Agile Manufacturing

In UK Aerospace Manufacturing Small to Medium Size Enterprises

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PREFACE

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Abstract

The North West of the UK has been described as probably the most important centre of high technology outside the south of England. The aerospace sector is a major UK employer and accordingly, is an important part of the North West economy. However, the aerospace supply chain approach is changing, and that change impacts on the aerospace manufacturing small to medium size enterprises (SMEs) in the region. Many aerospace companies are claiming to be adopting both agile and lean manufacturing principles. Research has indicated that the knowledge and understanding of agility in aerospace is modest and consequently the difference between lean and agile is not well known.

This thesis aims to assess agile manufacturing within UK aerospace manufacturing SMEs. The specific objectives are derived to provide focus for the research activities, in order to fulfil the specific aim of the research in a structured and scientific manner. Following an extensive literature survey of agile manufacturing, other relevant manufacturing strategic frameworks, change management, response to change in manufacturing environments and aerospace SMEs a theoretical model of Agile Manufacturing within the UK aerospace SMEs has been developed.

The theoretical model of Agile Manufacturing within the UK aerospace SMEs was used to assess agile manufacturing in four UK aerospace manufacturing SMEs (case study organisations). From an evaluation of the case study organisations and comparisons with the theoretical model, the findings enhance the understanding of Agile Manufacturing theory, concepts and practice. Additionally, the theoretical model presented in this thesis is considered appropriate for use in other aerospace manufacturing SMEs and is presented as a holistic aerospace agile manufacturing assessment tool.

The research has shown the complexity and interrelationship between four agility enabling integrated sub-systems of agile manufacturing strategy, external motivators, organisational psychology and operational characteristics. The key findings of the research indicate that the case study organisations do not actively promote an agile manufacturing strategy that takes into consideration the organisational psychology and its influence on the performance of the operational characteristics of agility. Likewise, not all the external motivators of agility are considered when developing and deploying their organisations' strategies. Consequently, the role of the agile strategy process, teams and organisational change are considered as important issues that need addressing by these case study organisations.

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Glossary of Terms and Abbreviations

4M's	Method, Machine, Material and Manpower
4P's	Plant, People, Process and Product
4S's	Surroundings, Suppliers, Systems and Skills
5S's	Seiri (organisation), Seiton (orderliness), Seiso (cleaning-the act of), Seiketsu (cleanliness-the state of) and Shitsuke (discipline-the practice of)
AAQG	American Aerospace Quality Group
ACE	Achieving Customer Excellence (BAE Systems Initiative)
AMME	Aeronautical, Mechanical and Manufacturing Engineering (Department at the University of Salford, UK)
AQAP	Aerospace Quality Assurance Procedure
AQL	Acceptable Quality Level
AS	Aerospace Standard
ASCS	The Aerospace Sector Certification Scheme
ASME	American Society of Manufacturing Engineers
ASMM	American Society of Motor Manufacturers
BAD	British Aerospace Defence Ltd
BAe	British Aerospace Ltd (British Aerospace Systems)
BEM	Business Excellence Model
BPR	Business Process Reengineering
BSI	British Standards Institute
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacture
CANDO	Cleanliness, Arrangement, Neatness, Discipline and Order
CBI	Confederation of British Industry
CBM	Condition Based Monitoring
CE	Concurrent Engineering
CEO	Chief Executive Officer
CENTRIM	Centre for Research in Innovation Management (University of Brighton)
CI	Continuous Improvement
CIM	Computer Integrated Manufacture
CPI	Continuous Process Improvement
CMMS	Computer Maintenance Management System
CQI	Continuous Quality Improvement
CVP	Customer Value Process (Rolls Royce Initiative)
DFM	Design for Manufacture
DTI	Department of Trade and Industry (UK)
EBQ	Economic Batch Quantity
EDI	Electronic Data Interchange
EFQM	European Foundation for Quality Mnagement
EMS	Environmental Management System
EPSRC	Engineering and Physical Sciences Research Council
FMEA	Failure Mode and Effects Analysis

Glossary of Terms and Abbreviations

GKN	GKN Westland Industrial Products
H&S	Health and Safety
IMI	Innovative Manufacturing Initiative
IS	Information Systems
ISDN	Integrated Services Digital Network
ISO	International Standards Organisation
IT	Information Technology
IQA	Institute of Quality Assurance
JIPM	Japanese Institute of Plant Maintenance
JIT	Just-in-Time (manufacturing philosophy)
KBE	Knowledge Based Engineering
KBS	Knowledge Based System
LAI	Lean Aircraft Initiative
Lech	Luneside Engineering Company (Halton)
LCC	Life Cycle Cost
LEM	Lean Enterprise Model
LO	Learning Organisations
MA&A	Military Aircraft and Aerostructures
MI	Maintainability Improvement
MIT	Massachusetts Institute of Technology
MoD	Ministry of Defence
MP	Maintenance Prevention
NATO	North Atlantic Treaty Organisation
NWAA	North West Aerospace Alliance
NW	North West
OEE	Overall Equipment Effectiveness
OHSAS	Occupational Health and Safety Assessment Specification
OH&SMS	Occupational Health and Safety Management System
OU	Open University
PEST	Political, Economical, Social and Technical
PDCA	Plan, Do, Check, Act: (Deming or Shewhart Cycle)
PM	Planned Maintenance or Preventive Maintenance
PQCDSM	Productivity, Quality, Cost , Delivery, Safety and Morale
QA	Quality Assurance
QC	Quality Control
QFD	Quality Function Deployment
QMS	Quality Management System
RA	Research Assistant
RCM	Reliability Centred Maintenance

Glossary of Terms and Abbreviations

RR	Rolls-Royce
SBAC	The Society of British Aerospace Companies
SCRIA	Supply Chain Relationships in Aerospace
SEP	Supplier Excellence Programme (BAE Systems)
SSM	Soft Systems Methodology
SME	Small to Medium Size Enterprise
SMED	Single Minute Exchange of Die
SPC	Statistical Process Control
TCE	Thorsman and Company UK Limited
TEI	Total Employee Involvement
TPM	Total Productive Maintenance
TS	Technical Specification
TQC	Total Quality Control
TQM	Total Quality Management
UKLAI	UK Lean Aerospace Initiative
UKLEM	UK Lean Enterprise Model
USLAI	US Lean Aerospace Initiative
USLEM	US Lean Enterprise Model
VE	Virtual Enterprise
VR	Virtual Reality
WCM	World Class Manufacturing

CHAPTERS

Chapter 1 Introduction

1.1 Introducing the Research Framework

This thesis represents the documentation of research work carried out by the author within the Aeronautical, Mechanical and Manufacturing Engineering (AMME) department and in the School of Management at the University of Salford, TIME Research Institute during the period July 1998 to September 2001. The framework of the investigations for the research is underpinned by recognising the need for the UK aerospace manufacturing small to medium size enterprise (SME) sector to remain competitive in a global and changing market place and be aware of modern manufacturing management trends such as Agile Manufacturing. An earlier research study by Broughton *et al* (1997), for the UK Lean Aerospace Initiative (UKLAI) and Society of British Aerospace Companies (SBAC), has shown that the concept of agile manufacturing is not well known within in the aerospace sector.

Additionally, even though the Agility Forum (Dove, 1995 and 1996) indicated many manufacturing industries believe competitive advantage will belong to agile manufacturing enterprises much of the literature on the subject of Agile Manufacturing like Sharp *et al* (1998), Kidd (1997) and Booth (1996) generalises its concepts. Current literature therefore does not recognise the specific nature of the aerospace-manufacturing sector, which exemplifies a highly legislated and regulated business producing super high value product with a predominantly highly skilled and educated workforce as described by Bamber *et al* (1999).

Furthermore, although the concept of Agile Manufacturing is well defined in literature from experts like Youssef (1992), Kidd (1994), Goldman, Nagel and Priess (1994) and Gunasekeran (1997) there is little documented on the subject within the aerospace small to medium size manufacturing sector. Similarly, case study reviews of Agile Manufacturing are few and far between because the subject is relatively new (i.e. agile manufacturing conceived in 1991 by Goldman *et al* (1991) and an understanding of agility continues to be developed by Lehigh University's Iacocca Institute the originators of the concept through an ongoing pilot study survey Sutphin (1995). While, in the UK joint research by Sharp *et al* (1998) aimed to identify where "Best Practice" companies are in their quest towards agile manufacturing has attempted to

validate a theoretical model of agility, again the concepts used were nevertheless very generalised. Similarly at Brighton University within the Centre for Research in Innovation Management (CENTRIM) research is being funded by the Engineering and Physical Sciences Research Council (EPSRC) to develop the concepts of agility from principles to practice for general applicability to Small to Medium Sized Enterprises (SMEs). Certainly within both the US and UK research projects mentioned in this paragraph no aerospace manufacturing SME companies responded to any of the questionnaires used for data collection.

1.1.1 Related and Linked Research Initiatives

Although this research project aims to produce an original piece of work to fulfil the requirements of a PhD award, the work is not being carried out in total isolation. Several other initiatives are being pursued in closely related and in many ways linked research areas. For instance, the UK Lean Aerospace Initiative, supported by the Society of British Aerospace Companies (SBAC) and the Engineering and Physical Sciences Research Council (EPSRC) are seeking to develop a framework for the UK aerospace industry in which processes and sub-process models are generated together with appropriate performance metrics. The aim of the SBAC research co-ordinated by the Universities of Bath, Nottingham, Warwick and Cranfield is to enable the development of lean and agile manufacturing processes, Broughton *et al* (1997). The work by SBAC is based upon the Massachusetts Institute of Technology (MIT) Lean Aircraft Initiative (LAI) and the framework for the research is represented in the Lean Enterprise Model (LEM). The LEM is a systematic framework for organising and disseminating the research results of the LAI and is shown in Appendix I. The LEM framework encompasses lean enterprise principles and practices and is populated by research-based benchmarking data derived from surveys co-ordinated by MIT.

Research in the aerospace supply chain area is being co-ordinated by the Supply Chain Relationships in Aerospace (SCRIA) initiative which have produced documents and materials aimed at disseminating their work (Sigma, 1998). However only one of the participating companies for this PhD research are involved with the initiative even though SBAC (1999) have described the aim of the SCRIA research, which has been supported by the UK Department of Trade and Industry (DTI), as:

"To enhance the competitiveness of the UK Aerospace Industry by improving Supply Chain Relationships and the efficiency of the Supply Chain."

Additionally the focus of the SCRIA initiative is to improve the supply chain through a code of practice framework that encompasses; communication; design for manufacture; continuous improvement; supplier qualification and auditing; commercial agreements; and ethics (SBAC, 1999). There is no argument therefore that following the SCRIA codes of practice will enhance the competitiveness of the UK aerospace industry, it is however necessary to appreciate that the initiative does not specifically address agility of aerospace manufacturing SMEs.

Throughout the research project the author has maintained collaborative links with members of the above research programmes from the representing universities and research bodies. This collaboration has been made possible partly through the author's involvement as Research Assistant (RA) on an EPSRC funded project described below in section 1.1.2. These links have been useful in contributing to the development of the literature survey Chapter 2.0 and thus in gaining an understanding of the aerospace manufacturing sector from a wider perspective than would be obtained without this interfacing.

1.1.2 The EPSRC Research Work with Salford and Loughborough Universities

The aim of this section is to summaries the activities of the research work being carried out under the EPSRC grant funded project number IMI/A/05/004, (see Appendix II for the project abstract). The project goal is to develop a lean and agile manufacturing methodology for SMEs in the aerospace supply sector and as such is closely related to the research area of this thesis. The relevance of mentioning this EPSRC project is that the University of Salford employs the author as a full-time Research Assistant working under the supervision of Professor John Sharp one of the two lead investigators. The other lead investigator, Professor Mike Woodhead of the University of Loughborough is the project leader.

The project follows an ethnographic research methodology, as described in section 1.4.4.1, and allows the author as Research Assistant to work in close collaboration

with the partner SME companies. Furthermore the author can spend a considerable amount of time 'on site' collecting information that is both relevant to the requirements and aims of both the EPSRC work and the research aims and objectives of this thesis.

The EPSRC research aims to meet the objectives of the Innovative Manufacturing Initiative (IMI) key success factors of; reducing delays and interruptions in the supply chain; increasing flexibility of aerospace SME suppliers; and reducing the cost of supply chain partnering in order to improve the competitiveness of UK aerospace. The following objectives have been identified and are taken from the project abstract in Appendix II and presented here to show the reader the links, similarities and differences between this thesis and the EPSRC funded project.

1. To contribute to the UK LAI lean enterprise model through:
    (a) Elicitation of best practices in supply chain SMEs.
    (b) To identify appropriate performance metrics in SMEs thereby verifying the relevance of LEM metrics.
2. To facilitate effective customer-supplier integration.
3. To disseminate elements of best practice throughout the aerospace supply sector.
4. To aid aerospace SMEs to adopt generic best practice from the lean and agile manufacturing philosophies.
5. To contribute to the theoretical understanding of supply chain business processes in SMEs.

1.1.3 The Background of the Author (Researcher)

The researcher, also the author of this thesis, studied as an undergraduate mechanical engineer at the University of Central Lancashire in Preston, UK. After following an industrial apprenticeship focusing on steel fabrication and steel processing has worked mainly in manufacturing environments as production engineer, design engineer and quality manager and operations manager. This experience is within the automotive, truck and bus industry and office furniture manufacture at small to medium size enterprises (SMEs). This experience includes first hand working knowledge of Ministry of Defence (MoD) contracts and military parts manufacture and procurement processes.

In total this provides the author with over 16 years industrial experience within SMEs and in particular in the steel and sheet metal processing industry working within manufacturing environments. The author has also been consultant and business advisor helping SME companies implement quality management systems to comply with BS EN ISO 9000 series of standards. In 1997/8 as operations manager at Thorsman and Co. (UK) Ltd. (TCE), a Pan-European manufacturing organisation, the researcher was project leader with the task of ensuring the organisation's management system and practice complied to the requirements of ISO 14001 Environmental Management System Standard, leading to third party certification in 1998. Other responsibilities, within SMEs, have included management of Health and Safety, maintenance, continuous improvement projects, introduction of new technologies and product design and development and project leadership.

While employed by TCE the author studied part-time postgraduate level management courses at the University of Salford leading to the awards of advanced certificate in management, post graduate diploma in management studies and Master of Science in quality management. The author has successfully carried out research to identify factors affecting successful implementation of Total Productive Maintenance (TPM) leading to the development of a seven-step implementation program (Bamber, 1998). Several publications in journals have followed this TPM research establishing the author as a recognised writer in the field of manufacturing management (Bamber *et al* 1999a and Bamber *et al* 1999b).

1.1.4 The Role of the Author

The main method of data collection for the above research proposal is to use an ethnographic approach. This approach comprises the fairly prolonged immersion of the researcher (in this case the author of this thesis) in the context that is to be studied as described above. According to Bryman (1988) the purpose of ethnographic approaches or participant observation is to gain first hand knowledge of that context, primarily through observation of individuals as they go about their daily work activities. This process allows the author to participate indirectly in events within the case study organisations without having a formal work role and therefore elicit information from

the natural work place environment. This also allows the author agreed access to each of the case study organisations and therefore eliminates the problems some times associated with the negotiation of access to companies that could have been time-consuming and unsuccessful.

Furthermore, it is worth mentioning at this stage that access to the case study organisations has been agreed at the highest level within each organisation, thus the potential for eliciting information at all levels is argued as being increased. Hence many knowledge elicitation techniques as described by Firlej and Hellens (1991) have been employed within this research and are explained in section 1.4.3.1. in more detail. Additionally more detailed descriptions of the methods of data collection employed and discussion of the advantages and disadvantages is presented in sections 1.4 and 3.3 of this thesis.

