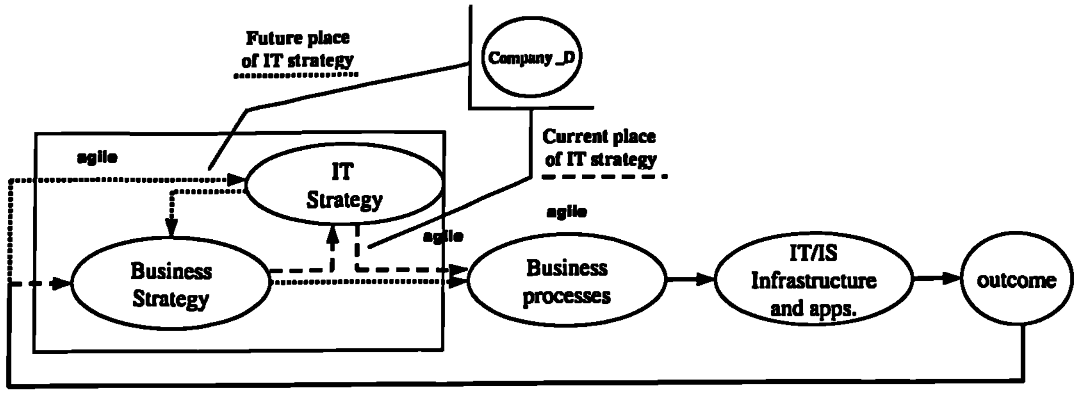

Figure 7.4 Implementation of an IT strategy leading company D.

The approach to the use of information systems presented in this work will ensure that IS deliver benefits through sustaining and enhancing agility. The use of an IT strategy to support upgrades and to influence the company's business strategy is an effective way to ensure benefits, facilitating the evaluation of the contribution of IT. In enhancing agility, information systems are a critical part of the business.

Unfortunately in many manufacturing organisation information technology/information systems are seen more as an expenditure rather than an investment, complicating the elaboration of business plans that may help to identify benefits. Gibbs (2001) provided a series of reasons why it is very difficult to obtain sound evidence that support investing in IT using evaluation models that include TCO (Total Cost of Ownership) and ROI (Return of Investment). According to the researcher, one of the main reasons why models of business processes are out of sync with reality is because IT can have only a broad, simplified idea of what business processes actually involve. Much of this limitation is because computers usually support the business rather than actually being the business. Finally, the author concluded that the key is to analyse the value a potential investment could bring to the organisation: *how does this investment make our business better?*, rather than analysing the price: *and what will this cost us?*

7.8 Comments on answers to research hypotheses.

A synthesis of the results obtained from the multiple case-study is presented in this section. A summary of the answers registered during the development of the multiple case-study is presented in the second half of Appendix E.

7.8.1 Synthesis of results for hypothesis 1.

H1: *The agility in manufacturing, seen as a contribution of Information Systems, is in part dependent on the support received from IS and on IS's condition of being critical, important and key in the support of agility.*

During the development of the multiple case-study participating companies agreed unanimously that manufacturing agility depends more on other factors rather than information systems. In fact, participating companies did not identified IS as the most critical or difficult part of the equation to achieve agility. Indeed, none of the companies denied the importance of IS to support their business processes. The most significant enablers of agility identified during the study include having a flexible manufacturing base (including machine flexibility with reduced set-up times and constant costs per unit), right attitude towards change, commitment to lean operations, training of employees, people's knowledge and skills. During the course of this study it was possible to find examples where lack of adequate operator training has been identified by the companies as an impediment to rapid progress towards agility in manufacturing.

The study revealed that the use of low-performing information systems was not an impediment to the achievement of agility in manufacturing, confirming the results that suggest that IS are not principal enablers of agility.

Structured questions enabled the identification of benefits of information systems in manufacturing operations. The analysis of the results showed areas which are not receiving adequate support from IS. Also, it enabled the prioritisation of IS benefits to manufacturing according to the conditions of the business environment being faced by the companies and the type of manufacturing systems currently being used.

The study revealed that characteristics of IS are closely associated to the characteristics of the manufacturing site, for example, low scores were given to capability for multi-site, data rationalisation and greater security in organisations with only one production site.

Participating companies recognised having poor metrics to measure the benefits of IS. There was consensus among them on the difficulty of measuring the contribution of IS.

Several discrepancies involving the use of IS were identified in terms of *achievement of competitive advantage*, *tasks that could not be done before*, *applications seen as a distinctive proprietary advantage* and *IS seen to maintain competitive position*. Some companies did not consider those issues as important in a business environment in constant change. Also discrepancies covered the dilemma of the standardisation-customisation of information systems in the four companies. The extensive IT-associated benefits listed in the academic literature contrasted with the results of the study that showed IS relegated to second-order enablers. Indeed, the study did not provide enough evidence to support IS position as central, critical, important and key for the achievement of manufacturing agility.

7.8.2 Synthesis of results for hypothesis 2.

The second hypothesis proposed for this research involved the alignment of IT and business strategies to determine the impact of IS in terms of agility.

H2: *IT-business strategy alignment determines the impact information systems may have on the agility in manufacturing.*

The results of the multiple case-study showed that in two participating companies the misalignment between business needs and the capabilities of the systems were to blame for the low performance experienced with IS. In those companies, the misalignment between business and IT strategies was a major factor behind the failure to realise benefits from IS in manufacturing operations. However, it happened that such misalignment was not an impediment to the development of agility in manufacturing. The multiple case-study showed that the achievement of manufacturing agility in an organisation requires the design and implementation of a sound business strategy targeting agility in business processes.

This work has shown that the implementation of an IT-lead strategy for an organisation is compatible with the concept of agile manufacturing only when agility has been achieved in business processes. The implementation of an IT-lead strategy in the absence of agile processes undermines the agility-enhancement capacity of information systems. Having an IT-lead strategy in the company, once agility is present in business processes (e.g. manufacturing operations), ensures the condition of IS as enhancement agents of agility and not of first-order enablers of agility.

7.8.3 Synthesis of results for hypothesis 3.

The following hypothesis was elaborated with the purpose of identifying the impact of an enabler of agility such as skills and expertise of employees has on information systems and how such impact determines the contribution of IS to manufacturing agility.

H3: *Information systems contribution to agility in manufacturing is dependent on the skills and expertise of employees.*

During the multiple case-study, skills and expertise of employees emerged as a major factor enabling the utilisation of low performing IS applications. In fact, it was the experience accumulated from past mistakes that enabled the companies to run their businesses in such a way that the low performance of information systems would not undermine the performance of manufacturing operations.

One factor identified by participating companies and related to the third hypothesis is training of personnel in the use of IS applications. Organisations regarded this factor as critical in realising benefits from IS.

The results obtained from the study showed that personnel skills and expertise is an agility enabler associated to the operation of information systems. If the performance of the IS in question is low, people expertise and skills would emerge as a critical factor to overcome such a problem. However the downside to this approach is the long learning curve associated with mastering the system and the costs and time involved in fixing mistakes.

7.9 Comments and remarks.

The absence of a specific IT strategy was not an impediment to experiencing benefits from the use of information systems (case of company *A*) nor to developing agility in manufacturing (the same case for company *A*). The study revealed that manufacturing organisations can be agile without having an IT strategy influencing their own business strategy. In fact, based on the results of the study, the use of an IT strategy to influencing the business strategy of an organisation cannot be considered as the first stage of the pathway towards agility. On the other hand the study highlighted the importance of non-technical and non-IT related enablers, such as skills and expertise of employees, need to change, attitude of employees towards change and having a flexible manufacturing base among others.

Skills and expertise of people emerged as an important factor behind the achievement of agility in participating companies and also important behind the operation of information systems. Skills and expertise of people were identified as critical factors in companies experiencing low performing IS.

During the multiple case-study, the participation of the four companies enabled the definition of a framework that involves the use of IS to enhance the agility of business processes. The proposed use of a business strategy followed by an IT strategy revealed the possibility of using a methodology that makes the enhancement of agility compatible with the use of IT. An organisation can be lead by an IT strategy once it has developed agility in its business processes, in this study it was manufacturing operations.

Certainly, the use of an IT strategy to influencing the business strategy of a company that has developed agility in its manufacturing operations is compatible with the emphasis put in the literature of agile manufacturing regarding the use of information technology. In the organisation, the use of an IT strategy defining a business strategy means that acquired IT capabilities may impact new services and products and at the same time lead the business strategy of the company.

Chapter 8

Conclusions and Recommendations

This work has enabled the identification of the role of information systems within the concept of agile manufacturing. In fact, two major factors identified in the academic literature support the relevance of this study. First, the high profile given to information systems within the concept of agile manufacturing. Second, the difficulty in identifying benefits of information systems in business processes, especially in manufacturing operations. A sound research methodology was designed to gather and analyse the data required to determine manufacturing agility as a contribution of information systems.

Several steps were taken to achieve the objectives of this work. The first stage of this research involved an extensive literature review in the fields of agile manufacturing and information systems evaluation. The review of the existing literature on agile manufacturing showed a significant number of works which regard information systems as a principal enabler of agility. The literature on information systems evaluation showed the work of numerous researchers who have documented the failure of IT/IS to deliver expected benefits and the difficulties that exist in identifying such benefits when they occur. This conscious review of the literature enabled the definition of three research hypotheses with the purpose of identifying the agility of manufacturing, as a contribution of information systems as well as identifying other factors affecting such contribution. The first year of the Ph.D. work was entirely dedicated to the review of the current academic literature, the definition of research objectives and research hypotheses and the design of a suitable research methodology. Some analytical methods to evaluate information systems using AHP and other techniques were developed during the first year of activities.

The accomplishment of the first stage was followed by the development of a survey research. The second stage of the research covered the design of a questionnaire that underwent a pilot test. Received comments were taken on board and were implemented before wider circulation to a thousand companies from the aerospace, automotive and electronics-computer-semiconductor sectors. The development of the survey involved different stages, from designing the questionnaire and getting the names and addresses of surveyed companies to the statistical analysis of all responses received. The survey enabled the identification of three major factors underlying seven IT/IS proficiency characteristics of agility, as prioritised by surveyed companies. According to the Agility Forum, those characteristics represent the interactive relationships among individual units of information automation equipment and software. It is important to remind the reader that the agility of the companies that answered the questionnaire was not an objective of the survey. The survey served to prioritise IT/IS characteristics as they were perceived by companies in dynamic business sectors and not to identify if a company was agile or not.

The identification of information systems contribution to the agility of business processes in manufacturing organisations required the accomplishment of a multiple case-study during a time period of ten months. The multiple case-study represents the third major stage of this research. The outcome of this stage was fundamental to answering the research hypotheses generated during the literature review. The multiple case-study enabled gathering data from participating companies; data that would not be possible to collect through a survey research. Final comments on each of the research stages of this work are provided in the following sections.

8.1 Development of survey research.

The accomplishment of the survey research was more difficult than was originally expected. In this research, a thousand questionnaires were sent to manufacturing organisations from the aerospace, automotive and electronics-computer-semiconductor sectors. The names and addresses of those companies were gathered from industrial directories like Kompass, Kellys and UK Trade, 1999-2000 versions. It took several months to complete this stage. In fact, from the time the questionnaires were mailed to the companies to the time the last questionnaires were received it was a period of more than six months. Also, the response rate of questionnaires received was quite disappointing. The criteria used to endorse the number of answered questionnaires required for the analysis was based on the number of variables defined in the questionnaire. The application of statistical tests like t-test, Cronbach's Alpha and Factor Analysis was adequate for the number of responses received. Control indices like Kaiser-Meyer-Olkin and Bartlett's test of sphericity validated the results of tests like Factor Analysis.

Three main tasks were done by the respondents during the development of the survey:

- Prioritisation of three characteristics of a dynamic business environment widely covered in the literature of agile manufacturing,
- Identification of the type of information systems applications found in surveyed companies based on the evolution of IS in manufacturing,
- Prioritisation of seven IT/IS proficiency characteristics of agile manufacturing identified by the Agility Forum.