1.1.5 The Economic Value of Northwest Aerospace SMEs to the UK

Mendros (1999), the chairman of the Northwest Aerospace Alliance (NWAA) indicates that the Northwest aerospace Small to Medium sized Enterprises (SMEs) have a combined total aerospace capability, which can provide components. Assemblies, software expertise, repair and overhaul, design or allied aerospace services. The Northwest (NW) regional aerospace area accounts for over a quarter of the total aerospace production capacity in the UK. This accounts for the NW region having an annual aerospace turnover of over £5billion, 75% of which is exported. Additionally the aerospace industry in the NW region employed over 60,000 people and continues to play a key role in the production of over 100 aircraft types (Mendros, 1999). These commentaries by Mendros highlight the important nature of NW aerospace SME companies to the national economy and hence gives reason, purpose and some validity to the choice of NW aerospace Small to Medium sized Enterprises in this research study.

On a nation wide basis research by the Society of British Aerospace Companies (SBAC) has shown that UK aerospace Small to Medium sized Enterprises achieved a combined turnover of £936 million in 1997 (Jandu, 1999). Figure 1.1 shows the SBAC analysis of the combined UK aerospace SME turnover in terms of sector and

destination of sales. In comparing figures from Mendros (1999) and Jandu (1999) UK aerospace Small to Medium sized Enterprises account for approximately one fifth of the Northwest aerospace industry turnover. This demonstrates the importance of aerospace Small to Medium sized Enterprises in the UK economy.

The pie charts shown in figure 1.1 indicate the important strategic positioning of the UK aerospace Small to Medium sized Enterprises. It also shows that these Small to Medium sized Enterprises are a substantial contributor to the UK economy. This and other research, such as commissioned by SBAC, outlined in Sigma (1998), stress the importance of Small to Medium sized Enterprises in the effectiveness and efficiency of the aerospace supply chain. Furthermore, Sigma (1998) showed that the old customer/supplier relationships can no longer be tolerated and improvements must be made to improve the aerospace supply chain performance.

The two largest aerospace companies operating in the UK, Rolls Royce and BAE Systems [both with major operations in the North West], mirror this view in current initiatives that are aimed at helping improve the supply chain and supplier performance (e.g. Supplier Excellence Programme at BAE Systems; Customer Value Programme at Rolls Royce) as described by Bamber *et al* (2001). The recognition that there is a need to improve the performance of the aerospace supply chain in the UK, hence the performance of the manufacturing Small to Medium sized Enterprises, in part, justifies the focus on Small to Medium sized Enterprises within this research thesis.

In terms of the number of people employed in them the North West may be seen to have a well above average representation in both high and medium high technology industries (see table 1.1). Accordingly, in 1999 more than 47,600 people or 8.4%, of Lancashire's employee jobs were within these sectors compared with 5.7% in Great Britain and 6.6% in the North West Region, of which 48,700 of these jobs are in aerospace. Restricting the comparison to employment in manufacturing alone, the high tech employee jobs comprised 13.8% of the Lancashire County manufacturing workforce compared with 8.9% in Great Britain. In these simple terms, the North West is probably the most important centre of high technology outside the south of England. .

	Lancashire		North West		Great Britain	
Sector	**No.**	**%**	**No.**	**%**	**No.**	**%**
Pharmaceuticals	1,200	0.2	13,100	0.5	62,400	0.3
Office Machinery & Computers	700	0.1	2,400	0.1	51,400	0.2
Electronics-Communications	1,900	0.3	8,300	0.3	121,900	0.5
Aerospace	13,600	2.4	24,800	0.9	111,500	0.5
Total "High Tech"	17,300	3.1	48,700	1.7	347,100	1.4
Chemicals	6,300	1.1	38,200	1.4	177,500	0.7
Non-Electrical Machinery	10,500	1.9	38,900	1.4	356,600	1.4
Electrical Machinery	4,900	0.9	21,400	0.8	177,000	0.7
Scientific Instruments	1,500	0.3	10,300	0.4	131,800	0.5
Motor Vehicles	7,000	1.2	26,600	0.9	205,700	0.8
Other Transport Equipment	200	0.1	1,700	0.1	18,200	0.1
Total "Medium High Tech"	30,300	5.4	137,100	4.8	1,066,600	4.3
TOTAL HIGH TECH	**47,600**	**8.4**	**185,800**	**6.6**	**1,413,800**	**5.7**

Table 1.1: Employment in high and medium high technology industry, 1999 - number and percentage of total employee jobs (from Kivel, 2001)

As shown in table 1.1, the above-average share of high tech employment is due to the dominating presence of aerospace manufacture in the Lancashire County and North West. This industry accounts for 78% of local high tech jobs in Lancashire alone (against 32% in GB at large) or 28% of the "high tech" and "medium high tech" jobs combined. Kivel (2001) has said that in practice, the local importance of this particular sector in high tech industry is certainly much greater than these statistics imply. High levels of out-sourcing by both the aerospace primes and their first-tier suppliers supports a large "hidden aerospace" sector in the County of sophisticated advanced engineering services, design and testing and information technologies not themselves classified to aerospace but which are effectively an integral part of the sector. This probably accounts for the Northwest figure of employed in aerospace of 60,000 provided by Mendros (1999).

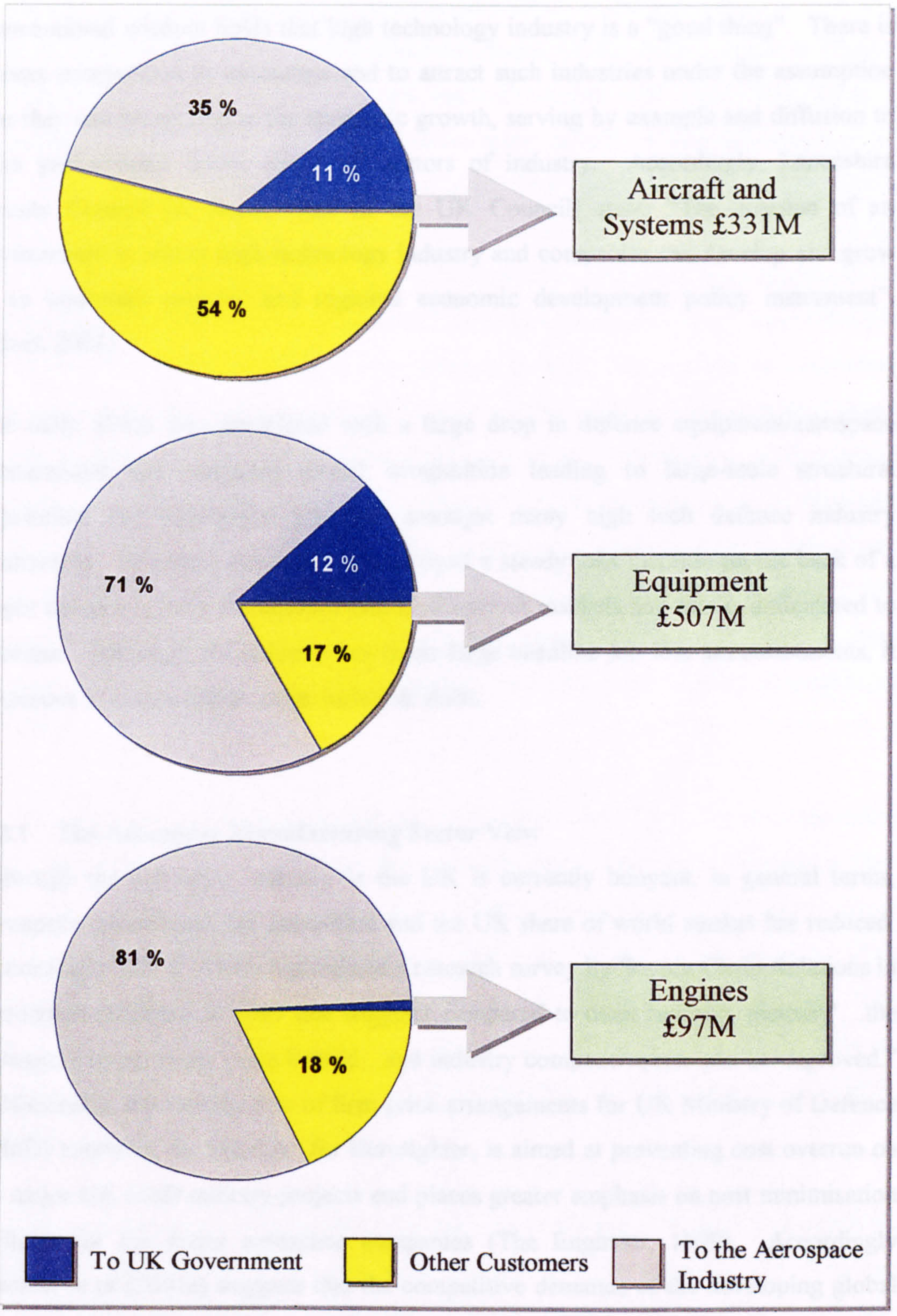

Figure 1.1: UK aerospace SME turnover by sector and destination, 1997

(Source; SBAC 1999)

1.2 The Need for the Research Project

Conventional wisdom holds that high technology industry is a "good thing". There is intense competition to encourage and to attract such industries under the assumption that they can be an engine for economic growth, serving by example and diffusion to raise performance levels across all sectors of industry. Accordingly, Lancashire County Council [A North West of the UK Council] state: "The creation of an environment in which high technology industry and companies can develop and grow is an important national and regional economic development policy instrument", (Kivel, 2001).

The early 1990s was associated with a large drop in defence equipment/aerospace procurement and increased global competition leading to large-scale structural adjustment and substantial job cuts amongst many high tech defence industry contractors. However, Aerospace has enjoyed a steady jobs increase on the back of a major up-turn in both the military and civil aircraft markets and this is anticipated to continue. Although the industry has made large headline job loss announcements, it continues to recruit higher order technical skills.

1.2.1 The Aerospace Manufacturing Sector View

Although the aerospace industry in the UK is currently buoyant, in general terms, aerospace competition has intensified and the UK share of world market has reduced. Accordingly SBAC (1999) highlighted a research survey by Supply Chain Relations in Aerospace (SCRIA) in 1997 that suggests compared to other industry sectors "...the aerospace sector is ten years behind...and industry competitiveness can be improved." Additionally, the introduction of firm price arrangements for UK Ministry of Defence (MoD) contracts, for example, for Eurofighter, is aimed at preventing cost overrun on 25 major UK MoD military projects and places greater emphasis on cost minimisation policies for the major aerospace companies (The Engineer, 1999). Accordingly Bamber *et al* (2001a) suggests that the competitive demands of the developing global aerospace manufacturing market have resulted in considerable change within the lower tiers of the UK aerospace manufacturing supply chain.

In the UK, many prime contractors and first-tier suppliers, such as BAE Systems, Rolls Royce and Lucas are continuing to develop an interest in the application of lean and agile manufacturing processes, (Woodhead and Sharp, 1998). BAE Systems at Warton and Salmesbury have reported a great deal of success with their Total Quality Management (TQM) initiative which includes many aspects of lean thinking such as team-work, waste reduction and focus on right first time production (CQI, 1994). Similarly, British Aerospace Defence Limited (BAD Ltd) at Lostock are working toward a World Class Manufacturing (WCM) initiative which has been successful in increasing throughput, reducing inventory and lead times and improving schedule adherence (DTI 1990). These improvements at BAD Ltd, aimed at increasing customer satisfaction include the use of Concurrent Engineering, Integrated Production Teams working with Kanban to achieve a 'Just-in-Time' environment with a heavy emphasis on Continuous Improvement through people involvement. In Northern Ireland Short Brothers, a manufacturer of aerostructures, wings, fuselage barrels, flight control surfaces, engine nacelle systems and defence systems employs over 7,000 people have fervently followed quality management initiatives and have attained "Award Winning" status from the European Foundation for Quality Management (EFQM).

Recent aerospace initiatives include many of the concepts of the lean manufacturing philosophy as described in detail by Womack and Jones (1996) including just in time (JIT) and Total Productive Maintenance (TPM) principles. For instance Short Brothers, (Anon. 1997), have published a major success story from adopting TPM manufacturing programme; and it is well known (Woodhead *et al*, 1998) that Rolls Royce and BAE Systems are actively aiming at reducing their supplier base as suggested by advocates of JIT and Lean Manufacturing such as: Cheng *et al*, (1996); Mondon, (1993) and Bicheno, (1994).

Furthermore marketers have predicted an increase in the sales of small and relatively inexpensive military aircraft brought about through global competition (i.e. BAe and SAAB collaboration) and niche marketing of planes, such as the "Hawk lead in fighter training" and the Grippen, to third world and developing countries as discussed by Gavel (1998) in a Northwest newspaper article.

In order to remain competitive in a global market the improvement efforts within UK aerospace manufacturing throughout the supply chain are focused primarily on cost reduction and supply chain lead-time reduction (Bamber *et al*, 2001a). This focus creates an emphasis on response time to manufacture, schedule adherence, improvements in integration of management systems and a need for the lower tier aerospace small to medium size Enterprises (SMEs) to collaborate or partner with other companies. The above mentioned and similar initiatives have not brought about the benefits required in a globally competing aerospace manufacturing sector, hence Lockhead Martin, Boeing, BAE Systems, Short Brothers and Rolls Royce are looking toward the latest manufacturing paradigm, agile manufacturing (Broughton *et al*, 1997). Research evidence is indicating that the "prime" aerospace companies are considering, and in some instances already adopting the principles connected with concurrent engineering, supply chain involvement and virtual partnering to varying degrees of success (Handley, 1997; Cooper *et al*, 1999). The influence of these "primes" coupled with the forecasted increases in civil aircraft manufacture; and potential entry from Far East competition (Whalley, 1999) in a business environment of fierce global competition and dynamism (Ellerker, 1998); all suggests that considerable change for the aerospace manufacturing SME companies in the UK is inevitable.

1.2.2 UK Manufacturing Competing in a Global Market

Skinner (1969) outlined his beliefs that the manufacturing function should be able to contribute to the strategic goals of an organisation. Skinner considered back in 1969 that manufacturing was the missing link in corporate thinking. He believed that manufacturing be viewed with as much importance as other corporate functions such as marketing, accounting and sales. A common view categorised manufacturing as that of a mundane work life typified with a never changing daily routine on the one hand and a low educational standing and low perception of value in terms of the job market and later career development on the other hand. As Skinner (1969) so clearly stated many see the job as involving; "...grubby routine, where days are filled with high pressure, packed with details and limited to low level decision making – all of which is out of the sight and minds of the top level executives." Despite these prevalent views, Skinner believed that by realising the positive contribution

manufacturing could make to the overall business, a lasting, sustaining competitive advantage could be achieved.

The Department of Trade and Industry (DTI) supported by the Confederation of British Industries (CBI) nevertheless have attempted to facilitate the improvements of UK manufacturing through their managing the 90's project and Best factory awards (DTI, 1990). Additionally, Gilgeous and Gilgeous (1999) have reported that in the last five years many improvements have been made within the UK manufacturing sector. However, Al-Rasby (1996) on surveying a broad sample of UK manufacturers indicates that only a third of the companies have a proactive manufacturing function. While, Desai (1998) suggests from a large survey of DTI companies the concepts of Agile Manufacturing are well understood but nevertheless not entirely applied. Therefore recent research evidence indicates, no matter what progress has been made to improve and develop the understanding of manufacturing as an important aspect of business and strategy, for some UK organisations, manufacturing still takes a back seat.

1.2.3 An Opportunity to Learn/Advancement of Knowledge

Agile manufacturing theory as discussed in section 1.1 has to date been very general and hence non-specific in its coverage of industry sectors. Furthermore studies of agile practice have also been very general, with a few exceptions, and very little research has been specifically set out to assess agility in Aerospace Small to Medium sized Enterprises. Moreover as discussed in section 1.1 research carried out by Broughton *et al* (1997) identified within the aerospace manufacturing sector as regards an understanding of agile manufacturing concepts a knowledge gap. Hence this knowledge gap that currently exists is not satisfied by either existing literature or current research. This thesis and research provides a genuine opportunity to advance existing knowledge and hence to learn about agile manufacturing in UK Small to Medium sized Enterprises. Figure 1.2 represents this knowledge gap between the available agile theories, practice and research, which are predominantly generalist, and agility in theory, practice and research specifically within UK aerospace Small to Medium sized Enterprises (SMEs).

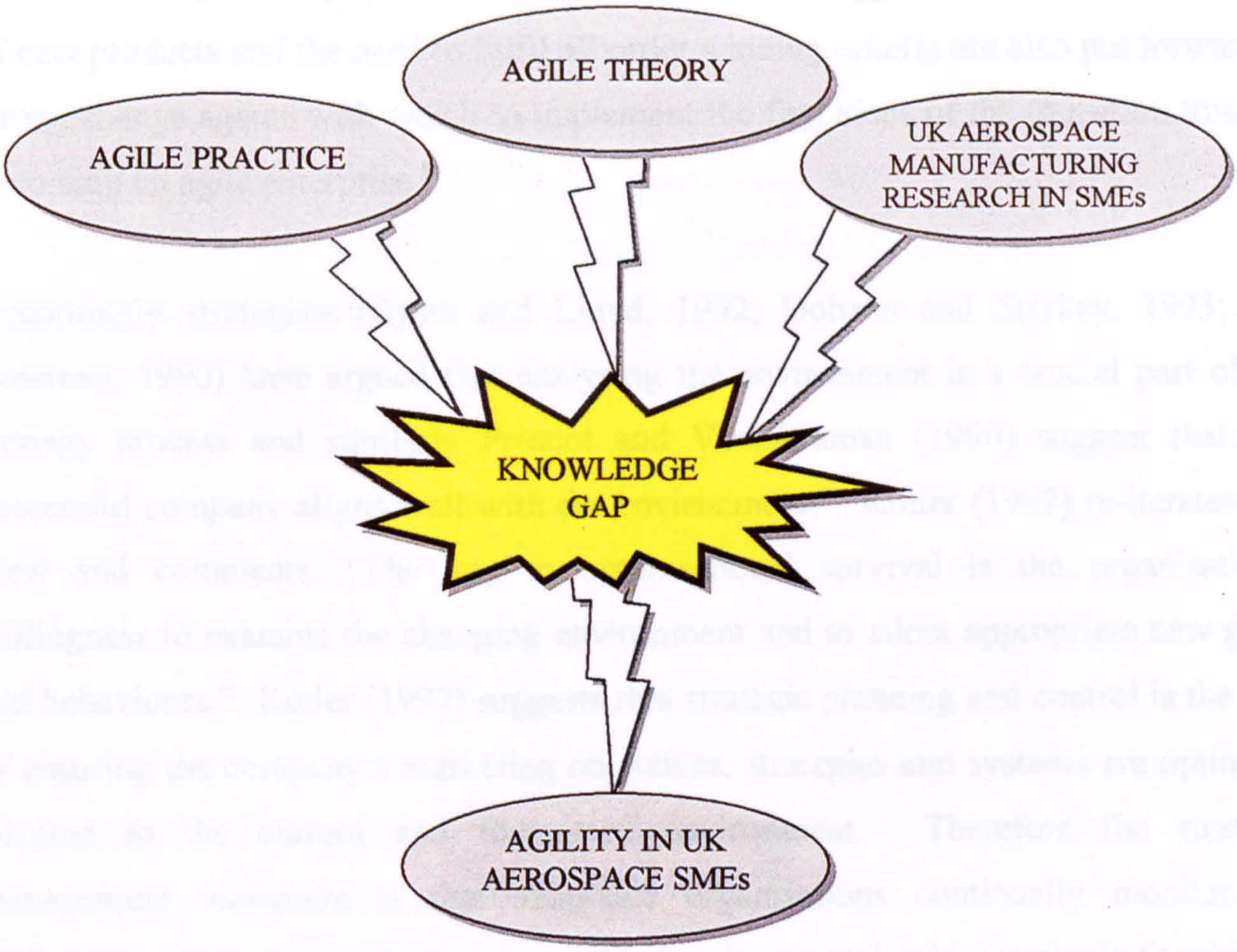

Figure 1.2: A schematic representation of the knowledge gap

From figure 1.2 it can be seen that because a knowledge gap actually exists then providing the research carried out within the thesis is valid then the outcome of the thesis will undoubtedly represent an original contribution to knowledge as described by Francis (1976) and Phillips (1991). The actual contribution to knowledge, and therefore the significance, of this research is discussed later in chapter 5 and chapter 6 within the discussion and conclusions to this work.

1.2.4 Global Benefits of the Work

The discussion in this section describes in essence the reasons that drove the American government to actively pursue research into a new manufacturing paradigm that is aimed at enabling the US to compete and outrival others in an environment of change, uncertainty and unpredictability as described by Goldman *et al* (1991, 1991a and 1991b). Furthermore this section considers the global environment as described by Woodhead *et al* (1998) that aerospace Small to Medium sized Enterprises are now

operating within, one that is buoyant but nevertheless fiercely competitive. Phillips (1999), a British Aerospace Airbus employee, likewise suggests that the "Development of new products and the need to fulfil all order winning criteria are also put forward as strong change agents with which to implement the first steps of the transition towards becoming an agile enterprise."

Accordingly strategists (Byars and Lloyd, 1992; Dobson and Starkey, 1993; and Bowman, 1990) have argued that analysing the environment is a crucial part of the strategy process and similarly Prescot and Venkatraman (1990) suggest that: "A successful company aligns well with the environment." Kotler (1997) re-iterates this view and comments: "The key to organisational survival is the organisation's willingness to examine the changing environment and to adopt appropriate new goals and behaviours." Kotler (1997) suggests that strategic planning and control is the task of ensuring the company's marketing objectives, strategies and systems are optimally adapted to the current and forecasted environment. Therefore the strategic management viewpoint is that adaptable organisations continually monitor the environment and attempt through strategic planning to maintain a strategic fit with the evolving environment.

Clarke-Hill and Gliester (1992) likewise suggest that the environment requires that political, economical, social and technical (PEST) aspects are considered. While, Porter (1980) considers that the five forces behind industry competition determine the intensity of competition in an industry environment. The five competitive forces are:

1. The threat of new entrants.
2. The bargaining power of buyers.
3. The bargaining power of suppliers.
4. The threat of substitute products or services.
5. The extent of rivalry among existing competitors in the industry.

However, Peters (1988) suggested that predictability is a thing of the past because strong global competition, changing and developing customer needs and expectations, technological advances, the changing economic environment, a more accessible but complex global marketplace, legal, legislative and socio-cultural influences are

prevalent in today's business. Recognition and consideration of these uncontrollable variables has nevertheless continued to be the focus of strategic management, but in this volatile world it is suggested here that only the foolish believe they can accurately predict or forecast the future. Additionally, Cambell and Yeung (1995) have said that to achieve a purpose in competition with other organisations, there needs to be a strategy, which provides commercial logic. Therefore it is suggested the role of manufacturing is to contribute to organisational strategy through the adoption and continued facilitation of agile principles.

The argument presented by this thesis is hence, that the UK aerospace Small to Medium sized Enterprises need to adopt the principles of agile manufacturing and further collaborate with the "primes" to continue to compete in a global market place as discussed in section 1.2.2. Therefore the aims of this thesis research as described in the following section 1.3 are developed with this argument in mind while the objectives outlined in section 1.3.3 have been put together to specifically address the knowledge gap outlined in section 1.2.3.

1.3 The Aims and Objectives of the Research Project

1.3.1 The General Aim and Type of Research

The general aim or purpose of conducting this research as outlined in section 1.2.3 is to generate more knowledge and understanding and hence build upon existing Agile Manufacturing theories based on the research findings. Therefore the aim is not to apply the findings of the research to specific problem areas within either manufacturing organisations, the aerospace sector or for that matter to any of the case study organisations represented in this project. The aim is to provide a deeper understanding of the concept of Agile Manufacturing in the environments of the case study organisations.

Consequently the findings of this research are intended to contribute to the building of knowledge of Agile Manufacturing with particular reference and emphasis to UK aerospace Small to Medium Sized Enterprises (SMEs). Hence the type of research carried out within this project is considered as pure research, basic research or fundamental research as described by academic research experts such as Robson

(1998) and Phillips (1991) even though the case study approach is used. More specifically the aim of the research is presented in section 1.3.2 below.

1.3.2 The Specific Aim of the Research

The specific aim of this research project is given in the following statement:

To assess agile manufacturing within UK aerospace manufacturing small to medium size enterprises (SMEs).

1.3.3 The Specific Objectives of the Research

The specific objectives of this research have been developed from the aim of the project as specified in the above statement. These specific objectives are derived to provide focus for the research activities in order to fulfil the specific aim of the research in a structured and scientific manner.

The specific objectives of this research are defined as:

1. To gain a theoretical and critical understanding of the following through a survey of relevant literature (see detail in section 1.3.4):

   - Agile Manufacturing.
   - Other relevant manufacturing strategic frameworks.
   - Change management and response to change in manufacturing environments.
   - Small to Medium Size Enterprise in the UK.
   - Aerospace Small to Medium Size Enterprise.

2. From the theoretical and critical understanding obtained from the literature survey develop a theoretical framework or conceptual model of Agile Manufacturing within the UK aerospace small to medium size enterprises.

3. With reference to the theoretical framework or conceptual model of Agile Manufacturing within the UK aerospace small to medium size enterprises assess

agile manufacturing in an appropriate number of UK aerospace manufacturing SMEs (case study organisations).

4. From an evaluation of the case study organisations and comparisons to the theoretical framework or conceptual model develop the findings into a theoretical generic aerospace SME Agile Manufacturing model (the theoretical model).

5. Provide a complete and detailed discussion of the developed theoretical model which shall:

- Include a framework for agility in the aerospace manufacturing sector with the focus and main relevance to UK aerospace SMEs.
- Enhance the understanding of Agile Manufacturing theory, concepts and practice.
- Have the ability to be an assessment tool for agile manufacturing in UK aerospace SMEs.

1.3.4 Aims of the Literature Review

The aim of the literature review is to enable the development of a theoretical framework or a conceptual model that represents the features of agile manufacturing that are most likely present in an aerospace UK manufacturing small to medium size enterprise. To this end the literature survey includes the essential theories, concepts and developments of agile manufacturing that are relevant to the focus of the research aim as expressed in section 1.1. Included, therefore in the literature survey is a short review of the antecedents of modern manufacturing management leading to Agile Manufacturing. Additionally, other related philosophies and concepts of manufacturing management such as lean manufacturing, world class manufacturing, strategic management, total quality, learning organisations and change management are reviewed to assess their implications and relationship to Agile Manufacturing.

The literature survey, as would be expected, critiques the works of the experts in Agile Manufacturing thus providing a major input into the theoretical model. However, to ensure the theoretical framework or conceptual model is relevant to the UK aerospace manufacturing SME sector other avenues of the survey include a review of published

work on UK aerospace management practice, strategy, change management and performance measurement. Likewise, a review of current theoretical and implementable manufacturing aerospace models such as the UK aerospace lean enterprise model (UKLEM) and work carried out within the framework of the Supply Chain Research in Aerospace (SCRIA) initiative has been included.

Overall the aims of the literature review shall provide an extensive but relevant critique of available theory that will enable the aim as described in section 1.3.2 to be achieved both successfully and effectively. In summary the literature review presented in chapter 2.0 is the documentation of a comprehensive critique of relevant published and unpublished work, the aims of which are to ensure that:

- Important variables of Agile Manufacturing in the UK aerospace SME sector are not left out of the research study.
- Clarity and precision of the research objectives are established and hence aims of the research met.
- Focus of the study is maintained and the research does not 're-invent the wheel.'
- An in-depth knowledge of Agile Manufacturing within the UK aerospace manufacturing sector is demonstrated.
- A good logical, well argued critique of existing research publications is provided.
- A foundation is provided for the development of a conceptual model of Agile Manufacturing in UK aerospace manufacturing SMEs adding to the solid body of existing knowledge of Agile Manufacturing.

1.4 The Research Methodology

1.4.1 A Critique of the Case Study Research Method

This section discusses the reasons for adopting the case study research approach for this research thesis and argues the efficacy of such an approach with reference to how the adopted research method has considered improving validity and enhancing the generalisability of the findings. Additionally, the approach adopted with a planned and systematic framework is argued as providing appropriate rigour and parsimony to the

research techniques to give confidence in the reliability of the findings leading to the research discussions and conclusions.

Accordingly Bell (1993) develops an argument that the case study approach is particularly appropriate for individual researchers because it gives an opportunity for one aspect of a problem to be studied in depth within a limited time scale. Bell (1993) also indicates the great strength of the case study method is that it allows the researcher to concentrate on a specific instance or situation and to identify, or attempt to identify, the various interactive processes at work. This supports adoption of the case study method for this research project because as discussed in chapter 1.0 the research has predominantly been carried out within the constraints of working toward fulfilling the requirements of a PhD as outlined by this theses and to fulfil the requirements of an EPSRC funded research project in a closely related area.

As in all research, the evidence in this case study approach is collected systematically, the relationship between variables is studied and the study is methodically planned. The number of case study organisations chosen has been purposefully kept to a minimum to be able to provide rich and valuable data under the resource and time constraints as expressed in section 1.1.4. In contrast to this approach, Bromley (1986) explains processes may remain hidden in a large-scale survey using data from large numbers of organisations but may be crucial to the success or failure of systems in organisations. Hence, focus on a few aerospace Small to Medium sized Enterprises (SMEs) that supply product to most of the top aerospace organisations in the world (e.g. Rolls Royce, Lockhead-Martin, British Aerospace, Lucas and Shorts) is likely to provide crucial and valid data.

Each organisation has it's common and unique features and consequently the case study researcher aims to identify such features and to show how they effect the implementation of systems and influence the way an organisation functions. According to Yin (1994) case study research is concerned with the interaction of factors and events and, as Nisbett & Watt (1980) point out: "Sometimes it is only by taking a practical instance that we can obtain a full picture of this interaction." Though observation and interview are most frequently used in most case study research, Nisbett and Watt in the above statement indicate no technique should be excluded

without due consideration. Therefore a range of methods for collecting information as shown in table 1.2 are discussed for assessing, agile manufacturing in aerospace small to medium sized enterprises, in section 3.2 and hence considered as potentially appropriate for fulfilling the aims as outlined in section 1.3 of this PhD thesis.

Additionally, critics of the case study approach used to study manufacturing organisations such as Blau *et al* (1976), draw attention to some problems posed by this research method, namely they point out the fact that generalisation is not usually possible and question the value of the study of single events. Many of these critics suggest it is difficult to cross-check information and say there is always the danger of distortion. However, as suggested by Bryman (1998 and 1995), the generalisability of the research may be enhanced when using a second case or a multiple case study approach to research, and comparisons allow the special features of cases to be identified much more readily. Consequently, the method advocated by many case study researchers is an approach that includes cross-checking and would use more than one method of data-collecting. This multi-method approach is described as triangulation in the Open University course E811 and described as: -

> *"Cross-checking the existence of certain phenomena and the veracity of individual accounts by gathering data from a number of informants and a number of sources and subsequently comparing and contrasting one account with another in order to produce as full and balanced a study as possible."* (OU course E811: 1988).