The results of the statistical analysis showed no association between the three characteristics of a dynamic business environment contemplated in this study and the seven IT/IS proficiency characteristics of agility identified in the literature. The analysis suggested that IT/IS proficiency characteristics of agility are independent from the influence of a dynamic business environment.

Also, the results of the statistical analysis revealed that the IT/IS proficiency characteristics of agility covered in this study are not associated with the use of a specific type of IS. These results suggested that the IT/IS characteristics of agility prioritised by participating companies do not belong to a specific type of information system.

Perhaps, one of the most interesting results of the analysis was the identification of three main factors underlying the IT/IS proficiency characteristics of agility. Factor analysis was a powerful tool to identify the main predictors loading the eigenvalues of the three factors detected. These results highlighted the relevance of *correction*, *augmentation* and *migration* characteristics to surveyed companies. Also, the results highlighted the significance of IT/IS infrastructure in prioritised IT/IS proficiency characteristics.

The statistical tests used for the analysis of the questionnaires received, answered the propositions associated with the survey. The results of the survey were expanded in a multiple case-study.

8.2 Development of multiple case-study.

During the development of the multiple case-study, participating companies agreed on the importance of agility in the future of their organisations. Emphasis was put on the development of agility of their manufacturing operations, specially having a flexible manufacturing base. However, in the study information systems did not emerge as the driving force behind the change towards agility. In fact, in two participating companies the performance of information systems support to manufacturing operations was described by them as poor.

The study revealed serious discrepancies regarding the benefits each company expects from information systems. That meant, companies giving high ratings and others giving low ratings to the same benefits in question. Identified factors that showed such differences include:

- Information systems delivery of competitive advantage.
- Information systems seen to maintain competitive position.
- Information systems seen as a distinct proprietary advantage.
- Investments in information systems seen to increase revenue through new business processes.

Also companies showed differences in their approach to the use of information systems. Some organisations believe that COTS applications should be customised and not used as standard. Others say that COTS applications should be standard and not customised to the processes of the organisation.

The study enabled the identification of a series of information systems-related factors which did not impede the achievement of agility in manufacturing. These were:

- The use of complex or simple information systems does not affect the development of agility in manufacturing.
- Low information systems support to manufacturing operations is not an impediment to the development of manufacturing agility.
- Low performance of information systems is not an impediment to the achievement of agility in manufacturing.
- The lack of metrics to register the contribution of information systems is not an impediment to developing agility in the firm.

The companies that participated in the study revealed that their primary efforts were concentrated on the operations side of the business with manufacturing operations among their priorities. Information systems were not considered in those primary efforts. Interviewees recognised that information systems are not the most important or most difficult part of the equation to become agile. Therefore, information systems have been catalogued as second-order enablers of agility.

8.3 The development of an IT strategy matching the needs of manufacturing organisations.

During the multiple-case study, skills and expertise of people emerged as a principal enabler of manufacturing agility. Also, the importance of this enabler became evident in companies using low performing information systems. In those organisations, skills and expertise of employees were used to overcome the shortcomings of IS. The study showed that the operation of low performing information systems was completely dependent on the skills and expertise of employees. Manufacturing agility is dependent on this enabler.

The information systems academic literature has identified the lack of alignment between business strategies and IT strategies, as being in part responsible for the failure to realise benefits from information systems investments. The results of the study showed that in two companies, the incompatibility between the needs of the organisation and the capabilities of information systems was the main reason for not realising benefits in manufacturing operations and for having low performing IS.

The analysis of the multiple case-study showed that organisations do not require the use of an IT strategy to develop manufacturing agility. Any use of information systems should be in terms of enhancing the agility of business processes and not as means to achieve it.

Based on the results of the study, a three-step framework has been proposed to enhance agility through the adoption of an IT-led strategy. The first step of this framework begins with introducing changes to business processes, in particular manufacturing operations, to make them agile. In the first step no IT strategy has been defined, and it is not an issue of concern. Here, information systems are used to support those business processes where IT is inherent to their operation (i.e. inventory transactions). The second step of this framework covers the development of an IT strategy to support a sound business strategy committed to agility. Finally, the third step involves having an IT strategy influencing the business strategy of the organisation. This is done with the sole purpose of enhancing the agility of business processes and not as means to achieve agility.

8.4 The role of IS within agile manufacturing.

Manufacturing organisations have recognised the relevance of information systems in supporting their businesses. Information systems are not critical for the achievement of agile manufacturing, although they may be required to support it, but certainly information systems are not among those enablers used in achieving agility in manufacturing operations.

Based on the results of the multiple case-study, it has been possible to identify that manufacturing agility is not a direct contribution of information systems. Also, information systems are not principal enablers of agility. This study classified IS as second-order enablers. Because information systems are used to enhance agility and not as means to achieve it, these should be considered "enhancing agents" of agile manufacturing. E-commerce, virtual enterprises, electronic market places, and other IT-based tools should be re-named as second-order enablers or enhancement agents of agility. During the case-study, one company with agile manufacturing operations regarded information systems as not important in achieving manufacturing agility.

The results of the multiple case-study linked to the findings of the research survey are presented in figure 8.1. This diagram summarises the highlights of this work.

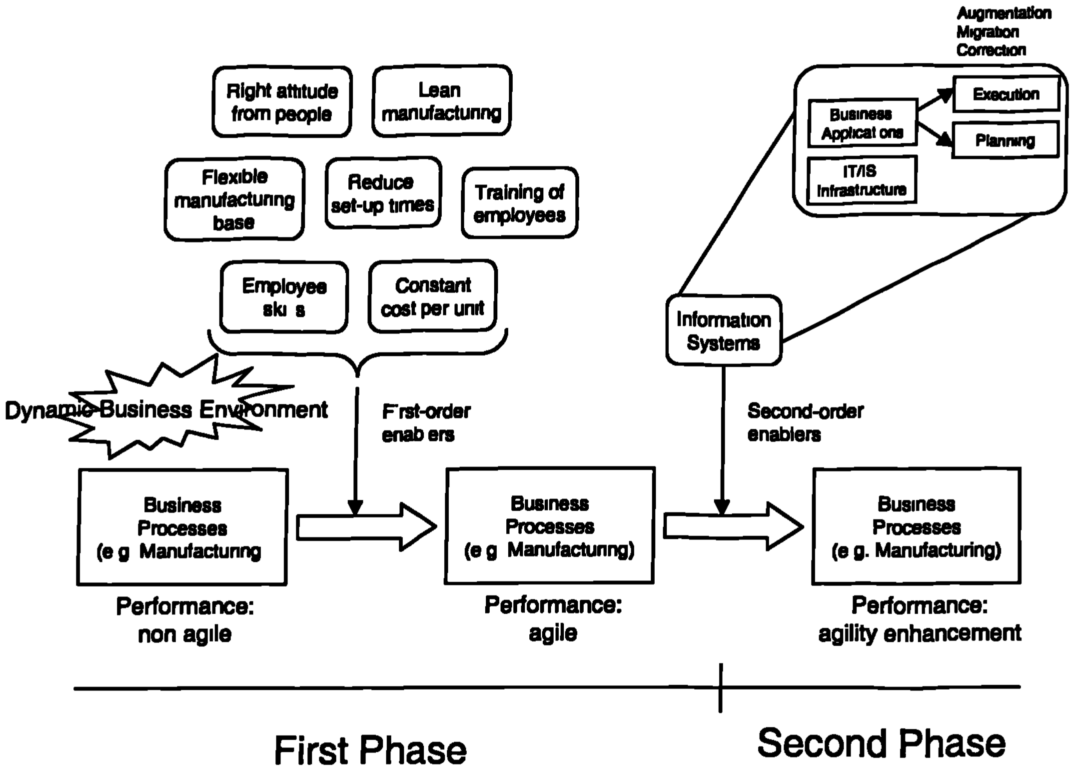

Figure 8.1 Summary of findings of the study.

8.5 Contribution to knowledge.

The results of this study have been useful in clarifying many labels given by the academic literature on agile manufacturing to information systems. Some of these labels include being: critical, key, important, essential and contributor to responsiveness. In fact, the results of this work show that it is difficult to justify the use of the above labels to information systems because the achievement of agility in manufacturing operations cannot be considered as a direct contribution of IS. Indeed, IS are second-order enablers of agility. The real contribution of information systems to manufacturing organisations is in enhancing the agility already achieved in business processes, particularly manufacturing operations. Furthermore, the findings of this study have challenged the agile manufacturing frameworks and methodologies that consider information systems as principal enablers of manufacturing agility.

Practitioners and researchers would be able to develop agility initiatives for manufacturing organisations based in the taxonomy of enablers presented in this work. This would allow organisations to prioritise resources to those enablers considered to be critical when moving a manufacturing organisation from non-agile to agile. Moreover, the identification of principal and secondary enablers is a new arrangement not previously available in the literature on agile manufacturing.

The contribution of this work to alleviating the difficulty of identifying benefits of information systems is that future evaluation schemes of IT/IS in manufacturing organisations would be focused on determining information systems capability of enhancing agility already achieved in business processes.

Also, this work has highlighted the importance of IT/IS infrastructure within the IT/IS proficiency characteristics identified by the Agility Forum. Furthermore, the statistical analysis of the survey identified three main factors underlying the IT/IS proficiency characteristics of agility as they were rated by organisations working in dynamic business environments. The results of the survey research would serve either as guidelines for the adequate management of IT in manufacturing organisations or in the definition of IT/IS requirements that meet the needs of manufacturing organisations moving towards agility.

The results of this work have been useful in clarifying the involvement of business and IT strategies within the concept of agile manufacturing. Indeed, the adoption of an IT strategy influencing the business strategy of an organisation was proposed as a feasible way of enhancing the agility of business processes. The misalignment between the needs of the organisation and what was offered by IS (misalignment between business and IT strategies) was found to be the main cause for low performing IS. However, in a manufacturing organisation the use of an IT strategy to influencing the business strategy is not a suitable way of achieving agility in manufacturing.

The findings of this work have highlighted the condition of skills and expertise of employees as a principal enabler of agility, not only on the shopfloor to achieve manufacturing agility but also in the daily use of information systems. Indeed, the results have shown skills and expertise of employees as an agility enabler with a "double-function" capability. This means complying to the requirements of principal enablers used in achieving agility in manufacturing and then, when required, supporting the use of low-performing information systems.

Also, the study has provided some grounds to question the feasibility of information systems developed exclusively for agile manufacturing. A number of cases presented in the academic literature include Internet based IS integrated to heterogeneous legacy systems. On the other hand, these systems have ultimately failed to evaluate the physical conditions on the shopfloor, the impact of IS on physical systems and the interaction with other enablers of agility such as skills of employees. The results of the study suggest that such prototype systems may be of little-value in real-world conditions.

Finally, the study has confirmed that despite being a concept that makes use of state of the art technology, agility will remain dependent on non-technology based enablers such as training of employees or employees skills and expertise.

8.6 Future work and recommendations.

The results of the study should encourage the development of new frameworks for the assessment of the contribution of information systems based on the role of IS presented in the findings of this work. Further work will be required to determine if the results of the study of SME's are replicated in large manufacturing organisations. Future research in the area should focus on studying if standard COTS (commercial of the shelf) applications are well suited to support and enhance the agility of business processes contemplated in the business strategy of a company. During the study it was possible to identify one company that used a standard COTS information system, no customisation was considered and implemented. After an assessment process, the company determined that the information system under consideration was adequate to meet the requirements of organisations in the aerospace industry. The system has standard procedures, and the company assumed that those procedures are best-fit for them.

A list of tasks that could be considered in future research works, based on the results of the study, include the investigation of:

- Level of customisation of COTS applications in organisations that have reached agility in manufacturing.
- Impact of e-commerce applications to support and enhance agility of business processes in manufacturing enterprises.
- Impact of Supply Chain Management and company portals to support and enhance agility of business processes in manufacturing enterprises.
- Register the improvements of implementing an IT-lead strategy to enhance the agility of business processes.
- Determine the immediate impact of the introduction of an IT strategy in a company which has developed agility in manufacturing.
- Generate a sound policy where IS investments are used to increase revenue through new agile business processes and not just new business processes.