The main restrictions or constraints posed by the triangulation method are the time and resource factors; therefore the extent of data-collection is influenced by the amount of time available to complete the research and the number of researchers available to help collect meaningful data. In consideration of these points of view and in particular to enhance the generalisability of the research findings, for aerospace SMEs, a multi-case study approach is used within this project. The central case study organisations used during the research are outlined in Chapter 4 and further cross-checking is achieved through a survey and analysis of published case study research papers on relevant topics. The discussion chapter, Chapter 5, critiques further aspects of validity, efficacy, generalisability, reliability and appropriateness of the approach used to collect data and information.

1.4.2 Alternative Methods to the Case Study Approach

Although in Section 1.4.1 it is considered that case study is an appropriate method of research for organisational study this is not the only method available to researchers wishing to use a scientific approach within organisations. Other organisational research approaches are discussed by Sekeran (1997), Robson (1998) and Bryman (1995) and include the methods of: - Action Research: Survey Research; Qualitative Research; Experimental Research; Field Research and Meta-Analytic studies. Each of these methods present benefits in organisational research.

However, because of the constraints outlined in sections 1.1 and 1.4.1 combined with the limited source of existing rich data (agile manufacturing as a concept being relatively new and aerospace case studies not prolifically documented, see literature review chapter 2) these methods are seen as inappropriate for the aims of this research. For example, with meta-analytical techniques large amounts of existing published data is needed, while with action research the research is 'involved' and looks at effects and impacts of advised lines of action. The former example is obviously not appropriate because of the lack of primary published data and the latter is not possible because of time and organisational constraints imposed on the research activities.

1.4.3 The Research Outline

The aim of the research design is to satisfy the research aims outlined in section 1.3 and as described in section 1.4.1 and 1.4.3 use the case study method. This should lead to an opportunity to identify other issues for future work both academic and applied to organisational settings. The research design also takes into consideration the time scale imposed by the EPSRC funding arrangements (although this is irrelevant for PhD work is an important practical consideration) and by the case study organisations. Of course, minimum interference within the organisations is expected as this research is not action research based, however the findings and consequent proposals may lead to this as future work.

The research design is broadly analogous to an approach that is advocated by Bryman (1995) shown in Figure 1.3. Although this method is considered a qualitative approach to organisational research, the essentials of this research process resemble a scientific approach to the conduct of research and are appropriate for organisational study. Thus, this provides the framework for a systematic approach and the methodology adopted in the research design is appropriate for assessment of agile manufacturing within UK aerospace SMEs and development of a generic aerospace agility model appropriate for UK aerospace SMEs. Figure 1.4 represents a schematic of the approach adopted in this research and entitled thesis research design.

The conceptual model that is developed from the theoretical studies as shown in figure 1.4 is proposed as a model of agile manufacturing in UK aerospace SMEs, this is described in more detail later in Chapter 3 and is encompassed in the theoretical framework. The theoretical framework is at the core of the research and for the reader of this thesis provides a description of the conceptual model of agility in UK aerospace SMEs. The conceptual model has led directly to the generation of agile aerospace small to medium sized enterprise assessment tools and techniques as detailed in section 3.2, which has allowed, as shown in figure 1.4, the development of the observation and data collection methods used within the case study organisations for this thesis.

1.4.4 Research Methods (Data Collection and Sources of Data)

The term research method is used in this section to describe data collection and data sources used within the research activities adopted in compiling this thesis.

Bryman (1995) makes a distinction between research designs and research methods (or techniques of data collection). Accordingly research design is the overall structure and orientation of the investigation, which provides a framework within which data are collected and analysed. While particular designs tend to be associated with particular methods of data collection, a distinction is useful because one does not necessarily imply the other. The chief research designs and methods in organisational research are presented in table 1.2 and sections 1.4.3 to 1.4.5 provide an overview of the research method and design adopted for this research thesis.

	DESIGNS		METHODS
D1	Experimental (major distinctions : laboratory & field experiments & quasi-experiments)	M1	Self-administered questionnaire
D2	Survey (including longitudinal survey design)	M2	Structured interview
D3	Qualitative research	M3	Participant observation
D4	Case study	M4	Unstructured interviewing
D5	Action Research	M5	Structured observation
		M6	Simulation
		M7	Archival sources of data

Table 1.2: Chief research designs and methods in organisational research (Source : Bryman, 1995)

Self-administered questionnaires (M1) are collections of questions that the respondent completes on his or her own, an example of which is discussed in section 3 [the agile operational characteristics matrices]. Another method of collecting information from individuals which has been used extensively in this research is the structured interview (M 2), a collection of specific and precisely formulated questions which are asked of a respondent by the interviewer. On the other hand unstructured interviews are carried out in a very informal way, allowing respondents considerable latitude in what they say, these two types of interview technique are used extensively in this research and contribute to the discussion in the case study organisation sections.

A technique adopted which involves the researcher spending a period of time observing particular activities within the organisational setting and context used within this research is participant observation (M3). This is a major method used in this research because the researcher being a full-time member of the EPSRC funded project as described in section 1.1.2 has reasonable autonomy and access to situations and events within the case study organisations. Likewise, there is scope for structured observation (M5) to predetermined schedules providing the opportunity for the researcher to record more specific events. Accordingly use of knowledge elicitation

techniques is a major part of this data gathering for this thesis as described in further detail in section 1.4.4.1.

Additionally, a major source of data available is archival information (M7) from the notes, minutes of meetings, project plans, and presentation materials, records of process measurement and procedure documentation. This information accrued both within the framework of the strict regulatory and traceability requirements imposed in the aerospace sector, mainly for safety reasons, and additionally other relevant activities that provide historical documents, contemporary records and existing statistics. For instance, the BS EN ISO 9002: 1994 Quality Management System and financial and operational measures of performance are good sources of archival information.

In the "research field" adopted by this research it is important that the case study personnel understand the questions asked of them from whatever approach is used to elicit knowledge. Hence, as described by Pugh *et al* (1963 and 1969) and shown also in figure 1.3 developed by Bryman (1995) operationalisation of terms, definitions and descriptions are required. This operationalisation aspect of research design is shown to best effect in the agile operational characteristics matrices discussed in section 3.3.1.4 in more detail.

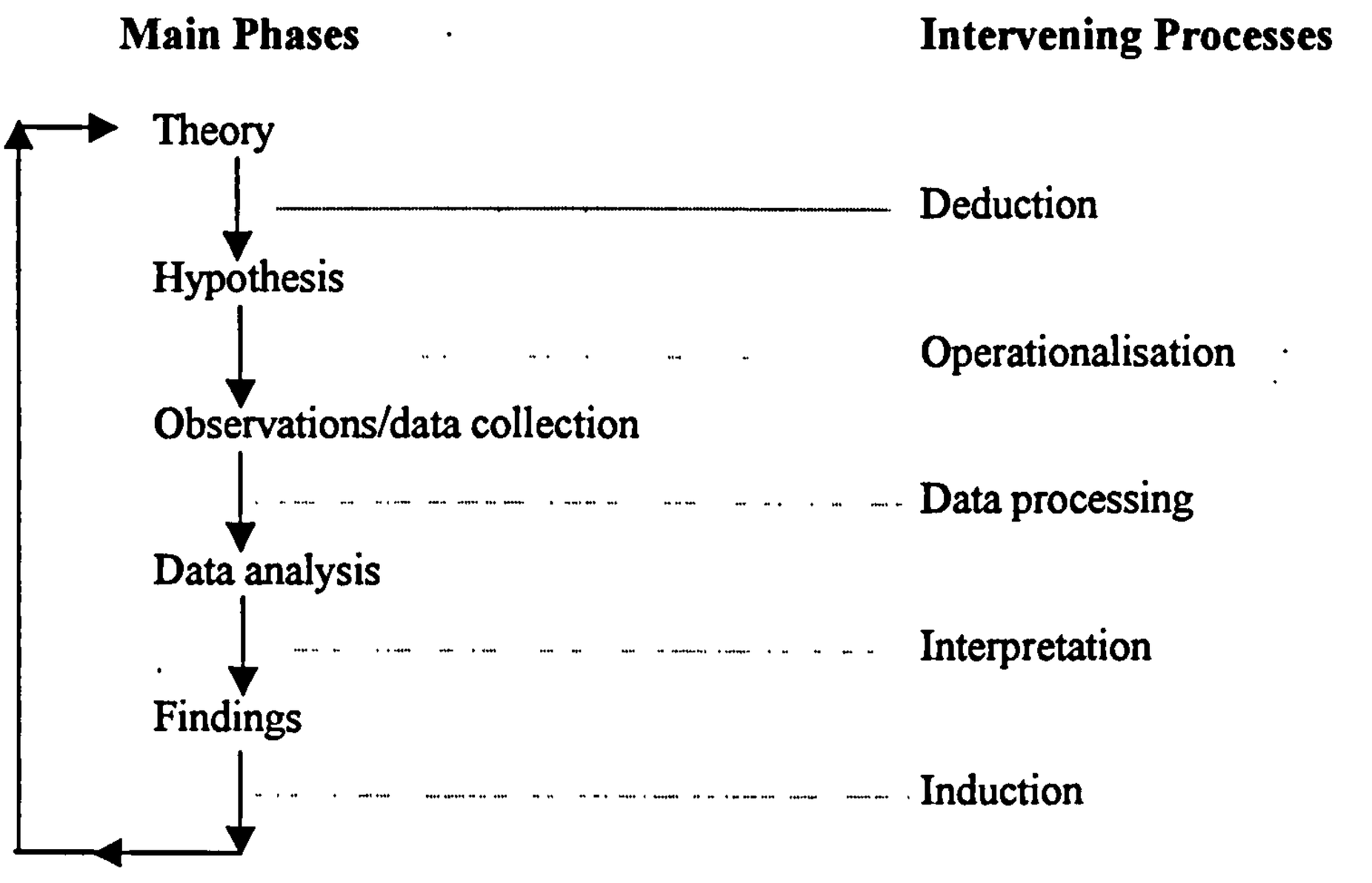

Figure 1.3: A research process (Source : Bryman 1995)

The operationalisation issue therefore is taken into account both during the development of conceptual models and in the data collection methods described later in section 3.3. In addition great care is taken throughout this research toward development of the questionnaire used (operational characteristics matrix) through the use of pilot study and review methods (i.e. part of the question set was tested after a period of researcher involvement in several case study organisations).

1.4.4.1 Knowledge Elicitation Techniques

The case study approach adopted by this research is considered in the main encompassed by an ethnographic research methodology that aims to elicit knowledge from "the cases" by the researcher becoming " ... a trusted and accepted part of the case(s) ... " as described by Serber (1981) in a study dedicated to the practice of ethnographic research in society. Within the ethnographic approach, the participative nature of the researchers' activities allows for collection of useful information in an informal manner. Additionally as described by Bryman (1989 and 1995) a further advantage ethnography or participant observation is that "....its unstructured nature may allow the researcher to happen on promising areas of investigation that could not have been anticipated at the onset." Notwithstanding, solely such a qualitative and unstructured approach, this research has developed an understanding of the concepts of agility expected within aerospace small to medium size enterprises through the literature survey documented in chapter 2 and drawn in a theoretical framework presented in chapter 3. Nevertheless the interview, structured or unstructured, is the central means or *main technique* of knowledge elicitation used as explained by knowledge elicitation experts Firlej and Hellens (1991).

The use of multi-site studies (several case study organisations as shown in chapter 4) indicates there is a need to draw reasonably comparable data across different cases that may provide potentially greater generalisability than single site studies, (Kotter, 1982). The consequences of this are that, as Bryman (1995) suggests, the ethnographic approach is accompanied by structured interviewing, data analysis and accordingly this research uses a structured questionnaire in the form of an agile assessment matrix (see section 3.3.2) for some knowledge elicitation and data collection.

1.4.5 A Critique of the Research Methodology Adopted

The case study approach is adopted because it is considered in the previous sections to be the most appropriate method of research for organisational research where there are time and resource constraints. A critique of the case study is given in section 1.4.1 which outlines the great strength of the case study is to allow the researcher to concentrate on specific situations and to identify, or attempt to identify the various interactive processes at work. These various interactive processes are observed in this research work only after a theoretical framework or conceptual model is developed through evaluating an extensive and relevant literature survey.

It is expected that generalisability is enhanced not only through using a number of case study organisations, as shown in figure 1.4, but through a literature survey and analysis of other case study publications on companies reporting to have some amount of 'success' with agile manufacturing principles. The benefit to other organisations is more likely to be to small to medium sized enterprises (SME's); and particular to producers of super high value products such as in the aerospace sector; as opposed to larger organisations with low value commodity type products, thus generalisation of the results will have certain limits.

The results and conclusions drawn from the research are strongly based on objective evidence obtained from literature, other case study information, observation and data analysis from the aerospace case study organisations. This is particularly important to note within this research report as the researcher is not part of the case study organisations and is therefore required to apply considerable rigor to the investigations and maintain a focused enquiry.

Additionally, the complexity of the problem must be analysed systematically in a structured approach, hence the research design represented in figure 1.4 provides a framework for achieving this. The examination of the unstructured situation must be sufficient to allow identification of critical factors rather than a great deal of variables or sub-factors that are deduced as aspects of agility within an aerospace SME. Crucial factors or elements of agile manufacturing once identified are more likely to be the most appropriate aspect relevant to the aims of this project and hence provide both parsimony and generalisability to the research.

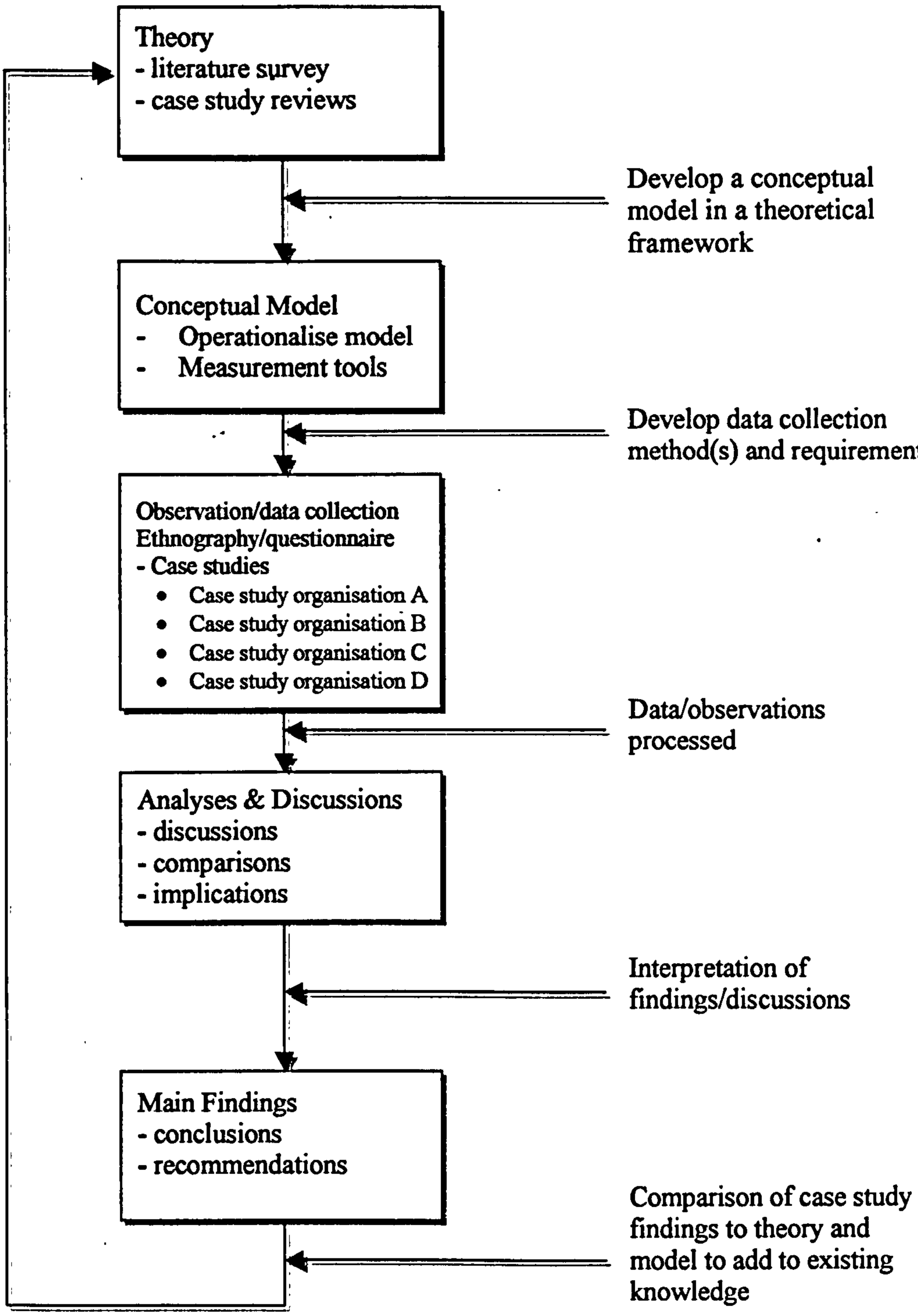

Figure 1.4: Thesis research design

Chapter 2 Literature Review

2.1 Manufacturing Management Techniques and Practices

This chapter represents the literature review carried out in order to develop an understanding of the concepts of 'managing agility' expected within aerospace small to medium size enterprises. Additionally through the theory applicable to the topic of investigation a theoretical framework can be developed and presented later in chapter 3. The aims of the literature reviewed in this chapter have already been discussed in great detail in section 1.3.4.

2.1.1 Lean Manufacturing

The Japanese manufacturing experts Eiji Toyoda and Taiichi Ohno [1988], took the manufacturing world by storm and, since the 1970's, ongoing research has identified the performance advantages of lean production management practices (James-Moore and Gibbons, 1997). Accordingly, lean manufacturing is able to offer managers a way to structure their manufacturing facilities (and also the rest of the organisation) to become more productive and more effective (Womack *et al*, 1990).

Acknowledged experts of lean thinking Womack and Jones (1996) consider the focal point of lean manufacturing is:

> *"...Its dedication to the elimination of waste. This is achieved by combining labour into cross-functional teams dedicated to an activity, sharing information, and concentration on continuous improvements and aspects of quality. All unnecessary tasks are eliminated and all steps are aligned into a continuous flow of activity. This enables the design development and distribution of products with less human effort, tools and overall expense."*

Lean manufacturing has been described by Bamber *et al* (1999) as a set of principles and practices that intend to remove all wastes from the system and is founded on maximal utilisation of resources focusing on reduction or elimination of wastes and non-value adding activities within the system. Bamber *et al* (1999) in a review of lean

and agile manufacturing in aerospace have stated that: "A particular focus of lean is to establish closer relationships with fewer suppliers and to reduce the number of links in the supply chain." Similarly this concept of reducing the number of suppliers is also discussed by Boyst, jr. III (1988), as an attitude and behaviour expected within a just-in-time (JIT) manufacture environment, but also takes the concept further in suggesting single source supply is best.

Many manufacturing Gurus have argued the Japanese manufacturing methods such as (JIT) production, Kaizen, total quality control (TQC), and worker incentives such as total employee involvement (TEI) have revolutionised the business world (Schonberger, 1986; Dertouzos *et al*, 1989; Willmott, 1997). Womack *et al* (1990) however, have shown, from research into Japanese manufacturing companies, it can clearly be seen that the Japanese production paradigm did not take place overnight. Other manufacturing researchers (Cusumano, 1994; Bicheno, 1994 and Cheng and Podolsky, 1996) go so far as to claim that the gradual transition from the extreme Tayloristic task-structured, material requirements planning (MRP) and inspection mentalities of buffered systems, to the multi-skilled worker, continuous improvement, just-in-time (JIT) and quality assurance features of the lean manufacturing system could have been predicted.

The limits of lean production in terms of its undesirable effects, including the lack of young labourers willing to work in the factories, the excessive product variety and the extreme pressure on suppliers has been highlighted by Cusumano (1994). Nevertheless, the Japanese manufacturing experts Toyoda, Ohno and Shingo worked closely with large companies like Toyota, acting as pioneers, in order to develop the lean manufacturing idea. According to Bicheno (1994) these Japanese experts knew that in order to become a world-class factory manufacturing organisations needed to satisfy the trilogy of Just In Time (JIT), Total Quality (TQ) and Team Involvement (TI), see figure 2.1. Desai (1998) discusses that beyond the factory floor a lean enterprise also requires supplier involvement, distribution logistics, effective design and attention to service. Accordingly and as shown by figure 2.1, JIT can be thought of as largely within the plant, and lean manufacturing extends the boundaries to consider the supply chain mechanics.

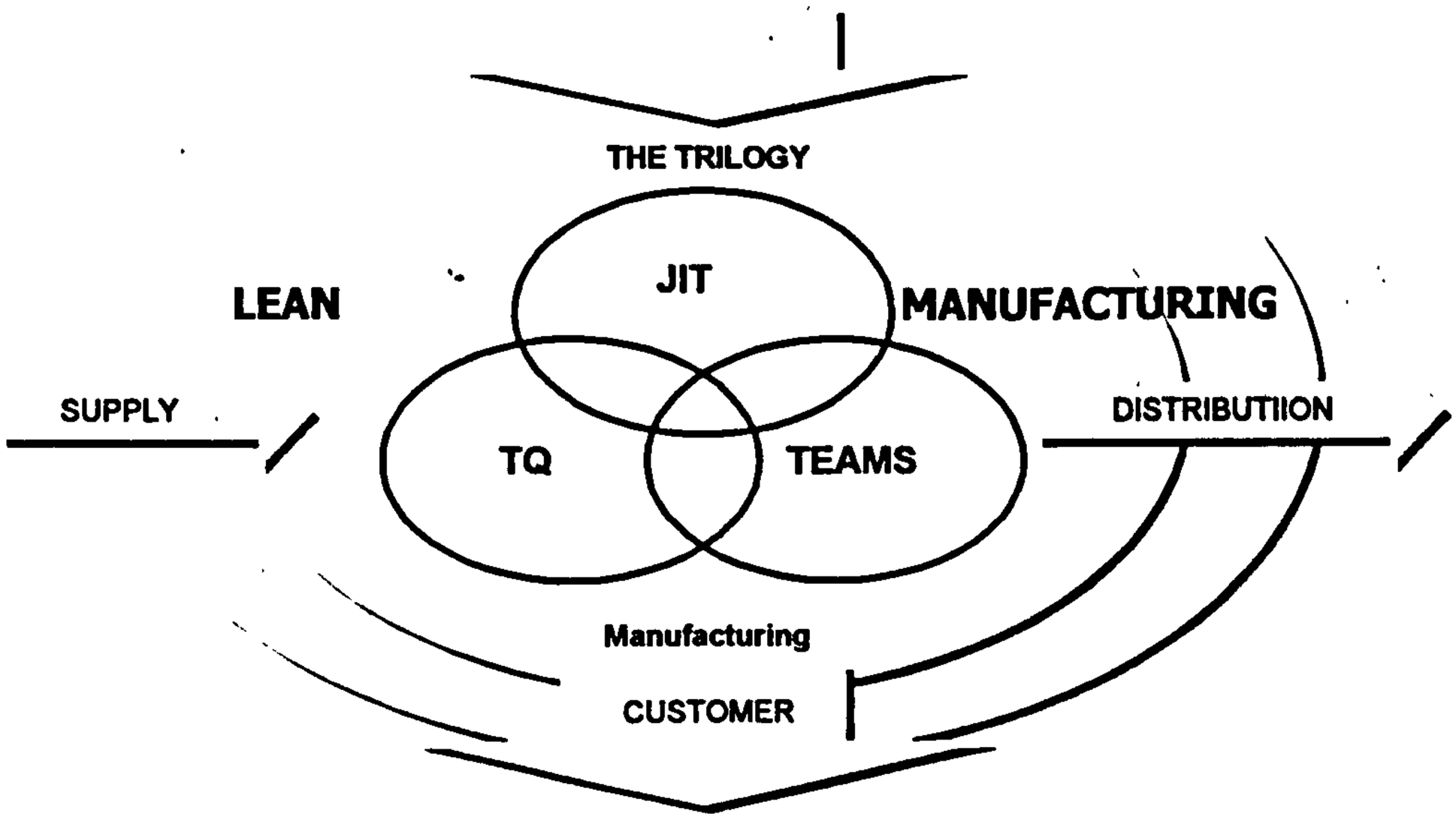

Figure 2.1: The manufacturing trilogy of JIT, TQ and TI (Bicheno, 1994).

It is moreover argued by Bicheno (1994) that JIT aims to continuously eliminate waste and reduce delay at every stage from raw material to final customer and from concept to market. While on the other hand, lean manufacturing aims to design and produce products and supporting services, which exceed customer expectations in terms of quality, cost and time. Womack *et al* (1990) also discuss reduction in waste using lean thinking as primarily focusing on the following achievable objectives:

- Using half the space.
- Using half the investment in tools.
- Using half the human effort.
- Using less than half the time.
- Using less than half the inventory.
- With less than half the defects.
- With greater product variety.
- With improved customer service.

In order to better understand the lean production paradigm, Desai (1998) has drawn a list of the characteristics of lean manufacturing, from a survey of lean manufacturing literature, as follows on the next page:

1. A purposeful and directed focus on the interests of the customer.
2. Close integration of design, manufacturing and distribution, with suppliers and subcontractors involved throughout.
3. Collaboration with suppliers in all aspects.
4. Sharing of the gains and benefits of the collaboration.
5. Respect for all the functional and operational areas and personnel of the company and its suppliers.
6. A Total Quality Management (TQM) oriented environment, with team-work, delegation, and information sharing through sound support systems.
7. The skills and contributions of all individuals are highly rated and valued.
8. Design and manufacturing functions collaborate continuously, especially when supporting or promoting the cause of quality or reflecting the interests of the customer.
9. Production process development and operation is directed towards continuous improvement of operating efficiency and defect prevention.

In contrast to lean manufacturing, mass production creates organisational systems that stress specialisation and de-skilling of labour, and production practices that encourage inspection and mistrust. These characteristics result in de-motivation, numerous labourer classifications, large inventory buffers and extensive rework. Lean production on the other hand, is based on the premise of a skilled, motivated, and flexible work force working to continuously improve quality and reduce inventories through preventive control and production system flexibility. These all result in a satisfying social system, and a buffer-less, reliable production system. Thus, lean production systems are able to achieve dramatically higher levels of quality and productivity, much lower inventories than mass production plants, and higher manufacturing flexibility (Womack *et al* 1990).

In "The Machine that Changed the World", Womack *et al* (1990) claimed that lean production would replace mass production and what was left of the crafts in all industrial sectors, becoming the global standard for the production systems of the twenty-first century.

2.1.2 World Class Manufacturing (WCM)

Lean thinking according to Womack and Jones (1996) has been adopted by many organisations as a means of becoming more competitive and achieving a world-class status of manufacturing organisations. Similarly the concept of world-class manufacturing (WCM) has been given much attention from organisations striving to become high performing manufacturers, (Hendry, 1998). Some authors have attempted to define the term WCM in a one-line statement, likewise, Burcher and Stevens (1996) quote several of these including the following, which is from one of the managing into the 90's series of booklets published by the DTI (1990):

> *"A world class manufacturer is one that can compete with the best anywhere in the world."*

This definition is hard to disagree with and must be universally applicable but leads to the questions of what is the "best in the world" and what is meant by the expression "can compete"? This ambiguity makes definitions of this type unhelpful for those seeking to improve their manufacturing performance through the application of techniques. Gilgeous and Gilgeous (1999) have researched the philosophy of WCM and suggested that most experts and practitioners believe that an incremental approach to manufacturing change is more effective than a "big bang" approach and quote Peter Urban, president of Camex Corporate Consultants, Ontario, who in this respect offers a definition of WCM:

> *"The world class manufacturer differs from an average manufacturer in his continuous striving for improvements in quality, cost, lead-times, customer service, and general responsiveness."*

It is more beneficial to present organisations with a more thorough definition of WCM such as that outlined by Greene (1991) when stating that WCM companies are:

> *"...those companies which continuously outperform the industry's global best practices and which know intimately their customers and suppliers, know their competitors' performance capabilities and know their own strengths and*

weaknesses. All of which form a basis of continually changing – competitive strategies and performance objectives."

Additionally other literature has looked at enablers of manufacturing excellence or at aspects of operations that signify best in class, for example, the DTI (1990) booklet claims that you are a WCM company if you can say yes to a checklist of ten questions, which are paraphrased below:

1. Is the plant clean?
2. Is the facility completely reliable?
3. Is documentation clear, up-to-date?
4. Do you emphasise the importance of developing your product and process engineering?
5. Is your workforce flexible?
6. Do you always achieve the shortest possible throughput time?
7. Are you committed to total quality and *kaizen*?
8. Are you committed to training?
9. Is the shop-floor a source of ideas?
10. Do you accept the need for continual change?

This sort of listing provides a checklist for manufacturing managers that are aspiring to adopt the principles of WCM while, other authors, including Ralston (1996), are more specific in terms of the improvements that can be expected. His checklist comprise the following:

- Inventory turnover of 20, 40 or even 200.
- A 40 per cent reduction in the cost of goods manufactured.
- Manufacturing lead times measured in terms of days or even hours.

This greater detail, of course, gives an opposite problem. It has been discussed by Hendry (1998) that:

"...it would be unrealistic for the capital goods manufacturer of, say, aeroplanes to aim for lead times of weeks, let alone days. Also, a 40 per cent

reduction in costs is far too general to be universally applicable – it assumes that all costs are universally too high by the same amount in the first place."

It is considered in this thesis that where a selection of possible values is given, the advice then becomes too vague – there is a huge difference between inventory turnovers of 20 and 200 for example. Therefore, lists of this type may be helpful for some manufacturers, such as the car industry or other mass producers on which the figures tend to be based, but will not be helpful for all types of company.

Schonberger (1986; 1996) provides two of the most comprehensive lists for WCM – covering cultural, operational and some strategic issue. While the 1986 list had 17 points and was referred to as "an action agenda for manufacturing excellence", the 1996 text has a set of 16 principles. In fact, Schonberger (1996) suggests that to remain a WCM company over the next ten years [to 2006], companies will have to enter into another change of management culture. There have already been changes from management by edict to management by procedure to management by policy. The next change is suggested to be to management by principle. According to CEO Lou Gerstner quoted by Schonberger (1996), this means that when a situation arises, there is no need to look at a manual; rather the individual knows in their head and their heart what to do. He states that policies and procedures are still needed, but principles are going to be required to remain a WCM company in the future.

This potential shift in management culture seems somewhat idealistic. To follow it, each company must first decide which principles to implement in their case. Theory of this type therefore has a similar effect to lists of WCM attributes such as those discussed above, mostly one of giving incentives for change and some idea of how to start. However, most managers want more detailed advice on what changes to implement within their manufacturing process and its support operations rather than advice on concepts and theories.

Most authors of texts and articles on the meaning of WCM would agree that this more detailed advice could not be prescribed because the precise working out of the processes to be followed will vary from one company to another. Therefore, it is often suggested that each company must assess its own starting point, its own strategic

position, and customer base and so on in order to decide how to make changes in its particular case. For example, Burcher and Stevens (1996) state that the basic steps are:

1. Starting point – understanding the current situation;
2. Objectives – understanding what the organisation should look like;
3. Strategy – building suitable measures of change that will then drive the process forward.