The future accomplishment of more multiple case-study, extensive research surveys and the consolidation of partnerships between academia and industry will provide the resources to develop the above tasks.

Also, the results of the multiple case-study put a question mark on concepts that have been conceived to support the development of agile manufacturing like the virtual enterprise. Because information systems were identified as second-order enablers of agility and the virtual enterprise is an IT-based agility enabler, therefore it cannot be considered as means to achieve agility, it will only enhance it.

A crucial test for the concept of agile manufacturing will come during the next few years. Agile manufacturing was coined during the first years of the economic expansion of the US economy which lasted for ten years. Many companies saw their profits increase substantially and IT investment and utilisation grew to levels never seen before. This situation stimulated the creation of thousands of software vendors who provided specific applications to assist manufacturing organisations in all their business activities. Such systems included: ERP (enterprise resource planning), b2b and b2c (business to business and business to customer), Internet based e-commerce, CRM (customer relationship management), Electronic Marketplaces, SCM (supply chain management), among others. Economic difficulties will reduce the total amount invested in IT and perhaps limiting the expansion and adoption of systems like those listed here. Nevertheless, the constant adoption of new technologies such as e-commerce applications (e.g. company portals) by manufacturing organisations will provide new paths of research in the fields of information systems and agile manufacturing.

Further studies in the field may include investigating how agile manufacturing organisations survive and prosper during periods of economic slowdown, even recession. Also, researchers should investigate the future of the concept of agile manufacturing.

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APPENDIX A

Analytical methods for the evaluation of information systems contribution.

A.1 Building an analytical assessment framework in terms of agility.

The framework presented in this appendix is an example of analytical methods used in assessment and selection processes. This section shows a self-assessment framework designed for intangible factors associated to the concept of agile manufacturing. Indeed, the proposed framework captures the perception of industrialists on four principal dimensions: *agility*, *information systems*, *agility attributes* and *competitive bases*. The concept of *agility* is based on the definition provided by Goldman et al. (1995); *information systems* are defined as the set of applications that gather individuals and information flow on information technology based devices and infrastructure; *agility attributes* are defined as those good practices that characterise the operation of agile organisations; and *competitive bases* are defined as sources of competitive advantage. The above elements have been considered in the works of Gunasekaran (1999) and Yusuf et al. (1999).

Figure A.1 depicts the proposed arrangement of the four principal dimensions considered in the self-assessment framework. Indeed, the dimensions of *IS*, *agility*, and *agility attributes* are used to shape the dimension of *competitive bases*.

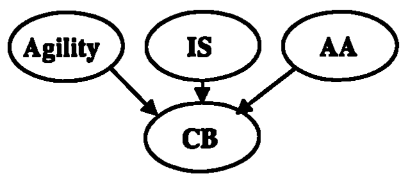


Figure A.1 Competitive bases, agility, information systems and attributes.

Six competitive bases that include speed, proactivity, quality, cost, innovation and flexibility, have been considered in the development of this framework. These six competitive bases were taken from the work on agility developed by Yusuf et al. (1999). A brief description of these competitive bases is provided next:

- Speed: concept-to-cash time or the time it takes to respond to perceived customer needs.

- Flexibility: the ability to adapt to variable customer requirements.
- Innovation: successful exploration of new ideas for products, services and procedures.
- Proactivity: the ability to influence and predict market trends.
- Quality: products and services that satisfy customer expectations over their life-times.
- Cost: the expense of resources required to produce goods or services to satisfy a market need which is lower than those of the competition.

Furthermore, the proposed framework makes use of 32 attributes of agility identified by Yusuf et al. (1999). The self-assessment framework required the use of five groupings for the manipulation of the thirty-two attributes of agility. The created groupings are compatible with the decision domains proposed by Yusuf et al. (1999) and these include: organisation commitment to integration and co-operation, *A1*; culture of quality and responsiveness, *A2*; state of technology to enhance flexibility and operations performance, *A3*; organisation commitment towards change, *A4*; and education and welfare of human resources, *A5*. Table A.1 presents the thirty–two attributes associated to the five created groupings.

Organisation commitment to integration and cooperation - A1
Multi venturing capabilities - A11
Encouragement of teaming with other companies – A12
Rapid formation of partnerships – A13
Strategic customer relationships – A14
Close supplier relationships – A15
Trust based customer and supplier relationships – A16
Enterprise integration – A17
Cross-functional teaming – A18
Concurrent execution of business activities – A19

Culture of quality and responsiveness – A2
Quality over product life – A21
Addition of value to products –A22
First time right designs – A23
Satisfaction of customer requirements – A24
Rapid development cycles – A25
Rapid response to changing market requirements – A26
Frequent new product innovation – A27
Customer-driven innovations – A28

State of technology to enhance flexibility and operations performance – A3
Technology awareness – A31
Leader in the use of current technology – A32
Using skill and knowledge enhancing technologies – A33
Use flexible production technology – A34
Open information environment – A35

Organisation commitment towards change – A4
Continuous improvement – A41
Embracing a culture of change – A42
Descentralisation of authority – A43
Learning organisation – A44
Bespoke business practice and structure – A45

Education and welfare of human resources – A5
Employee satisfaction – A51
Multi-skilled and flexible workforce – A52
Continuous training and development for Personnel – A53
Workforce skill upgrade – A54
Workforce empowerment – A55

Table A.1 Agility attributes and five groupings

The proposed self-assessment scheme can be defined as a general function for agility, as show in (1).

$$CB = f_{CB}\left(\sum_{i=1}^{n} A_{1n} + \sum_{i=1}^{n} A_{2n} + \sum_{i=1}^{n} A_{3n} + \sum_{i=1}^{n} A_{4n} + \sum_{i=1}^{n} A_{5n} \right) \qquad (1)$$

Where $\sum_{i=1}^{n} A_{1n}$ is the sum of all the significant coefficients of the attributes identified for that competitive basis in grouping A1 , and so on for A2, A3, A4 and A5. CB is any of the six competitive bases that have been defined in this model; S_{CB} –Speed-, F_{CB} –Flexibility-, P_{CB} –Proactivity-, I_{CB} –Innovation-, Q_{CB} –Quality- and C_{CB} –Cost-. The idea behind this approach is in identifying a value associating competitive bases with the concepts of agility and information systems. The coefficients are based on the perception of the person doing the self-assessment, normally a managing director or production manager using a five-point Likert scale. In fact, by calculating a number, it would be possible to determine the most important competitive basis in a specific organisation. A detailed explanation on the proposed framework is provided in the next paragraph.

The nature of the factors introduced in this section is of an intangible nature, so it is very difficult to define a specific measure for them. Moreover, the definition of an agility function for competitive bases and agility attributes using conventional methods is impossible. The best way to define a function that includes the association between the competitive bases, agility attributes and information systems is one that gives them ratings. Indeed, rating attributes is fuzzy by nature. Thus based on the fuzzy logic theory, a membership function for agility is one that takes values from 0 to 1 with an associated scale of grades. The scale of grades is used to simplify operations and it is similar to others used in methodologies for the evaluation of intangible factors. The proposed scale for this framework is shown in figure A.2 and it is used to prioritise the thirty-two attributes for agility shown in table A.1. The fuzzy language values used to derive their corresponding fuzzy numbers are presented in table A.2.

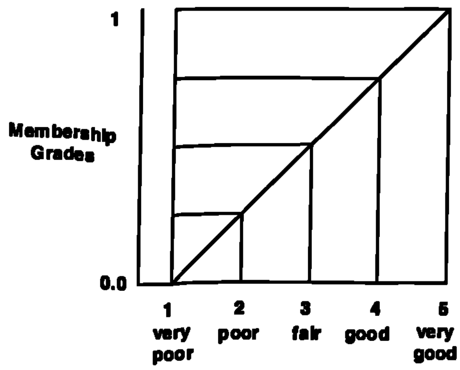


Figure A.2 Agility assessment curve.

Linguistic values	Mean of fuzzy numbers
Completely Disagree (very poor)	0
Disagree (poor)	0.25
Fair	0.5
Agree (good)	0.75
Completely Agree (very good)	1

Table A.2 Linguistic Values References.

The use of figure A.2 and table A.2 is in complete agreement with the theory of fuzzy logic where a fuzzy set is a number defined as $\mu_A(X) \in [0,1]$. Using the values presented in table A.2, it is possible to construct an evaluation matrix to identify the most important competitive bases. To facilitate this operation, a model developed by Cheng et al (1999) has been adopted. Cheng's model eliminated the utilisation of a scale of values that range from 1 to 9 using traditional AHP (Saaty 1980) or the utilisation of fuzzy numbers in complex matrices (Zhu et al. 1999). Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. A number of different methods employing fuzzy sets have been proposed by different authors to assist people during selection processes (Machacha and Bhattacharya 2000, Bandemer and Gottwald 1996, Gupta and Nagi 1995, Kartalopoulos 1996). In this work a group of companies were asked to prioritise the importance of competitive bases to information systems and the concept of agility. Furthermore, the companies were asked to prioritise the importance of each agile attribute in terms of competitive bases. The use of the above approach would enable the identification of the most significant competitive basis according to the self-assessment made by managing directors and production managers of surveyed companies.

In the evaluation matrix shown in table A.3, S denotes the competitive bases under assessment, X_j denotes the criteria with which scores are given (agility, information systems and agility attributes groupings, A1, A2, A3, A4 and A5) and X_{ij} denotes the score of element S_i with respect to criteria X_j.

$$\begin{array}{c} S_1 \\ \vdots \\ S_i \\ \vdots \\ S_m \end{array} \begin{pmatrix} X_1 & & X_j & & X_n \\ X_{11}/t_1 & \cdots & X_{1j}/t_j & \cdots & X_{1n}/t_n \\ \vdots & & \vdots & & \vdots \\ X_{i1}/t_1 & \cdots & X_{ij}/t_j & \cdots & X_{in}/t_n \\ \vdots & & \vdots & & \vdots \\ X_{m1}/t_1 & \cdots & X_{mj}/t_j & \cdots & X_{mn}/t_n \end{pmatrix}$$

$$= \begin{pmatrix} \mu_1(X_1) & \cdots & \mu_1(X_1) & \cdots & \mu_1(X_n) \\ \vdots & & \vdots & & \vdots \\ \mu_i(X_1) & \cdots & \mu_i(X_j) & \cdots & \mu_i(X_n) \\ \vdots & & \vdots & & \vdots \\ \mu_m(X_1) & \cdots & \mu_m(X_j) & \cdots & \mu_m(X_n) \end{pmatrix}$$

Table A.3 Evaluation matrix.

Once this is done, all total scores are normalised for every element of the criteria. Then a power of dilation/concentration is applied depending on the importance of each element. The power of dilation is determined by a linguistic hedge or modifier; an operation that modifies the meaning of a term, fuzzy set. Power of dilation is shown in (2) and power of concentration in (3).

$\mu\text{con}(u) = (\mu A(u))^n$; where $n > 1$ (2)

$\mu\text{dil}(u) = (\mu A(u))^{1/n}$, where $n > 1$ (3)

After applying the power of dilation/concentration the most important competitive basis is determined by maximising the minimum membership value over all the elements of the criteria using (4).

$\mu_A(xi) = \max_i(\min_j \mu_{ij})$ (4)

This approach would enable the identification of the most important competitive basis in a specific manufacturing organisation. A numerical example of this method using the answers given by a leading aerospace organisation, currently working with an ERP system, identified the most significant competitive bases for the company in terms of agility, information systems and attributes for agility. In this case the person doing the assessment identified the following values:

Agility

S_{CB}	F_{CB}	I_{CB}	P_{CB}	Q_{CB}	C_{CB}
0.5	0.75	0.75	0.5	0.75	0.75

Information Systems

S_{CB}	F_{CB}	I_{CB}	P_{CB}	Q_{CB}	C_{CB}
0.75	0.25	0.5	0.25	0.25	0

The complete evaluation matrix, including the values of the groupings of agility attributes, for the aerospace company is shown in table A.4.

CB	Agility	IS	A1	A2	A3	A4	A5
Speed	0 5	0 75	4.75	4.0	2.5	1.75	2.5
Flexibility	0.75	0 25	4 0	3.5	1.5	2.5	2.5
Innovation	0.75	0 5	4 5	4.5	2.75	2.5	3.5
Proactivity	0 5	0 25	5 5	4 0	3.25	3.25	2.5
Quality	0 75	0 25	4 0	3 5	2.75	2	2
Cost	0 75	0	4 5	3.75	4.25	2.25	2.25

Table A.4 Aerospace company matrix.

The normalised matrix is shown in table A.5. In this example, agility and information systems are recognised as very important and given a power of concentration of 1.5, as recommended by Cheng et al. (1999). The resultant matrix is shown in table A.6.

CB	Agility	IS	A1	A2	A3	A4	A5
Speed	0 125	0 375	0 174	0 107	0.147	0.122	0.163
Flexibility	0 187	0 125	0 146	0 150	0.088	0.175	0.163
Innovation	0 187	0 25	0 165	0 198	0 161	0.175	0.229
Proactivity	0 125	0 125	0 201	0.172	0 191	0 228	0.163
Quality	0 187	0 125	0 146	0.150	0.161	0.140	0.131
Cost	0.187	0	0 165	0 161	0.25	0.157	0.147

Table A.5 Aerospace company normalised matrix.

CB	Agility	IS	A1	A2	A3	A4	A5
Speed	0 044	0 185	0 174	0.107	0.147	0.122	0.163
Flexibility	0 080	0 044	0.146	0 150	0.088	0.175	0.163
Innovation	0 080	0 125	0.165	0.198	0.161	0.175	0.229
Proactivity	0 044	0 044	0.201	0.172	0.191	0.228	0.163
Quality	0 080	0 044	0.146	0.150	0.161	0.140	0.131
Cost	0.080	0	0.165	0 161	0.25	0.157	0.147

Table A.6 Aerospace company matrix after applying power of concentration.

Based on the results shown in the tables, innovation is the most significant competitive basis behind the operation of information systems and agility from the point of view of the participating aerospace company. The maximum value registered for the minimum of each competitive basis is for innovation with 0.080. Its corresponding maximum value is 0.229. These results can be used later to benchmark companies in the same industry.

The coefficients calculated using this approach can be labelled as agility indices for competitive bases matching the requirements of agility, information systems and agility attributes of a particular manufacturing organisation. The adoption of the scheme introduced in this work can be used to make better decisions regarding information systems and to improve the overall performance of the company.

APPENDIX B

Survey Research Questionnaire

AGILE MANUFACTURING AND INFORMATION SYSTEMS QUESTIONNAIRE
BRUNEL UNIVERSITY- DEPARTMENT OF SYSTEMS ENGINEERING

Please answer the following questions with respect to your plant, not with respect to the whole company that you might be a part of.

Summary: The present questionnaire is intended to gather data to test the significance of agility attributes, competitive bases and manufacturing metrics to design a model adequate for the assessment of agile manufacturing from an information systems perspective.

Section 1: General information on the enterprise.

Name of respondent: ______________________________
Position: ______________________________
Company name: ______________________________
Address: ______________________________
____
Contact no: ______________________________
Nature of business/Main products: ______________________________
Age of the business: ______________________________

For the next set of questions, tick on the relevant box.

How many employees are working at the site?

Under 25	
25 to 50	
51 to 100	
101 to 250	
251 to 500	
501 to 1000	
1001 to 2500	
2501 to 5000	
Over 5000	

What is the approximate turnover of the plant (at your site)?

Less than £5 million	
£5 million to £10 million	
£11 million to £25 million	
£26 million to £50 million	
£51 million to £100 million	
£101 million to £250 million	
£251 million to £500 million	
Over £500 million	

What information systems are used at your plant?

MRP, manufacturing operations, materials handling.	
MRPII, financial and planning modules to assist manufacturing operations.	
CIM, EDI, intelligent schedul ng, integrate different internal and external activities of the company.	
ERP, Enterprise integration, systems that addresses not only the information needs of manufacturing but also the information needs of the entire enterprise.	
E-commerce, active agents, systems that addresses the information needs of customers and suppliers.	

What is the number of people working in the Information Systems department? ___________.

For questions in sections 2, 3 and 4, tick on the appropriate box using the following scale:

1	2	3	4	5
completely disagree	disagree	not agree or disagree	agree	completely agree

Section 2: Business environment questions.

	1	2	3	4	5
The potential for continual growth in our market is high.					
Long range plans are extremely difficult to develop in our industry.					
To survive in this industry we must constantly introduce new products.					

Section 3: Information technology/systems structure.

	1	2	3	4	5
IT/IS in the enterprise provides an environment that promotes the development of customised solutions based on unique business needs.					
The IT/IS infrastructure ensures continued viability as components are improved, added or removed.					
The organisation constantly monitors developments in IT/IS in our industry and benchmarks it against other industries.					
Our IT/IS infrastructure anticipates future electronic interactions with customers and suppliers.					
New standards can be upgraded or modified to the IT/IS infrastructure without breaking other applications.					
In case of problem, fixings to the IT/IS infrastructure are in short periods of time.					
It is possible to make variations to the IT/IS standards in order to accommodate unique requirements.					

APPENDIX C

Survey development and statistical tests employed.

C.1 Survey development notes.

During the development of the survey, only seven IT/IS proficiency characteristics for agility were considered. Discarding the reactive IT/IS characteristics of *expansion* and *reconfiguration* helped to reduce the total number of answered questionnaires required to validate the survey. But the main reason supporting that decision is the outcome of a pilot study, not included in this thesis, developed during the Summer of 1999. The sixteen manufacturing organisations that participated in the pilot study were disagree or completely disagree with the statements representing those IT/IS proficiency characteristics.

Another reminder to the reader is that the identification of the agility of surveyed companies was not part of the survey. The survey research was strictly focused on analysing the prioritisation of IT/IS proficiency characteristics of agility as perceived by manufacturing organisations from dynamic business environments which include the automotive, aerospace and electronics-semiconductors industry sectors.

C.2 Statistical tests employed

The statistical analysis of the survey required the use of the software package SPSS 9.0 for Windows and Microsoft Excel. Factor analysis, descriptive statistics, t-test and variance tests were carried out using those software packages. References on the use of SPSS 9.0 and the chosen statistical tests can be found in the works of Bryman and Cramer (1997) and Kinnear and Gray (1997). A brief description of some of the statistical tests used during the analysis of responses is provided next.

Factor Analysis.

Factor analysis attempts to identify underlying variables, or factors, that explain the pattern of correlations within a set of observed variables. Factor analysis is often used in data reduction to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables (Darlington 2000).

The purpose of factor analysis is to discover simple patterns in the pattern of relationships among the variables. In particular, it seeks to discover if the observed variables can be explained largely or entirely in terms of a much smaller number of variables called factors.

Factor analysis is different to other statistical methods used to study the relation between independent and dependent variables. Factor analysis is used to study the patterns of relationship among many dependent variables, with the goal of discovering something about the nature of the independent variables that affect them.

The rules about number of variables are very different for factor analysis than for regression. In factor analysis it is right to have many more variables than cases. In fact, generally speaking the more variables the better, so long as the variables remain relevant to the underlying factors.

When factor analysis is employed, there are control indices that are useful to validate the results. For example, a Kaiser-Meyer-Olkin index value (measure of sampling adequacy) equal or greater than 0.5 means a satisfactory factor analysis to proceed. The Bartlett test of sphericity reveals if a sample is suitable for further analysis when its significance number is less than 0.05.

Theory behind Factor analysis.

Factor analysis includes both component analysis and common factor analysis. Factor analysis is used to study the patterns of relationship among many dependent variables, with the goal of discovering something about the nature of independent, variables that affect them, even though those independent variables were not measured directly. Thus answers obtained by factor analysis are necessarily more hypothetical and tentative than is true when independent variables are observed directly. The inferred independent variables are called factors.

Cronbach's Alpha.

Reliability analysis allows researchers to study the properties of measurement scales and the items that constitute them. The reliability analysis procedure calculates a number of commonly used measures of scale reliability and also provides information about the relationships between individual items in the scale. The Cronbach's Alpha is a model of internal consistency, based on the average inter-item correlation.

Factor Analysis is a procedure related to Cronbach's Alpha, especially if a researcher wants to explore the dimensionality of his/her scale items (to see if more than one construct is needed to account for the pattern of item scores).

t-test and F-test.

Two tests were employed to identify the association between IT/IS proficiency characteristics of agility, the characteristics of a dynamic business environment and the type of IS found in manufacturing organisations.

Mean Test (t-test).

The Paired-Samples t-test procedure compares the means of two variables for a single group. It computes the differences between values of the two variables for each case and tests whether the average differs from 0. The analysis uses a two-sample student's t-test. This t-test form assumes that the means of both data sets are equal; it is referred to as a homoscedastic t-test. Indeed, t-test is used to determine whether two sample means are equal. A paired-sample t-test was employed in the survey analysis to compare the scores of the respondents on two variables.

Variance Test (F-test).

Variance analysis performs a two-sample F-test to compare two population variances and it is used to test the uniformity of variances. In the particular case of the research survey, this test was employed to identify any significant differences between the people who answered questionnaires. These include managing directors, IT directors and production managers.

APPENDIX D

Multiple case-study questionnaire.

Information systems contribution to agility
Information systems evaluation – semistructured interviews

During the development of the multiple case-study, participating companies identified and provided a thorough description of the information system used to support their business processes with special emphasis on manufacturing operations.

Company details.

Name and position of interviewees.
Company name and address.
Sector.
Employees working in the site.
Annual turnover of the site.
Identification of the information system used to support business processes and manufacturing operations.

Open questions used during visits to participating companies.

Interviewees have been encouraged to describe and give details to each of the questions presented in this section. A dictation machine has been used to record interviewees' answers.

Information systems management.

What was the motivation for the implementation of this information system?

What is the current satisfaction level experienced with this information system?

So far, what are the main benefits achieved since the introduction of this information system?

Was the information system customised to specific business needs? If yes identify the major considerations for that customisation.

Who was responsible in choosing that information system?

How many departments participated in the selection of that information system?

What is the level of integration of this information system with the available IT/IS infrastructure?

How has the IT/IS infrastructure enabled the success or failure of the information system under study?

Information Systems in manufacturing operations.

Which manufacturing operation receives the most from IS?

What were the main problems in manufacturing operations prior the introduction of the information system?

What have been the problems created to manufacturing operations since the introduction of this information system?

What have been the main benefits provided by this information system to your manufacturing processes?

What type of training and duration, was given to your department to operate this information system?

What have been the impact of people skills and expertise on the achievement of agility in business processes, especially manufacturing, and in the operation of the company's IS?

What is the perceived complexity of the used information system?

What are the schemes utilised to ensure the integrity of the data entered?

Information Systems in relation to company's management.

Reasons for choosing that particular information system?

What were the major difficulties faced when evaluating the project?

What are the major difficulties faced in measuring the contribution of information systems?

What are the main performance measures utilised for the evaluation of information systems contribution?

What is the contribution of the application in terms of sales, customer relationship and reputation?

Does the application have any significant impact on the cost (profitability) and quality of the site?

What was the total cost of the project to implement the application?

What has been the performance of this application?

What is the business strategy of the company?, please provide a detailed description.

What is the manufacturing strategy of the company?

What is the IT strategy envisaged for the company?

What has been the role of an IT strategy behind the success/failure of IS in your company?

What is the main reason for the success-failure of information systems in your company?

What are the steps taken to achieve agility in the organisation?

Semi-structured & structured questions

Section 1. Information Systems.