Hence a manufacturing organization must build on objectives, developing a strategy for changing the *status quo* to higher levels of performance. However, despite making statements of this type, many authors do go on to give more detailed advice. More detailed advice on World Class Manufacturing (WCM) tends to concentrate on methods of operating that have come to be considered as "best practice" methods in recent years. Schonberger (1986) suggested: "What makes a world class manufacturer in one industry also seems to work in many other industries." and that: "The improvement journey follows a surprisingly well defined path." Hendry (1998) compliments this particular view and suggests the topics that tend to be covered in WCM text can be organised into seven categories as follows:

1. Workforce empowerment;
2. Design for products, processes and improved supplier relationships;
3. Simplify the shop-floor;
4. Capacity issues;
5. Improve quality and value for money;
6. Up-to-date appropriate planning and control systems;
7. Performance measurement, benchmarking and continuous improvement.

It should be noted that these categories are not mutually exclusive and some of the advice available fits under more than one heading. However, it is argued in this thesis that the categories provide a convenient means of summarising the type of advice found in texts devoted to explaining the concept of world class manufacturing as first popularised by Schonberger (1986).

2.1.3 Global Manufacturing/Global Competition

The concept of World Class Manufacturing (WCM) is important, as domestic borders are no longer a barrier to competition from foreign companies, (Kaplan and Norton, 1996). Furthermore, today most products are global composites of materials and services from manufacturers throughout the world, (Byrd, 1992). It has been discussed in much literature that business, including organisations devoted to manufacture, have to consider customers, suppliers, and competitors in global terms in order to succeed (Clarke-Hill and Gleister, 1992; Kotler, 1991 and 1997; Schonberger, 1996). Bamber *et al* (2001) have discussed that due to global competitiveness businesses are now trading internationally and are expected to have management systems certified to international standards enhancing customer-supplier relationships and stakeholder perceptions.

Bamber *et al* (2001) focus on the integration of quality, environmental and occupational health and safety systems (ISO 9001:2000, ISO 14001: 1996 and OHSAS 18001:1999 standards) of manufacturing organisations in order to enhance confidence of all stakeholders in operations. There are a number of reasons why international standards are important for globally competing companies which amongst other reasons includes the need for compatible knowledge based, communication and information systems. Further to this Kaplan and Norton (1996) discuss that companies are now operating in the information age and competing against the best companies in the world. They discuss that information age companies must combine the efficiencies and competitive honing of global operations with marketing sensitivity to local customers. In other words if companies are not able to supply their local market under globally competitive and integrated terms then they will not be in that market for long, because somewhere in the world will be a company looking for market entry with world class performance levels.

Kotter (1996) considers that globalisation is nowhere near finished and we are in a new economic era that is going to continue at least through the first quarter of the 21st century. Interestingly, Naisbitt (1995) has said that the global economy of the 21st century will be dominated by small and medium sized (SMEs) players. Naisbitt argues that although small is beautiful appropriate scale is what is required, he states: "I

know very well that I can't build a Boeing 747 in my garage. Of course we need big companies for these things. But it's all about finding the appropriate scale. Increasingly appropriate scale is smaller and more powerful." Naisbitt (1995) considers one of the main factors in developing the economic age of small companies is that the revolution in telecommunications is simultaneously creating the huge, global, single-market economy, while making the parts smaller and more powerful. Further to this belief that small is best Naisbitt (1997) proclaims: "What you see happening everywhere now is that even the really huge companies are restyling themselves as networks of entrepreneurs."

There becomes a dilemma when the belief is that smaller companies will dominate the economy, which is that individually a small company is unable to provide the competence and capacity for large projects. This dilemma in part is solved by Thurow (1996) who believes that; "... in tomorrow's global economy, there will be very tough economic competition, but the common environment will require global cooperation." Thurow (1996) really refers to cooperation of Nations but accepts that cooperation is also vitally important at all levels of the economy; in fact competition and cooperation must go hand in hand. Further to this concept of co-operating to compete in the global economy Kelly (1995) suggests that the global economy is " ... a network economy – in which there will be a variety of large players and a variety of small players." Kelly (1995) has discussed that the network economy is able to support the virtual organisation. Virtual organisations according to Kelly are ones in which, when you go to examine them, you find there is nobody there.

Strategic thinker Michael Porter (1994) has discussed global manufacturing in terms of the ability to competitively provide and receive goods to anywhere in the world. A strategic process for organisations is therefore, the capacity and capability of a company to martial and mobilize inputs and assets across borders. Porter (1997) discusses a shift in paradigm of global competitiveness from that of the scale of a firm being important to now that of the specialised nature of a cluster of smaller firms. This paradigm shift of globalisation is putting greater emphasis on specialisation, on doing particular things in particular locations, (i.e. Silicon Valley and microelectronics), rather than doing everything in one particular location. A given firms' scale, according to Porter (1997) can be smaller if there are a lot of other supporting companies around

to provide a network, cluster and infrastructure for activities necessary to be successful.

Furthermore, it has been argued by Johnson (1995) that to remain competitive in a global marketplace, the approach of an organisation to the strategy process must include both concepts of incremental change and more radical or fundamental shifts in direction. Johnson and Scholes (1999) have consequently considered a basic three-stage model of the strategic management process, that should be continuously applied as including strategic analysis, strategic choice and strategy implementation. While Sadler (1995) and Johnson (1988) have reviewed strategic implementation processes and considered the concept of "strategic drift" as problematic and hence organisational strategists must be prepared to review progress and strategic intent regularly. The strategic issues facing organisations is discussed further in section 3.3.1.1 and addressed within the conceptual model developed in this research.

2.1.4 Other Management Concepts

2.1.4.1 Total Quality Management

The total quality management (TQM) concept according to Atkinson (1990) depends upon the total commitment of every employee within the company and cannot be achieved through quality systems alone. This view prevails because quality systems traditionally focus on quality assurance and quality control rather than total quality management, (Bamber *et al*, 2000). Atkinson (1990) has further said that although it is important to have quality systems, such as the ISO 9000 quality management systems standard series, it is vital not to stop there, but to continually improve quality beyond the standard requirements by creating a culture change. Continuous improvement and culture are thus defined in the literature of TQM as key to organisational success.

There are differing viewpoints on what constitutes a TQM organisation, for instance Crosby (1979) defines four legs on which a quality programme stands; management participation; professional quality management; original programmes and recognition while Tenner and DeToro (1992) have defined in more detail a framework, which is represented in figure 2.2, for TQM that encompasses a more rigorously researched view than that of Crosby. Figure 2.2 has been shown by Hellman and Sahlin (1993) as

representing a robust and valid model in which other authors; Oakland, 1989; Spenley, 1992; Atkinson, 1990; Garvin, 1987; and Feigenbaum, 1991, theories can be superimposed or categorised within.

Tennor and DeToro (1992) state within their model of TQM that leadership, quality, policy, communication, rewards, and recognition, measurement, education and training and supportive structure as key elements supporting TQM. The model further incorporates the concept of three total quality principles of total involvement; process improvement and customer focus which are universally acceptable as enablers of TQM and discussed in the literature of the DTI, 1990 accepted quality gurus Juran, 1988; Deming, 1986; Ishikawa, 1985; Crosby, 1979; and Feigenbaum, 1991.

This model, figure 2.2 provides a framework for TQM while the British Standards Institute, BSI, (BS 7850, part 2, 1992), states that in order to implement TQM the environment has to encompass responsible managers and good leadership; values; attitudes; and behaviours that support quality among employees; goals for quality improvement; communication and team work; recognition and education; and training.

The model, shown in figure 2.2, proposed by Hellman and Sahlin (1993) supposes a causal relationship from the supporting elements of TQM through the principles that provide customer satisfaction.

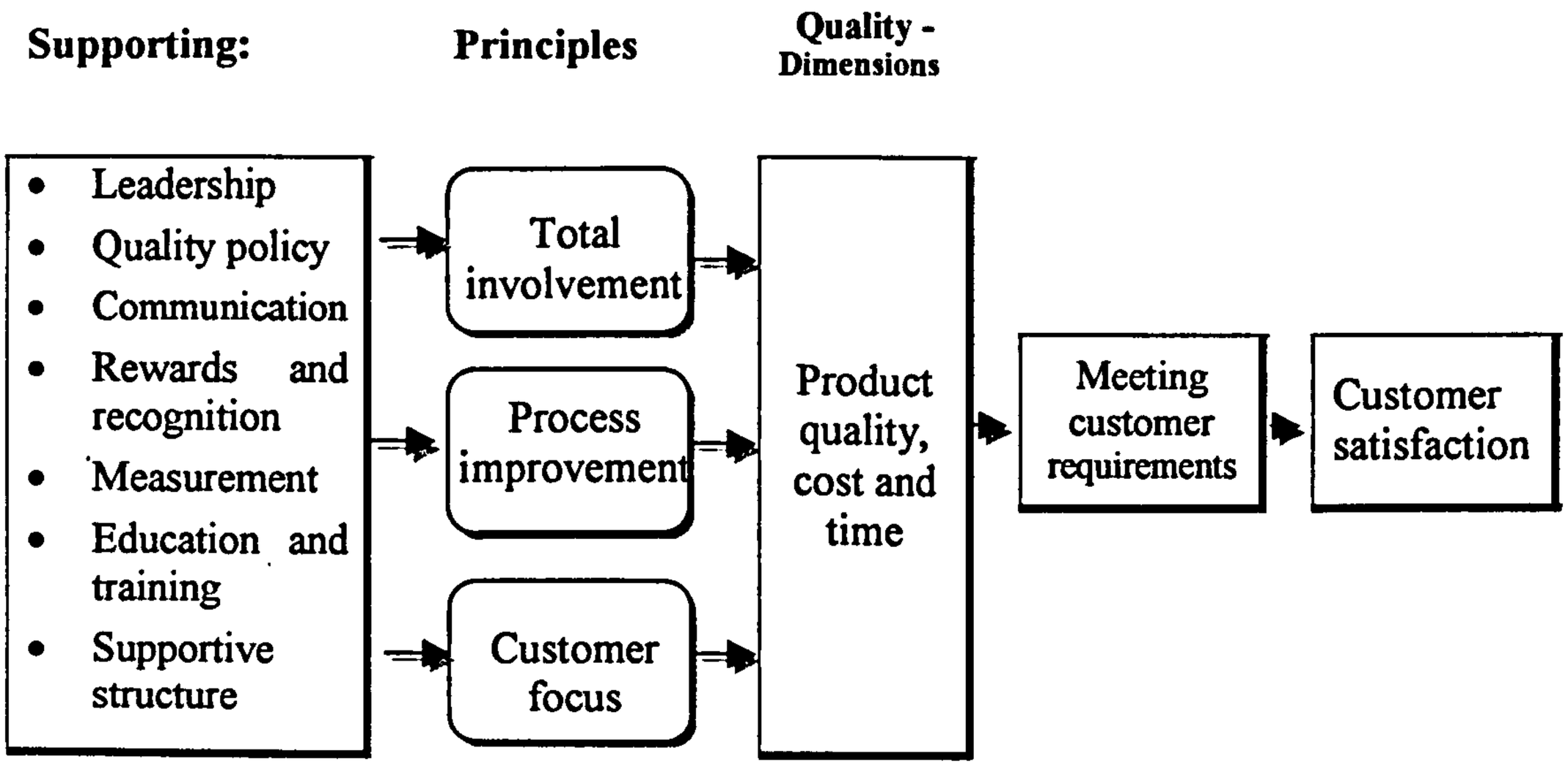

Figure 2.2: A model of a TQM system *(source: Hellman and Sahlin (1993).*

Accordingly BS 7850 suggest that the management responsibilities are organisation for planning and measuring of quality improvement. This approach to quality management is similar to that advocated by Juran (1964, 1988, 1989, 1992) in the quality trilogy of planning, control and improvement. However more recently the International Standards Institute have introduced a revised version of the ISO 9000 series of standards which are now more in line with the philosophy of total quality management and ISO 9004: 2000 provides a more advanced quality management systems framework based on eight quality management principles:

1. Customer Focus
2. Leadership
3. Involvement of People
4. Process Approach
5. Systems Approach to Management
6. Continual Improvement
7. Factual Approach to Decision Making
8. Mutual Beneficial Supplier Relationships

The above represents the principles of an advanced quality system while ISO 9001: 2000, represented in figure 2.3, although it takes these principles into consideration, provides a quality management systems requirements model that is devised so it can be used by internal or external parties, including certification bodies, to assess the organisation's ability to meet customer, regulatory and the organisation's own requirements.

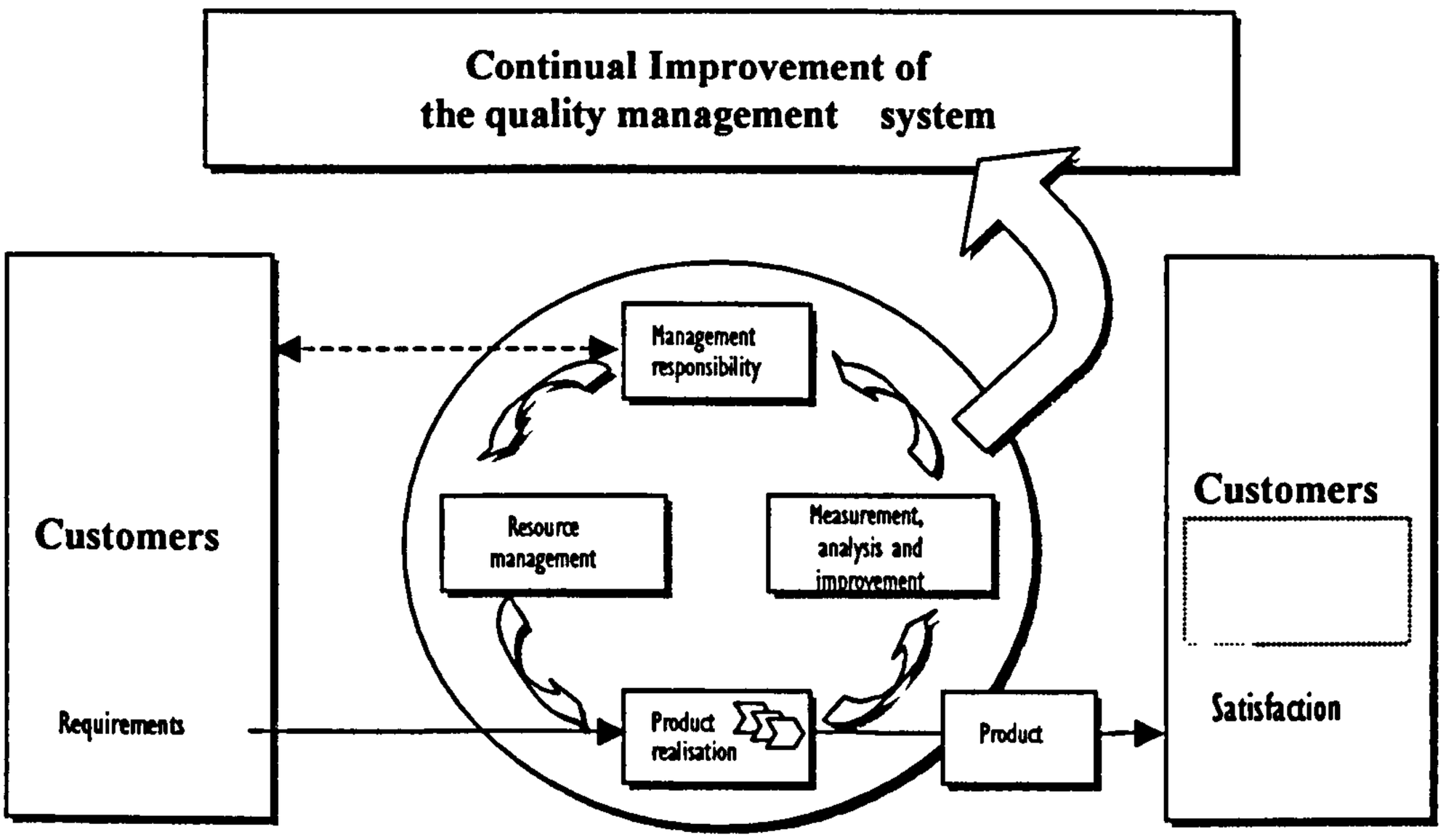

Figure 2.3: Model of a process based quality management system (*From ISO 9001:2000, Quality Management Systems-Requirements)*

ISO 9001: 2000 as opposed to ISO 9001: 1994, which is now superseded, delivers a model of a process-based quality management system as shown in figure 2.3 which illustrates the process linkages as described within the clauses of the standard. The eight management principles that are mentioned above are the foundation of the ISO 9001 standard, which are all, underpinned by the continuous improvement cycle of plan-do-check-act as advocated by the American quality Guru Deming (1986).