1. General issues for information systems.

a) What is the annual IT/IS budget as a percentage of the company's turnover? _________.
b) Number of people working in the department? _________.
c) What is the proportion of the budget allocated to new investments in IT/IS? _________.
d) What is the percentage of the IT budget allocated to the following?

Infrastructure (e-commerce, internet, intranet, b2b, operating systems, etc.): ________.
Planning (MRP, ERP, APS, CRM, etc.): ________.
Execution (workflow, scheduling, data warehousing, etc.): ________.
Others (training and maintenance): ________.

e) What is the annual distribution between the following projects?
Package-based developments using COTS (Commercial of-the-shelf): ________________
In-house software development: ________________

2. Difficulties observed in perceiving the contribution of information systems.

a) Identify those issues (if any) as reasons for dissatisfaction with the current IT/IS infrastructure (tick as appropriate):

- Non-existent functionality. ☐
- The IS infrastructure probably has the functionality but it has been under used. ☐
- The functionality is as specified but inappropriate. ☐
- Inefficient and ineffectively IS infrastructure. ☐

Description of IT/IS infrastructure under use:
Operative systems platform: ________________________________
Software platform: ________________________________

3. Evaluation of information systems.

Given the characteristics of the business environment faced by your organisation answer the following statements.

1 Not important at all	2 Not important	3. Fair	4. Important	5. Very important

a) Criteria of evaluation for information systems in your organisation.

Simplicity and robustness	1	2	3	4	5
Ease of configuration and re-configuration	1	2	3	4	5
Rapid implementation	1	2	3	4	5
Ease of learning	1	2	3	4	5
Scalability	1	2	3	4	5
Distributed data with replication	1	2	3	4	5
Expandable across the enterprise	1	2	3	4	5
Capability for Multi-site, multi-company, multi-enterprise	1	2	3	4	5
Adequate training for new/upgraded versions	1	2	3	4	5

b) Benefits sought from the information systems function in your organisation.

	1	2	3	4	5
Support real time decision-making.					
Real-time adjustments to support business goals					
Creation of flexible plans and schedules					
Simultaneous assessment of materials and plant resources					
Data rationalisation					
Data accuracy					
Elimination of duplication					
Standardised information					
Quick access to the information needed					
Better sharing of information					
Greater security					

4. Use the scale below to answer the following questions related to IS function management.

1. Very Poor	2 Poor	3 Medium	4 Good	5. Very Good

How are current metrics utilised to measure the contribution of information systems in your organisation?

1 2 3 4 5

The current IT/IS infrastructure and applications guarantee managing processes (e.g. order fulfilment, new product introduction, interorganisational supply chain management) that span beyond their business units and require integration with other companies.

1 2 3 4 5

The information systems department has the capability to react quickly to changes perceived in the business environment and make pertinent changes.

1 2 3 4 5

The speed brought by the IS function is adequate to support our processes under the demands of the business environment.

1 2 3 4 5

Expertise to deal with legacy systems and rapid changes in operating systems and applications versions.

1 2 3 4 5

Please, give your assessment to the next statements using the following scale:

1. Not important at all	2. Not important	3. Fair	4. Important	5. Very important

The business environment as a major driver in determining the management of the IS function within the organisation.

1 2 3 4 5

Awareness of the IS department in creating an agile and flexible IT/IS infrastructure according to the rate of change in technology.

1 2 3 4 5

Section 2. Manufacturing Operations.

1. Manufacturing operations
a) Identify key manufacturing processes in your plant? ______________________________
____.

b) Identify the principal type of manufacturing system used in your plant.

Jobbing ☐ Flow line ☐
Batch ☐
Mass production ☐
End product variety 1-10 ☐ 11-50 ☐ 51-100 ☐ >100 ☐

c) Number of components in the product with the largest sales? ________.
d) Number of suppliers of raw material? __________.
e) Number of customers? __________.

Rate the support of the information systems function to the following manufacturing related activities.

1. Very Poor	2 Poor	3 Fair	4 Good	5. Very Good

Design	1	2	3	4	5
Demand Management	1	2	3	4	5
Capacity Planning	1	2	3	4	5
Inventory Management	1	2	3	4	5
Shopfloor Systems	1	2	3	4	5
Quality Management	1	2	3	4	5
Distribution	1	2	3	4	5

f) Rate the following issues as benefits sought from your information systems function to your manufacturing processes according to the business conditions faced by your organisation. (OPERATIONAL BENEFITS).

1 Not Important at all	2 Not Important	3. Fair	4. Important	5.Very Important

Automate processes	1	2	3	4	5
Eliminate bottlenecks	1	2	3	4	5
Optimise delivery times	1	2	3	4	5
Reduced overhead apportion	1	2	3	4	5
Reduce finished stock levels	1	2	3	4	5
Reduced WIP inventory	1	2	3	4	5
Reduced raw material inventory holdings	1	2	3	4	5
Reduced direct labour	1	2	3	4	5
Reduced indirect labour	1	2	3	4	5
Reduced scrap and rework	1	2	3	4	5
Reduced warranty claims	1	2	3	4	5
Increase throughput	1	2	3	4	5
Reduce manufacturing lead times	1	2	3	4	5
Reduce machine set-up/changeover	1	2	3	4	5
Reduce working capital	1	2	3	4	5
Reduce cycle times	1	2	3	4	5
Reduce quality control	1	2	3	4	5
Sort out specifications	1	2	3	4	5

Rate the following manufacturing flexibility questions using the scale below:

1. Not important at all	2. Not important	3. Fair	4. Important	5. Very important

Introduction of new products into production quickly.
1 2 3 4 5
Adjusting capacity rapidly within a short period.
1 2 3 4 5
Customisation of products to customer specifications.
1 2 3 4 5
Handling changes in the product mix quickly.
1 2 3 4 5
Handling variation in customer delivery schedule.
1 2 3 4 5

What is the main difficulty found to measure the benefits of information systems to manufacturing operations?

____

____

Use the following scale for the last two questions.

1 Not developed at all	2 Poorly developed	3 Regular	4 Developed	5. Very developed

What is your overall view of information systems support of manufacturing operations?
1 2 3 4 5

Rate the degree your manufacturing operations are agile?
1 2 3 4 5

Section 3. Organisation's management.

1. Development of agility as an improvement programme.

a) According to the definition of agile manufacturing presented in the introduction of this work, where does your company stand in the adoption of a policy to meet those conditions?

Not developed at all				Very developed
1	2	3	4	5

Explain: ____.
____.

b) Has the implementation of agility as a policy already being undertaken? YES NO
c) Has it been considered in future plans? YES NO

d) What other improvement programmes have been introduced in your organisation?

	Under taken	Future plans	Dissatisfied				Successful
TQM	☐	☐	1	2	3	4	5
JIT	☐	☐	1	2	3	4	5
BPR	☐	☐	1	2	3	4	5
Lean manufacturing	☐	☐	1	2	3	4	5
Concurrent Engineering	☐	☐	1	2	3	4	5
Cellular Manufacturing.	☐	☐	1	2	3	4	5
Benchmarking	☐	☐	1	2	3	4	5
ISO9000 accreditation	☐	☐	1	2	3	4	5

e) What is the importance of agility among other improvement programmes for manufacturing?
____.
____.

2. Business environment.
a) The following questions were identified critical in determining if an organisation is in a dynamic business environment.

1 Completely Disagree	2 Disagree	3. Not agree or Disagree	4. Agree	5. Completely Agree

	1	2	3	4	5
There are low entry costs in our industry.					
There are low switching costs in our industry.					

3. Assessment Techniques.
a) Identify the utilisation of the following techniques to assess information systems investments and their contribution.

	YES	NO	NOT FAMILIAR WITH TECHNIQUE
ROI (Return on Investment).	☐	☐	☐
Return on Management (i.e. management-Value added divided by cost of management).	☐	☐	☐
Payback.	☐	☐	☐
Cost Benefit Analysis.	☐	☐	☐
Net Present Value.	☐	☐	☐
Internal Rate of Return.	☐	☐	☐
Profitability Index.	☐	☐	☐

Discounted Cash Flow.	☐	☐	☐
Activity Based Costing.	☐	☐	☐
ROCE (Ratio of Capital Employed)	☐	☐	☐
Option Valuation	☐	☐	☐
Market Value Added (MVA)	☐	☐	☐
Economic Value Added (EVA)	☐	☐	☐
Return on Assets (ROA)	☐	☐	☐
Return on Equities (ROE)	☐	☐	☐

b) Does your organisation have procedures to measure and document significant monetary value as a contribution of information systems? **YES** **NO**

Explain: ____.

____.

4. Agility measures for information systems.

1. Not Important at all	2 Not Important	3. Fair	4. Important	5.Very Important

a) The following issues have been identified in the literature on agile manufacturing. How important are them in terms of contribution of information systems to your organisation?

Employees accessing company-wide data	**1**	**2**	**3**	**4**	**5**
Increase electronic links with customers and suppliers	**1**	**2**	**3**	**4**	**5**
Value of information content of products	**1**	**2**	**3**	**4**	**5**
Working teams with access-wide to all data	**1**	**2**	**3**	**4**	**5**
Achievement of competitive advantage	**1**	**2**	**3**	**4**	**5**
Tasks that could not be done before	**1**	**2**	**3**	**4**	**5**
Applications seen as a distinct proprietary advantage.	**1**	**2**	**3**	**4**	**5**
IS are seen to maintain competitive position.	**1**	**2**	**3**	**4**	**5**

b) Other benefits sought through the acquisition of information systems.

Reduce total number of transactions	**1**	**2**	**3**	**4**	**5**
Improve accuracy	**1**	**2**	**3**	**4**	**5**
Minimise obsolescence	**1**	**2**	**3**	**4**	**5**
Increase focus in planning and procurement	**1**	**2**	**3**	**4**	**5**
Support sales	**1**	**2**	**3**	**4**	**5**
Manage of customer relationship	**1**	**2**	**3**	**4**	**5**
Sustain and improve the reputation of the firm	**1**	**2**	**3**	**4**	**5**

Use the scale below to answer the following question.

1 Not Important at all	2.Not Important	3. Fair	4. Important	5.Very Important

Our investments on IT/IS are intended to increase revenue through new business processes.

1 2 3 4 5

APPENDIX E

Multiple case-study development.

This section provides further explanation of the questions used for the multiple case-study.

Information Technology/Systems evaluation.

The purpose of the utilisation of structured and semi-structured questions regarding information technology/systems is provided here.

Question	Purpose
Criteria of evaluation of information systems: • Simplicity and robustness • Ease of configuration and re-configuration • Rapid implementation • Ease of learning • Scalability • Distributed data with replication • Expandable across the enterprise • Capability for multi-site, multi-company, multi-enterprise • Adequate training for new/upgraded versions	These characteristics have been identified as part of the criteria of evaluation of information systems developed by Boar (1994) and are related to hypothesis 1. The assessment to these characteristics will enable the comparison between them and the performance of IS in the organisation plus the achievement of agility in business processes, especially manufacturing operations. Also, ease of learning provides arguments to support/reject hypothesis 3.
Expected benefits from IS: • Support real time decision-making. • Real-time adjustments to support business goals • Creation of flexible plans and schedules • Simultaneous assessment of materials and plant resources • Data rationalisation • Data accuracy • Elimination of duplication • Standardised information • Quick access to the information needed • Better sharing of information • Greater security	This list of benefits represents tactical benefits from the use of information systems. The identification of benefits at the data process level is related to hypothesis 1. The performance of information systems in the participating companies, the support provided to manufacturing operations and the achievement of agility in the organisation represent benefits at a data process level.
• How are current metrics utilised to measure the contribution of information systems in your organisation?	Identify the use of specific metrics to measure the contribution of IS in participating companies.
• The current IT/IS infrastructure and applications guarantee managing processes (e.g. order fulfilment, new product introduction, interorganisational supply chain management) that span beyond their business units and require integration with other companies.	A basic characteristic of IT to support agility. Infrastructure was highlighted as an important element behind the factors identified during the survey research. The state of IT/IS infrastructure within agility was addressed by E. Subrahmanian (1998), the n-dim team, Carnegie-Mellon University, Pittsburgh PA, USA.