2.1.4.1.1 Aerospace Quality Systems Standards in the UK

The aerospace sector in the UK has long since been controlled by governmental regulatory requirements aimed at the quality assurance of product supplies to aerospace original equipment manufacturers. Such requirements according to Scrimshire (2001a) have included the North Atlantic Treaty Organisation (NATO) Aerospace Quality Assurance Procedure (AQAP – 1) that is basically a standard to ensure product quality control rather than quality systems management or for that matter systems improvement as discussed in BS 7850 as mentioned in section 2.1.4.1 previously. The aerospace sector certification scheme (ASCS) published the technical specification, number 157, similarly is requested by many UK aerospace prime contractors (such as BAE Systems, Lockheed Martin) as a prerequisite for supply.

Technical Standards (TS) 157 issue 4 published in August 2000 and available from the Society of British Aerospace Companies and according to Scrimshire (2001b) to comply with TS 157 "The mandated quality system standard to be applied is now AS 9100." This quality system Aerospace Standard, (AS) 9100, was introduced in the US in May 1997 as a direct result of several aerospace companies – such as GE Aircraft Engines, Lockheed Martin, McDonnell Douglass, Pratt and Whitney and Boeing – forming the American Aerospace Quality Group (AAQG) in 1995, (Scrimshire, 2001b). Consequently, AS 9100 was published as a truly international aerospace quality system standard and is according to Barker (1999) a major development of the earlier document produced in the US. These developments of AS 9100 include among other issues a need to focus on quality improvements, safety and reductions in cost through the "value stream". In these respects AS 9100 goes beyond the product control requirements of AQAP – 1 and pre-issue 4 of TS 157 schemes and considers quality management to include management systems improvement aspects.

2.1.4.1.2 The Application of Business Excellence and the EFQM Model in the UK Aerospace Sector

The ISO 9001: 1994 quality management systems requirements standard and the ISO 9004: 2000 quality management systems guidelines for performance improvement provide a framework for Total Quality Management that is similar to the European Foundation for Quality Management (EFQM) excellence model. The EFQM framework as shown in figure 2.4 has also undergone recent changes [in 1999] to include an innovation and learning feedback loop to the model and is known as the Excellence Model.

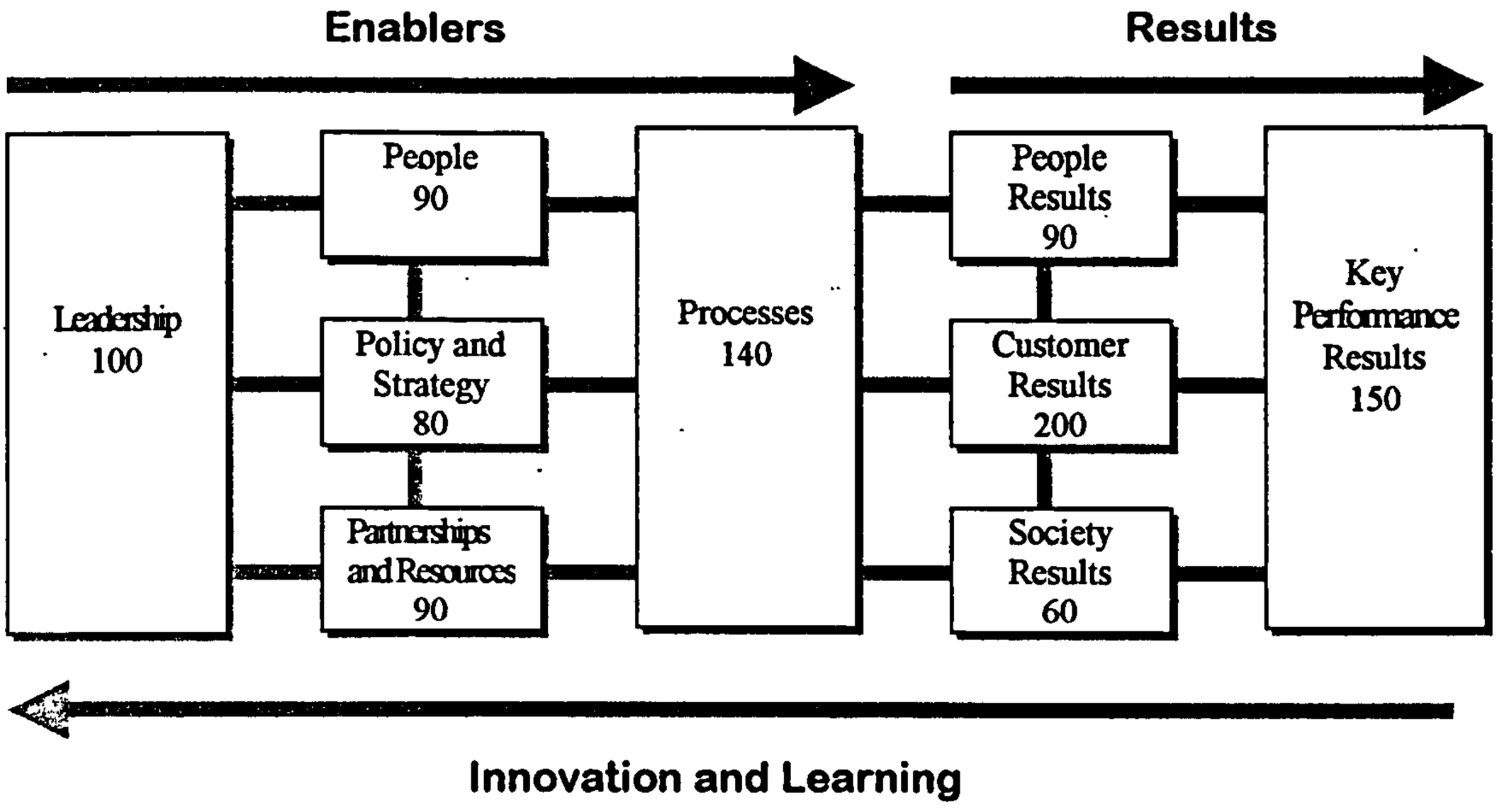

Figure 2.4: The EFQM Excellence Model... this version includes improvements made in 1999 *(source: Jeanes, 2000)*

Within the UK aerospace small to medium size enterprise (SME) manufacturing sector the North West Aerospace Alliance have assessed the take-up of the Excellence Model and believe that very few [if any] of their SME members have detailed knowledge or understanding of the concept, (Guilfoy, 2000). Acknowledging this position NWAA are currently encouraging members to become familiar with the Excellence Model through workshops and training packages as well as aiming to establish research initiatives in this area (Guilfoy, 2000).

The Excellence Model (EM) formerly known as the European Foundation for Quality Management (EFQM) framework, nevertheless, has been adopted by many of the larger aerospace companies (primes) as the framework for Total Quality Management, continuous improvement initiatives and stakeholder performance assessment regimes, (Bamber *et al*, 2001a). However the primes have adopted, adapted and developed the EM to be more relevant to their business sector requirements and hence several local company specific business improvement initiatives have emerged.

Furthermore, the competitive demands of the developing global aerospace manufacturing market have resulted in considerable change within the lower tiers of the UK aerospace manufacturing supply chain. International, national and global business excellence initiatives are shown to be continually impacting upon the lower tier manufacturing enterprises, (Bamber *et al*, 2001a).

The adoption by BAe Systems [prior to December 1999 known as BAe Military Aircraft & Aerostructures (MA&A)] of the Business Excellence Model (BEM) has been very successful and this is shown in MA&A winning a UK Business Excellence Award in 1999 for the category of "Large Private Sector Organisation" (Anon, 1999). Two core programmes support the BAe-Business Excellence initiative: Achieving Customer Excellence (ACE) and Supplier Excellence Programme (SEP).

Similarly, Rolls Royce (RR) in the UK recognise that to remain successful, improvements in the supply chain effectiveness are necessary. Rolls Royce has launched an approach called the Customer Value Process (CVP) in which cross-functional and cross organisational teams from both RR and suppliers work together to improve the supply chain processes and practices.

2.1.4.2 The Learning Organisation

The improvement in the European Foundation for Quality Management (EFQM) excellence model recognises the influence that the concept of the learning organisation has had on quality and excellence management thinking in the last decade. Nevertheless the concept of the learning organisation is neither new nor revolutionary in thinking however according to (Ho, 1995) a renowned guru of the learning

organisation philosophy Peter Senge (1994, 1997) has proposed the framework of the learning organisation, i.e.:

- Personal mastery (learning individual).
- Mental models (learning individual).
- Shared vision (learning team).
- Team learning (learning team).
- Systems thinking (learning organisation).

Although Senge has been considered as the world's authority on learning organisations a number of TQM gurus had already developed some important teaching on the learning organisation (Ho, 1995). Accordingly, Ho (1995) quotes amongst them are the following works:

1. *W. Edwards Deming (1993)* – new management philosophy. Ten of Deming's 14 Points are arguably related to learning:
   - Point 2: Adopt the new philosophy, i.e. learning organisation.
   - Point 6: Institute training.
   - Point 7: Institute leadership.
   - Point 8: Drive out fear.
   - Point 9: Break down barriers between departments.
   - Point 10: Eliminate slogans, exhortations and numerical targets for the workforce.
   - Point 11: Eliminate numerical quotas or work standards.
   - Point 12: Remove barriers to taking pride in workmanship.
   - Point 13: Institute a vigorous programme of education.
   - Point 14: Take action to accomplish the transformation.
2. *Joseph M. Juran (1988)* – upward spiral for continuous learning.
3. *Kaoru Ishikawa (1986)* – quality circle and team-learning.
4. *Yoshio Kondo (1989)* – creativity and quality work.
5. *Claus Moller (1987)* – personal quality.

Additionally, the work of *Reg Revans (1983)* is broadly based on what is now considered the concepts of the learning organisation:

"...that its Chief Executive Officer (CEO) places high among their own responsibilities that of developing the enterprise as a learning system: this he or she will achieve through their personal relations with their immediate subordinates;

- Maximum authority for subordinates to act within the field of its own known policies that become known by interrogation from below;
- Codes of practice and other such regulations are to be seen as norms around which variations are deliberately encouraged as learning opportunities;
- Any reference to what appears an intractable problem to a superior level should be accompanied both by an explanation of why it cannot be treated where it seems to have arisen and a proposal to change the system so that similar problems arising in future could be suitably contained and treated;
- Persons at all levels should be encouraged, with their immediate colleagues to make regular proposals for the study and reorganisation of their own systems of work."

Argyris and Schon (1978); Dreyfus and Dreyfus (1984) and Kim (1993) have all published on the concept of the learning organisation and although the concept of the learning organisation has become popular researchers from Trondheim in Norway, Klev and Oyum (1999), have argued that the literature has defined just two ways of what learning is:

> *"Firstly we may define learning as a change in behaviour. That is, learning has occurred if you, in a given situation, demonstrate different behaviour compared to similar situations in the past. Secondly, we may change our understanding of the physical or social world in the organization, we have learned. In this definition, however, learning is not linked to observed change in behaviour. Instead learning improves the individuals alternatives for future actions, and thus meeting future goals."*

2.1.4.2.1 Why a Learning Organisation?

As organisations struggle to survive and prosper in the increasingly competitive environment, much is written about the virtues of enhancing the potential of the "human asset" to achieve sustainable competitive advantage and cope with change (Porter, 1994 as discussed in section 1.2.4; Senge, 1990). One approach is to constantly identify learning opportunities for individuals and the organisation (as a collection of individuals), share the learning from these and continuously transform the organisation. This requires, according to Sambrook and Stewart (2000) re-thinking structures, working practices, communication systems and management styles.

Argyris and Schon (1978) suggested that organisational learning is a process in which members of an organisation detect error or anomaly and correct it by restructuring organisational theory of action, embedding the results of their inquiry in organisational maps and images. The key point here is that errors are detected and corrected or organisations cease to survive. Argyris and Schon suggest three forms of learning – single, double and triple (or deutero) loop. Single loop learning is concerned with detecting and correcting errors in the current operating system – this is achieved by changing the ways in which tasks are performed within the same system of operation. Double loop learning involves detecting errors, but finding solutions outside the current ways of thinking and acting – there is a change in the system itself. Deutero learning involves changing the ways of thinking about error detection and solution – a process often referred to as learning to learn.

Senge (1990) linked learning with "excellence" (Peters and Waterman, 1987), a concept enthusiastically embraced by employers and managers as a means of securing competitive advantage in a turbulent trading environment. This allows organisations to move beyond survival to sustainable success. The concept suggests that, while individuals may learn themselves, unless this learning is shared and acted on, and unless the organisation as a whole can change, then there is no learning organisation. Individuals learning alone can choose not to use their learning, or even take their learning with them if they leave the organisation. The building blocks of a learning organisation are, initially, individuals and then teams, who create, share and act on collective learning. Such an organisation operates an organisational learning cycle (Nonaka, 1991; Dixon, 1994) – where new knowledge is created, captured, shared and

implemented. In a learning organisation, managers have a key role in creating opportunities for learning and sharing learning in work (Garavan, 1991; Rossiter, 1997), whether for individuals and/or teams.

In the UK, Pedler *et al.* (1991) have made a significant contribution with their work on the learning company. They suggest, " ... a learning company is one which facilitates the learning of all its members, and which continuously transforms itself". Within this definition is the notion that it is members of an organisation who learn, learning can be enhanced, and learning results in changes – in shape (structure), direction (strategy) or values (culture) which is analogous to that process described in figure 2.6 although precedence in these change elements is not given by Pedler *et al* (1991). In addition, they identified 11 interconnected characteristics associated with learning organisations. Many of these features are included in what Rossiter (1997) defines as a learning infrastructure, yet too many formal systems can slow the learning process.

2.1.4.2.2 The Concept of Learning Oriented Organisations

The term "learning oriented organisation" was devised by Leys *et al.* (1992) and further elaborated by Tjepkema and Wognum (1996). The term refers to organisations with intent to become a learning organisation (Tjepkema and Scheerens, 1996). A learning oriented organisation can be described as an organisation which deliberately:

- Creates opportunities for informal employee learning, both "on the job" and "off the job"; and

- Stimulates employees not only to attain new knowledge and skills, but also to acquire skills in the field of learning and problem solving and thus develop their capacity for future learning, or "learning to learn" (Tjepkema and Scheerens, 1996).

Thus, a learning oriented organisation seeks to become a learning organisation, and as described by Sambrook and Stewart (2000);

> *" ...attempts to achieve this by supporting individual life long learning, whether formal or informal, and by encouraging the sharing of this learning in order*

that all members of the organisation might learn and change and improve performance (organisational learning and development)."

Accordingly, the argument in this thesis is that a learning organisation is one that embraces change and has a change competence or proficiency as described by Kidd (1994).

In order to explore the ways in which individual companies are attempting to become more competitive, an audit tool has been developed by Lee *et al* (2000), which draws upon insights from the organisational learning literature. Eight characteristics of organisational learning, which are particularly appropriate to the smaller firm situation, have been identified by Lee *et al* (2000) that are:

1. *Shared mental models:* where leaders encourage a shared vision and understanding of the direction in which the organisation is trying to move and the environment in which this is taking place.