• The information systems department has the capability to react quickly to changes perceived in the business environment and make pertinent changes.	Capability to respond quickly to changes in the business environment is an agility characteristic.
• The speed brought by the IS function is adequate to support our processes under the demands of the business environment.	Speed is a competitive basis related to agility (Yusuf et al. 1999). The performance of the IS function in terms of speed provides elements for the assessment of the capacity to react to changes in the business environment.
• Expertise to deal with legacy systems and rapid changes in operating systems and applications versions.	Dealing with legacy systems is a situation faced by companies implementing new systems and it is an issue of concern in those organisations facing dynamic business environments.
• The business environment as a major driver in determining the management of the IS function within the organisation.	The influence of a dynamic business environment has been widely addressed in the literature. Its influence on the IS function of a company is investigated in this question.
• Awareness of the IS department in creating an agile and flexible IT/IS infrastructure according to the rate of change in technology.	The creation of an agile and flexible IT/IS infrastructure has been highlighted by the n-dim group (Subrahmanian 1998) as an important element of IS support of agility.

Manufacturing operations evaluation section.

The support information systems provide to manufacturing operations was addressed to the interviewees during the development of the multiple case-study. Several other questions were addressed with the sole purpose of supporting hypothesis 1.

Question	Purpose
Identify key manufacturing processes in your plant.	This is an open question targeted to identify the most important processes in manufacturing operations.
Identify the principal type of manufacturing system used in your plant. • Jobbing • Flow line • Batch • Mass production	These four types of manufacturing systems are typically found in manufacturing SMEs.
End product variety 1-10 11-50 51-100 >100	The question identifies the product variety produced in the company facing a dynamic business environment.
Number of components in the product with the largest sales?	Question with the purpose of identifying the size of the operations of the company participating in the multiple-case study.
Number of suppliers of raw material?	Identify the size of the operations of the company in terms of the number of suppliers.

Number of customers?	Question with the purpose of identifying the size of the operations of the company in terms of total number of customers.

Each company was asked to rate the support IS provide to seven manufacturing-related activities using a five point Likert scale. Gunasekaran (1999) highlighted the use of IS to support the following manufacturing-related activities.

Activity	Purpose
Design	IS support of design. Companies that are subsidiaries of multi-national organisations may not have design operations in-site.
Demand management	IS support of management of demand.
Capacity planning	IS support of capacity planning. It may be difficult to evaluate in very dynamic business environments.
Inventory management	IS support of stock control.
Shopfloor systems	Support of IS to shopfloor systems.
Quality management	IS support of quality management.
Distribution	IS support of logistics and distribution.

Benefits of information systems in terms of manufacturing operations – Operational benefits, included:

Question	Purpose
The following issues have been considered as benefits from IS in manufacturing: • Automate processes • Eliminate bottlenecks • Optimise delivery times • Reduced overhead apportion • Reduce finished stock levels • Reduced WIP inventory • Reduced raw material inventory holdings • Reduced direct labour • Reduced indirect labour • Reduced scrap and rework • Reduced warranty claims • Increase throughput • Reduce manufacturing lead times • Reduce machine set-up/changeover • Reduce working capital • Reduce cycle times • Reduce quality control • Sort out specifications	Each of the characteristics listed here are performance issues associated to World Class Manufacturing organisations. These characteristics were proposed originally by Maskell (1991) and they give the opportunity of identifying benefits expected by manufacturing organisations. Also, the evaluation of these characteristics provides more elements to support or reject hypothesis 1.

The next questions are related to the importance of five types of manufacturing flexibility in visited companies.

Question	Purpose
New product - Introduction of new products into production quickly. **Volume** - Adjusting capacity rapidly within a short period of time. **Modification** – Customisation of products to customer specifications. **Mix or changeover** - Handling changes in the product mix quickly. **Delivery time** - Handling variation in customer delivery schedule.	Flexibility has been identified as a main component of agile manufacturing. Five types of flexibility were identified in the manufacturing literature. Selected works on the field include Gupta and Somers (1996), Kathuria (1998), Shewchuk and Moodie (1997), Nemetz (1990) and Ritzman et al. (1993). This question reveals the background of the manufacturing operations of visited companies and is related to hypothesis 1. A five-point Likert scale was employed

The following question is related to the difficulty of measuring IS benefits:

Question	Purpose
What is the main difficulty found to measure the benefits of information systems to manufacturing operations?	This is an open question directly addressing the problem of measuring and perceiving IS benefits in manufacturing processes. It provides more arguments to accept or reject hypothesis 1.

The next two questions are related to the assessment of the support of IS to manufacturing operations and the current level of agility present in manufacturing operations.

Question	Purpose
What is your overall view of information systems support of manufacturing operations?	Interviewees use a five-point Likert scale that goes from developed to not developed at all to answer this question. It provides arguments to reject/support hypothesis 1.
Rate the degree your manufacturing operations are agile?	Direct question for the assessment of manufacturing operations in terms of the agility developed in the company. Question related to hypothesis 1.

Company management.

The importance of agility to improve manufacturing operations is addressed in the following questions.

Question	Purpose
Development of agility as an improvement programme. According to the definition of agile manufacturing presented in the introduction of this work, where does your company stand in the adoption of a policy to meet those conditions?	The respondent is asked to provide an assessment of the current development of agile manufacturing using a five point-Likert scale. An explanation for the answer is provided by the respondent. Question related to hypothesis 1. The respondent is encouraged to expand his answers verbally.
Has the implementation of agility as a policy already being undertaken?	Respondents answer the question with YES or NO. It provides evidence of the development of agility in the participating company.

Has agility been considered in future plans?	Respondents need to answer YES or NO to this question. It provides evidence of the development of agility in the organisation.

The following questions are used in identifying improvement programmes that preceded agility in participating companies.

Question	Purpose
What other improvement programmes have been introduced in your organisation? TQM JIT BPR Lean manufacturing Concurrent Engineering Cellular Manufacturing Benchmarking ISO9000 accreditation	The eight improvement programmes for agility provide a snapshot of the situation present in visited companies. This question is used to identify the level of awareness of the companies on improvement programmes for manufacturing. Respondents are required to give ratings if such programmes have been undertaken or considered in future plans. The interviewees evaluated each improvement programme using a five-point Likert-scale.
What is the importance of agility among other improvement programmes for manufacturing?	Identify the importance of agility as viewed by the participating companies who have already implemented one or more improvement programmes for manufacturing.

Characteristics of the business environment were also addressed in this section.

Question	Purpose
There are low entry costs in our industry	Identify the company's view on low entry costs stimulating the entry of new players in industry, making it more competitive.
There are low switching costs in our industry	Identify the company's view on low switching costs making very easy for customers to change suppliers, making the sector very competitive.

Financial techniques are commonly used in the assessment of investment projects and they are used as well in the assessment of IT/IS investments.

Question	Purpose
Identify the utilisation of the following techniques to assess information systems investments and their contribution. • ROI (Return on Investment). • Return on Management (i.e. management- • Value added divided by cost of management). • Payback. • Cost Benefit Analysis. • Net Present Value. • Internal Rate of Return. • Profitability Index. • Discounted Cash Flow.	Participating companies are asked about their familiarity with some of the most common techniques used in the assessment of investments. Popular metrics employed in manufacturing include ABC, ROCE, ROA and ROE. Also not very common techniques are also included here to identify the level of expertise of the company. Some of them are MVA, EVA and Option Valuation.

• Activity Based Costing. • ROCE (Ratio of Capital Employed) • Option Valuation • Market Value Added (MVA) • Economic Value Added (EVA) • Return on Assets (ROA) • Return on Equities (ROE)	
Does your organisation have procedures to measure and document significant monetary value as a contribution of information systems?	The purpose of this question is to identify procedures of measuring IS contribution. Subrahmanian (1998) insisted that organisations must develop procedures to measure IT contribution an ensure value added to the business.

Several other benefits from investments in information systems have been considered at the enterprise level. The benefits listed below are neither confined to benefits at a data-information process level -as it was the case in the first section of the questionnaire-, nor confined to benefits in terms of manufacturing operations, operational benefits, -as it was the case in the manufacturing section of the questionnaire-.

Question	Purpose
Benefits sought from information systems at the company level: • Employees accessing company-wide data • Increase electronic links with customers and suppliers • Value of information content of products • Working teams with access-wide to all data • Achievement of competitive advantage • Tasks that could not be done before • Applications seen as a distinct proprietary advantage • IS are seen to maintain competitive position	The assessment of factors related to the competitiveness of a firm, viewed as a series of IS-related benefits, would enable comparing them to the current performance of IS and to the agility achieved in the firm. The answers to this question will provide arguments to accept or reject hypothesis 1.
More benefits include: • Reduce total number of transactions • Improve accuracy • Minimise obsolescence • Increase focus in planning and procurement • Support sales • Manage of customer relationship • Sustain and improve the reputation of the firm	Interviewees assessed other factors related to the competitiveness of a firm. Those factors are viewed as a series of IT-related benefits. The assessment would enable the comparison of the current performance of the company's IS and the current impact on the agility achieved in the firm. The assessment of these factors would provide arguments to accept or reject hypothesis 1.

One last question included in this section is:

Question	Purpose
Our investments in IT/IS are intended to increase revenue through new business processes.	This question reveals the purpose of IT investments in the company as it intends to provide arguments to sustain or reject hypothesis 1.

The inclusion of open-ended questions, the use of a dictation machine as well as access to company specific data sets enabled collecting data to support/reject hypotheses 2 and 3.

Question	Purpose
What was the motivation for the implementation of this information system?	Answer to the question would show the reasons why the information system under study was implemented, giving arguments to support or reject hypothesis 2.
What is the current satisfaction level experienced with this information system?	The current level of satisfaction with an information system is closely related to the support IS give to the business strategy of the company and it is related to hypothesis 2.
What is the performance of such information system?	The performance of such IS, specially support to manufacturing operations. Hypothesis 2.
Who was responsible in choosing that information system?	Identify the department responsible for the outcome experienced with the information system.
Was the information system customised to specific business needs? If yes identify the major considerations for that customisation.	Identify the customisation of software required in supporting the particular needs of the business. Hypothesis 2.
What is the business strategy of the company?, please provide a detailed description	Identify the business strategy of the company and find if there is any compatibility with what has been delivered by information systems.
What is the manufacturing strategy of the company?	A sound manufacturing strategy is closely related to the development of a business strategy.
What is the IT strategy of the company?	The definition of an IT strategy is compared with the business strategy of the company. Hypo. 2
What are the main reasons for the success-failure of IS in your company?	Identify arguments that link having a business strategy and IT strategy aligned behind the success of IS. Hypothesis 2.
What are the steps taken to achieve agility in the organisation?	It is expected that the respondent will acknowledge having business and IT strategies as key factors to achieve agility.

The following questions are related to identifying the role of personnel skills and expertise in the achievement of agility whilst impacting the use of IS and impacting the operations in the shop-floor.

Question	Purpose
What type of training and duration, was given to your department to operate this information system?	Expertise and skills of personnel is expected to be a key factor. Hypothesis 3.
What is the perceived complexity of the current information system?	End users are always aware of the mistakes that can be committed when using a complex system.

What are the schemes utilised to ensure the integrity of the data entered?	The integrity of data entered into the system is a factor closely related to expertise and skills of the personnel interacting with it. The answer to this question would provide arguments to support/reject hypothesis 3.
What has been the impact of people skills and expertise on the achievement of agility in business processes, especially manufacturing, and in the operation of the company's IS?	IS and personnel skills are two enablers interrelated in achieving agility in manufacturing organisations. Identify arguments to support/reject hypothesis 3.
What is the place of information systems among enablers of agility like skills and expertise of employees?	Compare two enablers of agile manufacturing, information systems and skills & expertise, and identify which one has the most relevant role.

E.1 Some metrics employed by participating companies.

In the case of the aerospace sector, six metrics are currently being used to monitor the performance of organisations in this sector. These metrics include: customer acceptance/reject rate, value added, stock turns, floor space utilisation, employee training and development and delivery schedule achievement. Units for obtaining each measure are presented next:

CUSTOMER ACCEPTANCE/
REJECT RATE
Quality Focus

$$1 - \left(\frac{\text{Quantity of agreed and accepted rejects}}{\text{Total quantity of units delivered}} \right)$$

VALUE ADDED
Waste Elimination

$$\frac{\text{Output value - input value}}{\text{Number of employees}}$$

STOCK TURNS
Inventory Reduction

$$\frac{\text{Sales turnover of product}}{\text{Value of raw material + WIP + finished goods}}$$

FLOOR SPACE UTILISATION
Smoother Flow

$$\frac{\text{Sales turnover}}{\text{Square metres}} \quad \text{£/sq. metre/year}$$

EMPLOYEE TRAINING AND DEV.
Employee Involvement

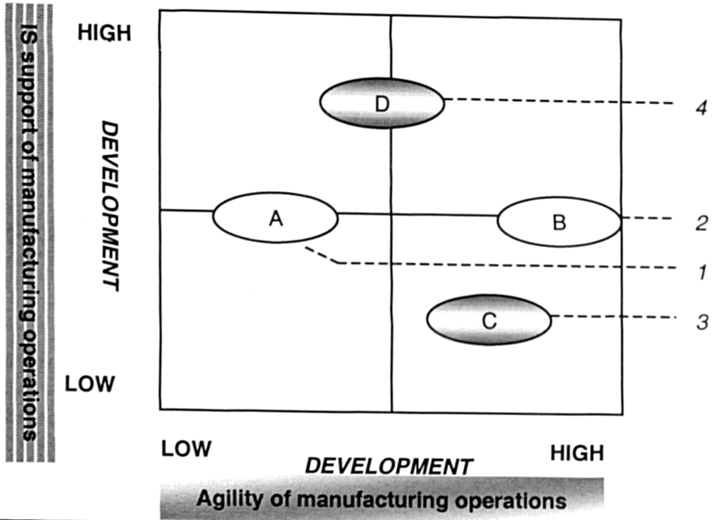
$$\frac{\text{Total number of structured training \& development days per year}}{\text{Total number of full-time employees}}$$

DELIVERY SCHEDULE ACHIEVEMENT
Customer Satisfaction

$$\frac{\text{No. of planned deliveries - (no. of deliveries outside the customer delivery window + no. of partial deliveries}}{\text{No. of planned deliveries}}$$

Success Factors of IS in participating companies

1 - Training of personnel.
2 - Meet specific needs of the business
3 - Customisation of applications
4 - Improvement steering committee



IS support of manufacturing operations

Benefits sought from IS

A (jobbing & batch) — **Important:** automate processes, eliminate bottlenecks, optimise delivery times, reduce finished stock *levels, reduce WIP inventory, reduce manufacturing lead times,* reduce cycle time. **Medium:** reduce overhead apportion, reduce raw material, reduce scrap and rework, reduce warrant claims, increase throughput, reduce machine set-up, reduce working capital, reduce quality control and sort out specification.

B (jobbing) — **Important:** optimise delivery time, reduce overhead apportion, reduce finished stock levels, reduce WIP inventory, reduce warranty claims, sort-out specification. **Medium:** reduce quality control.

D (batch & flow line) — **Important:** Looking for all 18 benefits of IS to manufacturing operations
We don't do anything without IS

* C (batch & JIT) — **Important:** eliminate bottlenecks, optimise delivery time, reduce overhead apportion, reduce indirect labour, reduce scrap and rework, reduce warranty claims, increase throughput. **Medium:** automate processes, reduce raw material inventory holdings, reduce direct labour, reduce machine set-up, reduce working capital, reduce cycle times, reduce quality control, sort out specification.

IS support of related manufacturing activities

A — **Good:** demand management, inventory management
Medium: design, shopfloor systems, quality management
Poor:capacity planning, distribution

B — **Good:** design, shopfloor systems, quality management, distribution
Medium: demand management,
Poor: capacity planning, inventory management

* C — **Good:** quality management, distribution
Medium: design, demand management, inventory management, shopfloor systems.
Poor: capacity planning

D — **Good:** quality management, distribution
Medium: inventory management, shopfloor systems
Poor: demand management, capacity planning

Agility of manufacturing operations

Important types of flexibility present

B — New product introduction, volume, modification, mix/change and delivery time.

* C — Volume, mix/change and delivery time.

Difficulty to measure benefits from IS applications to manufacturing.

A — It is almost impossible to establish a measurement that relates IS improvement to operations.

B — No direct link bespoke hands on work.

* C — Ensuring physical systems and flexibility make use of such systems.

D — Aligning MRP systems with customer demand.

* scored the highest in the development of agility.

B — Every system manufactured is bespoke and shipped in 24 hours.
Manufacturers in industry are becoming service providers as well.
The company has to invent itself almost every three months.
Too flexible and moving too quickly. Respond to different customer needs.
Suppliers supply us only when components are required.

* C — Production employs batch and JIT, depending on the customer.
Manufacturing schedules are provided directly by the customers, work under a manifesto.
Concurrent manufacturing and cellular manufacturing are in place.
Two years to get more flexibility out of manufacturing operations.

D — High volume, high variety, as much as possible in the aerospace industry.
Customers do not carry stock. TRW kits several parts that make a product.
Development of lean manufacturing.

Development of agility as an improvement programme.

Company A	MEDIUM
Company B	MEDIUM
Company C	HIGH
Company D	MEDIUM

Importance of agility.

A	Agility is very important, our customers demand ever higher standards of flexibility.
B	No change as we seek more service business. Need to improve quality and to learn to change.
C	High need to respond quickly on new products and reduce costs of existing ones.
D	Opportunity to react quickly to change.

Standing in the adoption of agility.

	Standing in the adoption of agility	Satisfaction with I.P.*	Assessment Techniques
A	We have to develop further to meet the needs of our customers	C.E., Bench., ISO9000	ROI, Pay, CBA, IRR, ABC, ROCE
B	First stage solutions aimed at automating a simple manufacturing solution.	JIT, BPR, Lean, C.E.	Pay, CBA, MVA, EVA
C	Respond to market fluctuations.	TQM, JIT, BPR, Lean, C.E. Cel., ISO9000	ROI, Pay, NPV, IRR, PI, ABC, ROCE, MVA, EVA, ROA, ROE
D	Probably using agile manufacturing processes in response to customer satisfaction/global req.	TQM, JIT, BPR, Lean, C.E. Cel., Bench., ISO9000	ROI, ROM, Pay, CBA, NPV, IRR, PI, DCF, ABC, ROCE, EVA, ROA, ROE

***I.P. : improvement programmes**

Information Systems Management

	IS management in terms of agility	Business Environment and Agile Infrastructure	Criteria of Evaluation	Benefits sought for data manipulation
A (all except portability)		**Important:**	**Important:** simplicity and robustness, rapid implementation, ease of learning.	**Important:** all except, adjustments to support business goals, data rationalisation, data accuracy & greater security.
B (all)	**Good:** Metrics Infrastructure Cap. Reaction Speed by IS	***B.E.*** ***Agile Infra***	**Important:** simplicity and robustness, ease of configuration, rapid implementation, ease learning, distributed data, expandable across the enterprise.	**Important:** all except, simultaneous assessment of material and plant resources, data rationalisation & greater security.
C (N/A)	**Good:** Legacy Sys.	***B.E.***	**Important:** all benefits.	**Important:** all benefits.
D (all except portability)	**Good:** Cap. Reaction Legacy Sys.	***B.E.*** ***Agile Infra***	**Important:** simplicity and robustness, ease of configuration, ease of learning, expandable across the enterprise, capability for multi-site, adequate training for new versions.	**Important:** all except, simultaneous assessment of material and plant resources.

data manipulation benefits

- Support real time decision-making.
- Real-time adjustments to support business goals.
- Creation of flexible plans and schedules.
- Simultaneous assessment of materials and plant resources.
- Data rationalisation
- Data accuracy
- Elimination of duplication
- Standardised information
- Quick access to the information needed
- Better sharing of information
- Greater security

Measure contribution of IS

A	NO	Not sure if any attempt to do so would be meaningful.
B	YES	Accounting and management reports.
C	YES	Monthly report accounts.
D	YES	They have developed a balanced scorecard.

Information Systems support of Agility in small-medium manufacturing enterprises.

	Operating Systems	IS Application	Level of Satisfaction	Success Factor related to the operation of IS	Complexity of application
A	NT + Novell	JobShop	Worthwhile investment	Training is a key issue to ensure success of an IS application.	Easy to operate but reasonable complex.
B	NT/Windows98	RAD application Access	High level	Specific needs of the business are supported by the system.	Very simple application.
C*	AIX	Tetra CS3	Performance of the application has been fair, not good	Something that can be made bespoke to the organisation.	Relatively complex.
D	NT/Windows98	CINCOM	Poor level	Have to learn from past mistakes Set a group of teams -steering committee to make sure it works.	Very complex application.

*** IS investments are not seen to increase revenue**

Contribution of information systems to the organisation (issues rated as important or very important).

	A	B	C	D
Achievement of competitive advantage	A		C	D
Tasks that could not be done before	A		C	D
Applications seen as a distinct proprietary advantage		B	C	D
IS are seen to maintain competitive position	A		C	D
Employees accessing company-wide data	A	B	C	D
Increase electronic links with customers and suppliers	A	B	C	D
Value of information content of products		B		D
Working teams with access-wide to all data	A	B		D

Benefits sought from the acquisition of information systems (important).

	A	B	C	D
Reduce total number of transactions	A		C	D
Improve accuracy	A	B	C	D
Minimise obsolescence			C	D
Increase focus in planning and procurement	A	B	C	D
Support sales		B	C	D
Management of customer relationship		B		D
Reputation of the firm		B	C	D

Benefits from the implementation of their IS application.

A — Information is better and much easier as it was.
Lower WIP, better manipulation of stock figures and savings in purchasing costs.

B — Take responsibilities at different stages.
Merge data and present it in a different manner.
Information is common across the company.
Produce complex quotations, job sheets and spreadsheets.

IT/IS investments in participating companies.

	% of turnover invested in IT	People in the IT dept.	Proportion of the allocated to new inv.	% allocated to infrastrucuture	% allocated to planning	% allocated to execution	% allocated to others	% of COTS applications	% of RAD applications
A	2	1	10	20	20	20	40	100	0
B	3.7	5	80/40	65	5	25	5	20	80
C	0.6	2	0.4	50	40	0	10	100	0
D	4	3	NA	50	25	0	25	100	0

Above average.
— Acceptable in industry.

	IT strategy present	Personnel IT skills	Business/Manufacturing strategy
A	There is no IT strategy as such. Software purchases based on what are the perceived needs at the time.	— Poor quality training is more related to poor quality of data entry rather than human errors.	— Invest in machining equipment and provide the customers with innovative solutions for what they want
B	Use of the internet to find solutions to customer problems. Integrate the information into a new complete shared package.	— All employees are computer literate. Two training sessions and then learn when working with the system.	— Flexibility to respond to different customer needs while keeping the size of the company and looking for longevity in the market place.
C	Move to an ERP software that will link the company to a global organisation in the long term.	— People experience is more related to operate the system when there are big changes. People effort is responsible for the operation of the system.	— Minimise waste, stock control and time utilisation to become more efficient, become more agile. Maintain our competitiveness, respond to our customer requirements. Have the flexibility to meet future demands and ensure the profitability of the company.
D	Design of a company portal and start implementing an upgraded version of the CINCOM software.	— Knowledge of the people who use the system, very much dependent on people adapted to carry on operations. Experimenting, learning from past mistakes.	— Medium-complex manufacturer of components to the European manufacturing and assembly sites. Maintain annual sales growth of 20%. Divide the current site in 5 business units responsible for their own operations.

Adoption of performance schemes for participating companies.

D

Utilises six metrics to measure its performance:
- customer acceptance/reject rate; i.e. quality focus
- delivery schedule achievement; i.e. customer satisfaction
- value added; i.e. waste elimination
- employee training and development; i.e. employee involvement
- stock turns; i.e. inventory reduction
- floor space utilisation; i.e. smoother flow

APPENDIX F

MRP description

MRP is a set of computer programmes that are run periodically, usually once a week, to incorporate the latest schedule of production requirements, new information about current conditions, and updated schedules for component receipts. The programmes must be supported by accurate data in the numerous files of MRP to operate correctly. Details on the use of MRP systems can be found in the work of practitioners like Sartori (1988). This appendix explains the details of the operation of MRP based on the anonymous contributions of some academics.

Various types of information can be coupled by an MRP run, but basically MRP performs three important functions:

1. Order planning and control: when to release orders and for what quantity.
2. Priority planning and control: how the expected date of availability compares to the need date for each item.
3. Provision of a basis for planning capacity requirements and development of broad business plans.

Although MRP can be used in a variety of settings, such as distributed operations, job shops, and process industries, it is applicable primarily to companies performing fabrication and assembly of standard products. A diagram of an MRP system is shown in figure F.1.

On top of the diagram depicted in Figure F.1 there is a flowchart providing a general overview of MRP as means of co-ordinating and controlling purchasing activities to support manufacturing as well as the material and capacity requirements within manufacturing. The MRP programme performing the requirements calculation of the MRP technique, is the central focus of the initial input plans and the feedback loops. The flowchart also shows the types of information developed from these calculations and some of the files that must be accurately maintained to keep the system working properly.

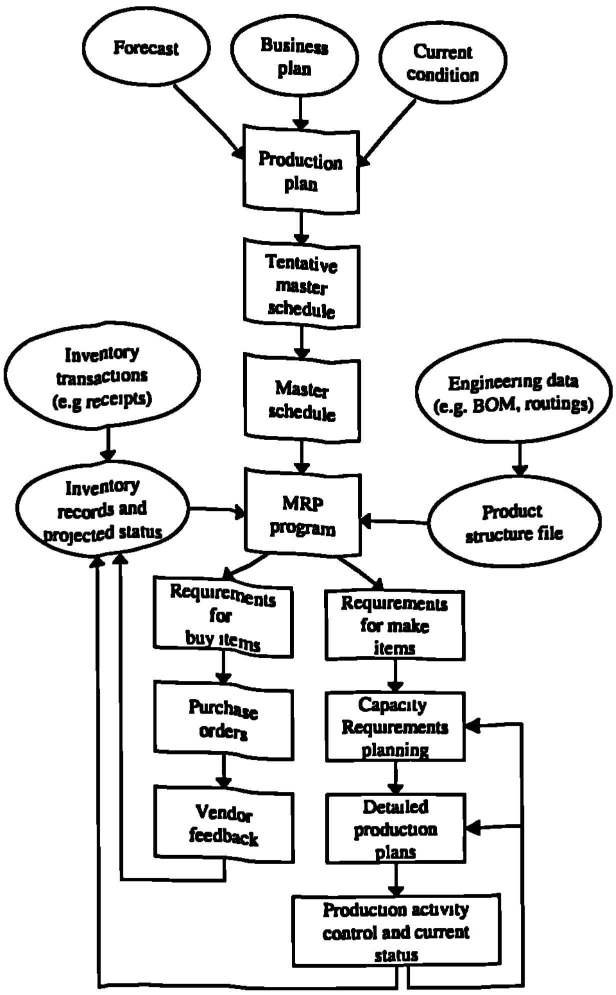


Figure F.1 MRP diagram

Top-level executives develop the business plan, which considers the co-ordinated overall operation of all functions in the company. The production plan represents manufacturing's responsibility in carrying out the business plan and states the number of units of each product family to be produced during each general time block, often a month, throughout the planning horizon.

Schedules under the direction of middle managers develop a more-detailed plan by converting the production plan into a master schedule that states the specific products to be produced in more-specific time periods, such as each week, for a horizon that typically extends for a year or more. The master schedule is the basic input that derives the rest of the system. The MRP programme develops even more-detailed plans by determining which specific components of all end items in the master schedule would have to be purchased or produced and when the orders to initiate these activities should be released.

When purchase orders are released to vendors, a delivery date is established. This information and information from follow-up contacts to vendors are fed back to provide the projected inventory status for these items. Similarly, information is fed back on the status or actual completion of orders for items to be produced internally. Feedback action brings actual progress into the new plans and is what "closes the loop" in closed-loop MRP. New plans are based on updated information of current conditions. The kind of information obtained from a MRP run may answer the following questions:

- What orders should be placed?
- What open orders should be expedited (indicated priorities)?
- What open orders should be cancelled or suspended?
- What order releases are planned for the future?
- Information for load reports (capacity requirements planning)?

It is obvious from this overview that MRP needs to be used in conjunction with numerous activities to keep a manufacturing site running efficiently.

The functionality of the information systems registered in the participating companies is depicted next:

I. **Company *A*.** A block representation of the information system currently being used in company *A* is depicted in figure F.2.

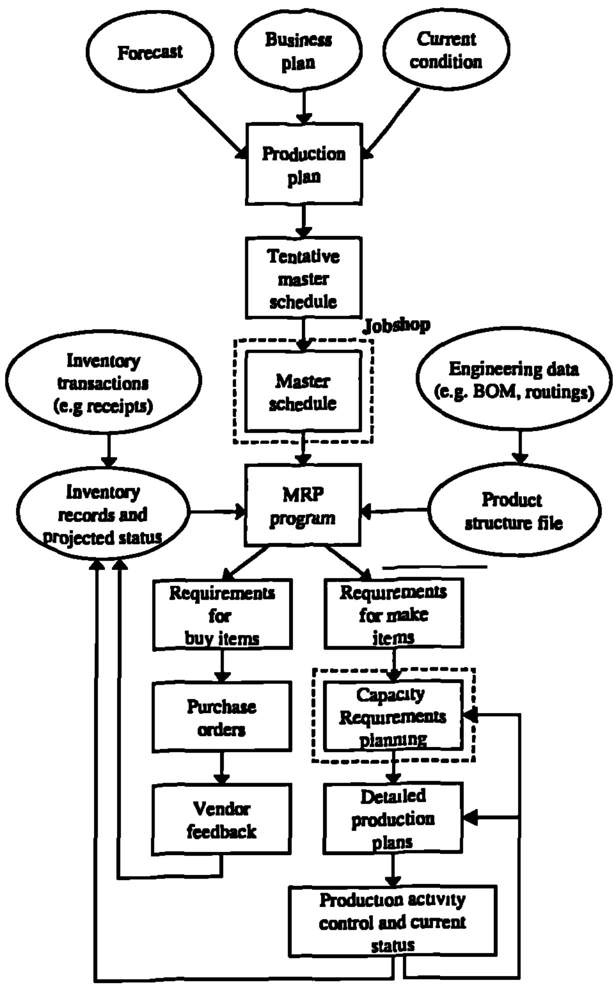


Figure F.2 IS in operation in Company *A*.

II. **Company *B*.** Figure F.3 depicts the system used in company *B*.

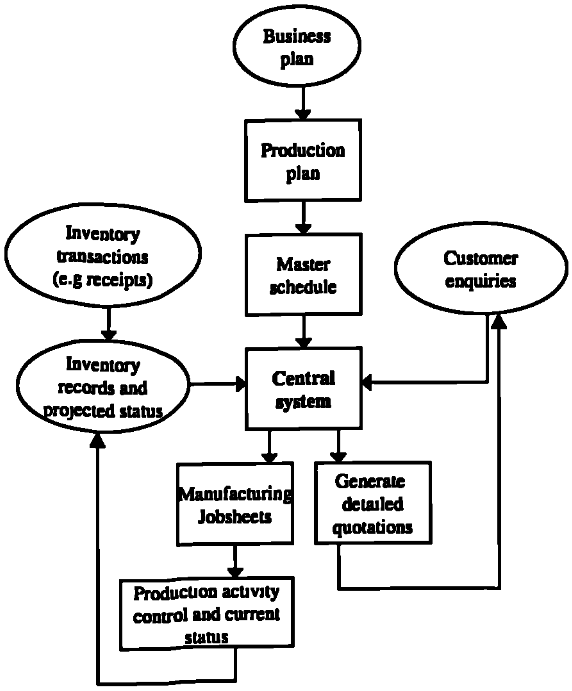


Figure F.3 IS in operation in Company *B*.

III. **Company *C*.** Figure F.4 depicts the system used in company *C*.

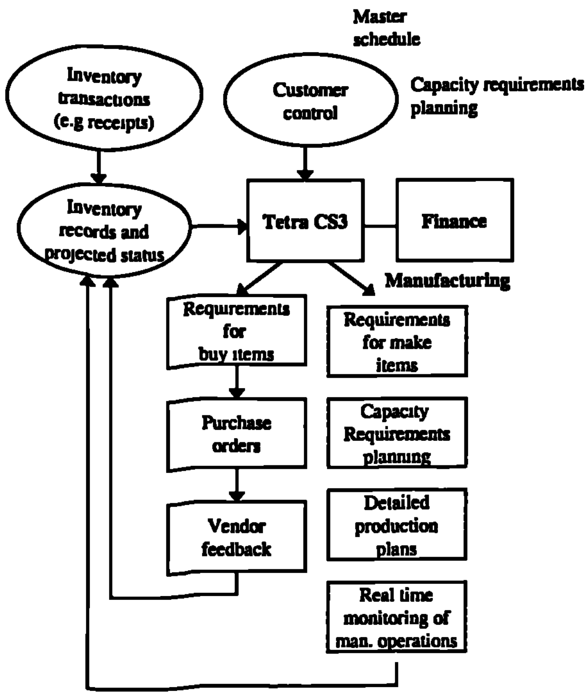


Figure F.4 IS in operation in Company *C*.

IV. **Company *D*.** Figure F.5 depicts the system used in company *D*.

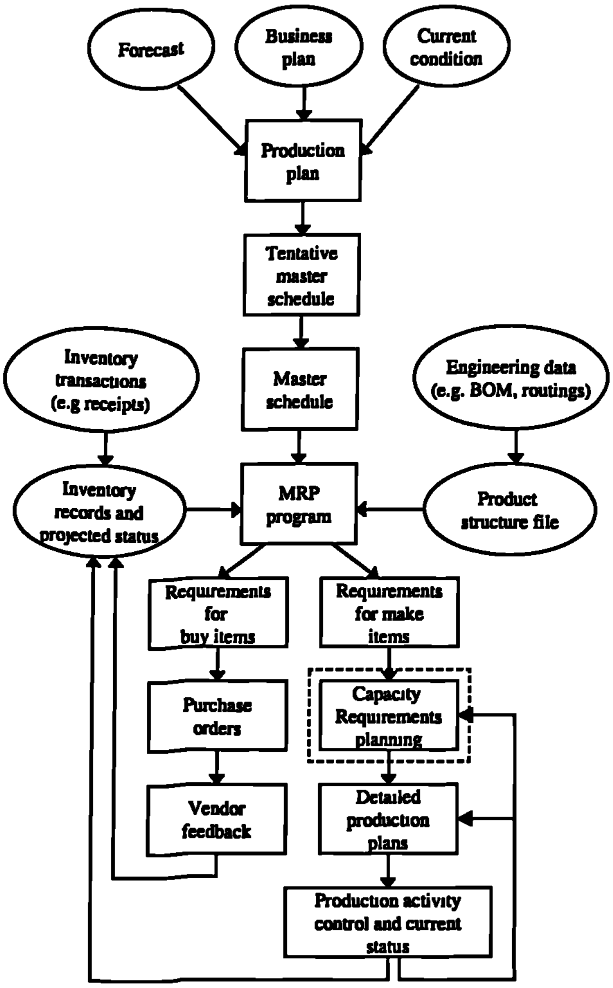


Figure F.5 IS in operation in Company *D*.