2. *Learning values:* the company supports key values associated with learning and encourages groups interacting to create new organisational learning. People feel free to challenge the opinions of others even if they are more senior and personal responsibility and respect for others is part of the culture.

3. *Experimentation and innovation:* which reflect the readiness of companies to push beyond accepted boundaries and conventional ways of working. Systems and processes tap originality and creativity from employees and risk taking is encouraged but skilfully managed.

4. *Legitimate politics:* where an enabling and facilitating leadership is willing to see power and authority widely dispersed, reaching decisions through negotiation and collaboration. People are allowed to pursue their own goals and interests but management ensures that these are aligned with the needs of the business.

5. *Learning from the past:* the importance of learning from the past and tacit knowledge is recognised. Co-operative problem solving is encouraged, past decisions are recorded and evaluated, measures are put in place to monitor results and guide future action and feedback sought and applied for continuous improvement.

6. *Synthesising perspectives:* the importance of learning through others is recognised, the views of others are actively sought and people are willing and able to adopt alternative perspectives.

7. *Commitment to professional development:* people are encouraged to take responsibility for developing their knowledge and skills and there is widespread commitment to personal learning.

8. *Participative information search:* information on the business environment is sought for instance from customers and suppliers and there is on-going recording of relevant information to enhance company planning.

The first six of the eight characteristics relate to the elements of learning organisations, which have been identified earlier in 2.1.4.2, from the literature on learning organisations. While learning from the past and tacit knowledge are invaluable elements of organisational learning, these need to be built upon by continuing the process. Thus, as Lee *et al* (2000) suggest, firms aspiring to become learning organisations also need to engage in commitment to professional development and participative information search. Similar to the last of Lees' points learning organizations are also characterized by their drive to continually enhance their base of knowledge (Nonaka, 1991). Learning is viewed as a never-ending process, in which all individuals in the organisation are expected to be active participants. Therefore these two characteristics have been added for the purpose of data collection and analysis as presented in chapter 3 and 4 of this thesis.

2.1.4.3 Management of Change

The management of change has already, in this thesis - section 1.2.1, been mentioned as important for aerospace organisations to remain competitive. It is argued by Ho (1999 and 2000) that change in an organisation would, in the long run, lead to change in the organisational culture. A typical example is the learning organisation, where people are excited in trying out new ideas and recognise that failure is an important part of success. The traditional strategic change process that can broadly be summarised by five key steps (Ho, 1998) and shown in figure 2.5 illustrate the precedent relationships of deploying the vision of an organisation that drives a

behaviour via the organisational mission and change in actions which leads to culture development within the organisation:

Figure 2.5: A strategic change process (adapted from Ho 1998)

A new paradigm suggested in a later publication by Ho (2000) is shown in figure 2.6 which provides the same elements within the process of culture change but the elemental precedents are different i.e action now becomes the starting point for culture change:

Figure 2.6: A new paradigm for the strategic change process
(adapted from Ho 2000)

Similarly to this proposed new paradigm for managing strategic change is the work of Peters and Waterman (1987) who found out from over 46 successful firms that most of them choose "action" as step number one in their pursuit towards excellence. The new idea advocated by Ho (2000), shown by figure 2.6, is that action leads to behavioural change of employees and culture change follows. This arises from the learning process, and as Revans (1983) said: "There is no learning without action and no action without learning". This could provide the argument that learning and change are synonymous. Ho (2000) further discusses that if learning has been taken successfully, organisational behaviour will be lifted to a dynamic and challenge-seeking level providing the organisation with a culture of continuous improvement.

Continuous improvement can be considered an example of what strategy theorists have called "dynamic capability" (Teece and Pisano, 1994). Likewise Ellerker (1998) has said that continuous improvement and change are synonymous. Bessant and Francis (1999) suggest that dynamic capability through continuous improvement (innovation and learning) offers mechanisms whereby a high proportion of the organisation can become involved in its innovation and learning processes. Sustaining competitive

advantage on price alone is no longer a viable strategy for most firms and accordingly Meredith and Francis (1999) have suggested that " ... competitive advantage increasingly rests upon a dynamic capability to compete successfully in an environment of frequent, challenging and often, unpredictable change."

The capacity and ability of an organisation to be able to successfully foster and manage change, through continuous innovation and learning, is discussed by many authors (Bessant and Caffyn, 1997; Bessant, 1998; Robinson, 1991) as providing a significant strategic advantage. Accordingly, Bessant and Francis (1999) have discussed that when a high proportion of an organisation gets involved in learning and innovation processes: "Its strategic advantage is essentially as a cluster of behavioural routines – but this also explains why it offers considerable competitive potential, since these behaviour patterns take time to learn and institutionalise, and are hard to copy or transfer." Additionally, Bamber (1998) and Castka *et al* (2001) have discussed involvement in the change process as a factor in reducing resistance to change and improvement which indicates that, there is a strong relationship between learning, innovation, involvement and successful organisational change.

2.2 A New Manufacturing Management Paradigm

The manufacturing paradigm that is prevalent today is summarised as the concept termed lean manufacturing as described in section 2.1.1. This concept is considered within this thesis insufficient in that the entire focus of such a paradigm is based on the minimisation of all wastes within the system of manufacturing whereas an improved concept could be that of World Class Manufacturing (WCM) as described in section 2.1.2. However, WCM concepts have still failed, in a similar way to lean, to recognise the dynamic nature of the market place and the global manufacturing arena that companies now operate as described in section 2.1.3, moreover WCM allows a company to benchmark against sector best and eventually achieve best-in-class but does not sufficiently help create a change competence or dynamic capability as described as necessary in section 2.1.4.3.

It is similarly argued that lean manufacturing; world-class manufacturing and the other techniques mentioned in the preceding sections are insufficient concepts to manage modern organisational activities. For instance, the literature relating to lean manufacturing emphasises the need for the development of a lean supply chain founded on lean principles of waste minimisation from the supply processes (Lamming, 1996), but according to Gunnesson (1997) today's successful ventures are a result of partnering and alliances brought about by the virtual enterprise.

Nevertheless according to Hormozi (2001) most businesses have a fear of divulging too much information to other organizations, even if they are not direct competitors. This fear is perhaps a manifestation of some long-standing governmental laws and regulations prohibiting trusts. Or perhaps it is a simple fear of losing competitiveness if corporate secrets are revealed. Whatever the reason, writes Hormozi (2001) the outcome is the same; cooperation among businesses in many countries is minimal. Hence there is a need for a new paradigm that takes into consideration these shifts in global operating conditions and need for collaborating to meet these conditions.

The concept of the total quality management (TQM) organisation and the learning organisation (LO), nevertheless, as described in sections 2.1.4.1 and 2.1.4.2, does however address the notion of continuous improvement as a prerequisite to building a change management competence. Described in the last few paragraphs, is a need to improve the culture through changing actions and behaviour using learning and continuous improvement activities, these are the softer issues of management not addressed entirely in world class manufacturing (WCM) or in lean manufacturing literature. Change management literature, likewise as described in these sections, is considered synonymous with both learning and continuous improvement. Having also said that lean and WCM practice is insufficient for manufacturers and that there is a need to develop a systems thinking approach and a dynamic capability for manufacturing organisations to remain competitive then a new manufacturing paradigm must be sought.

As Hayes *et al* (1988) pointed out, there is nothing new about change. However it is argued that today's rate of change is much higher than ever before giving rise to the turbulence and uncertainty in the business environment that has become the main

cause of failures in manufacturing industry, (Small and Downey, 1996). A major change that has faced the UK aerospace sector is the fierce competition from overseas producers of aerospace parts, assemblies and sub-assemblies. The Operations Director of Aerostructures, Neil McKay (1999), BAE Systems site, Chadderton, UK has said "The UK SMEs cannot compete on price with Czech Republic, Polish, or far east manufacturers of small components ... it is inevitable these parts are to be manufactured overseas as collaborative packages of work." The impact of this move is a radical change in the way UK aerospace Small to Medium size Enterprises are to operate, and indeed are operating, as less component work is available, larger packages of work are out to tender, as John Whalley (2000) of North West Aerospace Alliance points out:

> *"Co-ordinating the work of large numbers of contractors was an unthinkable prospect for many smaller companies, but the consortium members [NWAA member companies] Hurel Dubois UK Ltd, Pendle Aeroform, AIT (Aero Industrial Technologies) soon found the benefit of innovative working practices."*

The prevailing view in the North West of UK is that partnerships are necessary for continued success in aerospace manufacture, (Mendros, 1999). This view that partnerships are a must in a dynamic and changing environment is one that, unlike literature on TQM, Lean or WCM, is found throughout literature devoted to the concept of agile manufacturing, (such as Handley, 1997 and Gunneson, 1997).

2.2.1 The Development of the Agile Manufacturing Paradigm

Increased global competition is discussed, in section 2.1.3 and presented by Rattner and Reid (1994), as primarily responsible for the development of a new production management approach that designs agility into work processes. Accordingly, as discussed in section 1.2.2, way back in 1969 Skinner had led the way in considering that a manufacturing strategy should be the paramount driver for a competitive business strategy and was the missing link in many organisations' business improvement efforts. The perceived radical trend of change as discussed in the previous paragraph has made ground for the emergence of a new business era beyond

traditional ones such as mass production, World Class Manufacturing principles and lean production. A new manufacturing paradigm, known as "agility" has been described in a report published by Lehigh University's Iacocca Institute in 1991: 21st Century Manufacturing Enterprise Strategy: An Industry Led View.

The purpose of the 21st Century Manufacturing Strategy Enterprise report was to identify the requirements for U.S. industry to return to manufacturing competitiveness. Its conclusion was that incremental improvement of the current [1991] systems of production would not be enough to become competitive in today's global marketplace. From this early concept of agility Lehigh University led the way in developing the agile manufacturing paradigm through research, focus groups and industry collaboration, (Dove, 1994). The work of the Agility Forum, which has evolved from the early developments of agility as a concept, has contributed much to the theory of agile manufacturing, (Agility Forum, 1996).

The members of the US Agility Forum have continued to develop the understanding of agility and in several ways have defined agility; four examples are:

"Agility is dynamic, context specific, aggressively change embracing, and growth oriented. It is not about improving efficiency, cutting costs, or battening down the business hatches to ride out fearsome competitive storms. It is about succeeding and about winning profits, market share and customers in the very centre of competitive storms that many companies now fear." (Goldman, Nagel and Preiss, 1995).

Agility is the ability to thrive and prosper in a competitive environment of continuous and unanticipated change, to respond quickly to rapidly changing markets driven by customer-based valuing of products and services. It is the coming business system that will replace the mass production businesses of today." (Agility Forum, 1996).

"Agility is a capability; it is an organization's capacity to respond rapidly and effectively to unanticipated opportunities and to proactively develop solutions for potential needs. It is the result of an organization and the people who

comprise it working together in ways which benefit the individual, the organization, and their customers." (Nelson and Harvey 1995).

"Being Agile means being proficient at change – and allows an organization to do anything it wants to do whenever it wants to." (Dove 1994).

These four definitions describe agility in terms of outcomes and thus they are not too specific about what agility is or how it can be operationalised. Although the work of the US agility forum has done much to provide operationalised characteristics of agility Paul Kidd has carried out significant work in the UK aimed at developing the concepts, which are considered in section 2.2.3.

2.2.2 The Work of The Agility Forum

From the research undertaken by the Agility Forum "Agile Manufacturing" is described as the ability to thrive in a competitive environment of continuous and unanticipated change; to respond quickly to rapidly changing markets driven by customer specified products and services, (Dove, 1996). Therefore underlying agility is a capability to rapidly adapt or reconfigure in response to changes in the business environment which implies change proficiency as described by the Agile Forum (Goldman *et al*, 1991); or change competence as described in a publication by Paul Kidd (1994) to deal with significant uncertainty as well as unpredictable events. Accordingly the Lehigh University (Goldman and Stuphin, 1995) researchers have expressed agile manufacturing as having four underlying principal dimensions of agility, which may be articulated as:

- Mastering change and uncertainty – entrepreneurial organisation
- Enriching customers, products and solutions (providing total solutions)
- Leverage of people through knowledge and information
- Co-operating to enhance competitiveness - virtual partnerships (collaboration)

2.2.2.1 Mastering Change and Uncertainty – Entrepreneurial Organisation

Agile competition is based on the ability to thrive on change, unpredictability and uncertainty. Companies that have traditional hierarchical and bureaucratic structures

with command and control management are considered unable to respond quickly to the needs of the changing environment. Many experts therefore argue that for an agile company the structure must be as flat as possible to be dynamic. To move toward agility thus mastering change and unpredictability, companies must learn how to rapidly mobilise their people through the use of a flatter more entrepreneurial organisational strategy. This requires people to have broader responsibilities than a traditional hierarchical organisation and the authority and empowerment to respond to the needs of the changing demands of customers.

An agile approach to manufacturing faces the reality of a dynamic business environment where customers and markets are becoming continuously more fragmented and specialised. Companies that thrive in turbulent markets have developed an inherent agile ability, particularly in their design to manufacture processes, by using the techniques of rapid prototyping and concurrent engineering. Accordingly, Balsmeier and Voisin (1997) have shown rapid prototyping to be used in some cases to provide strategic competitive advantage, gaining market share through the ability to cut the design–to–market time by 75% or more.

The mastery of change and uncertainty is discussed by Liles *et al*, (1995) as being the enterprise-engineering characteristic of effective management of environmental issues. Enterprise engineering defines the way in which it views the world into a unique overall perspective defined by several basic assumptions. This paradigm determines the framework necessary to develop the discipline through practice and research and must be complex and substantial enough to be divided into sub-disciplines or sub-areas. Accordingly, there are three assumptions that reflect the depth of enterprise engineering. The first assumption is that the enterprise can be viewed as a complex system. This is necessary because systems in organizations are systems of organized complexity. Secondly, the enterprise is to be viewed as a system of processes. These processes are engineered both individually and holistically. The final assumption is the applicability of engineering rigor in transforming the enterprise.

The enterprise-engineering paradigm thus views the enterprise as a complex system of culture, process, and technology components that can be engineered to accomplish specific organizational strategic objectives. Enterprise engineering recognizes the

ever-hanging organic nature of the enterprise, thus is a valid worldview or paradigm (Liles *et al*, 1995). Additionally Frederick and Christman (1996) have provided a managed transformation model that shows the essential elements of changing organisational behaviour toward a vision of the future that masters change and uncertainty. Figure 2.7 is the illustration of the managed transformation model from Fredrick and Christman (1996) that indicates that a key to successful agility is to change the attitudes and behaviours of the organisations' employees toward a common vision of the future.

Fredrick and Christman (1996) indicates the benefits of mastery of change and uncertainty are:

> *"Organisations rapidly reorganise their human and physical resources or reinvent themselves to meet customer and market needs effectively. Reengineered processes achieve rapid response to changes in the marketplace. People have broader responsibilities and more significant rewards for accomplishments. Information is readily available to enable informed decisions to respond to and lead the marketplace changes."*

The role of people is hence, within the agile organisation at the centre of mastery of change and uncertainty. Therefore developing a competence for change is essential to building up, not only an acceptance of change as discussed by most literature on change management, but an organisation that thrives on change. The managed transformation model, figure 2.7, further indicates that the important issues an organisation faces when attempting to master change and uncertainty are the human factors related to behaviour and attitudes.

Accordingly the model suggests that for agility these psychological dimensions of organisational behaviour should be developed toward a clear vision of the organisations' future through the change cycle from awareness to reinforcement. Furthermore the model indicates that a commitment to change is necessary for the organisational transformation to take place, while awareness and understanding are critical foundations for managed transformation.

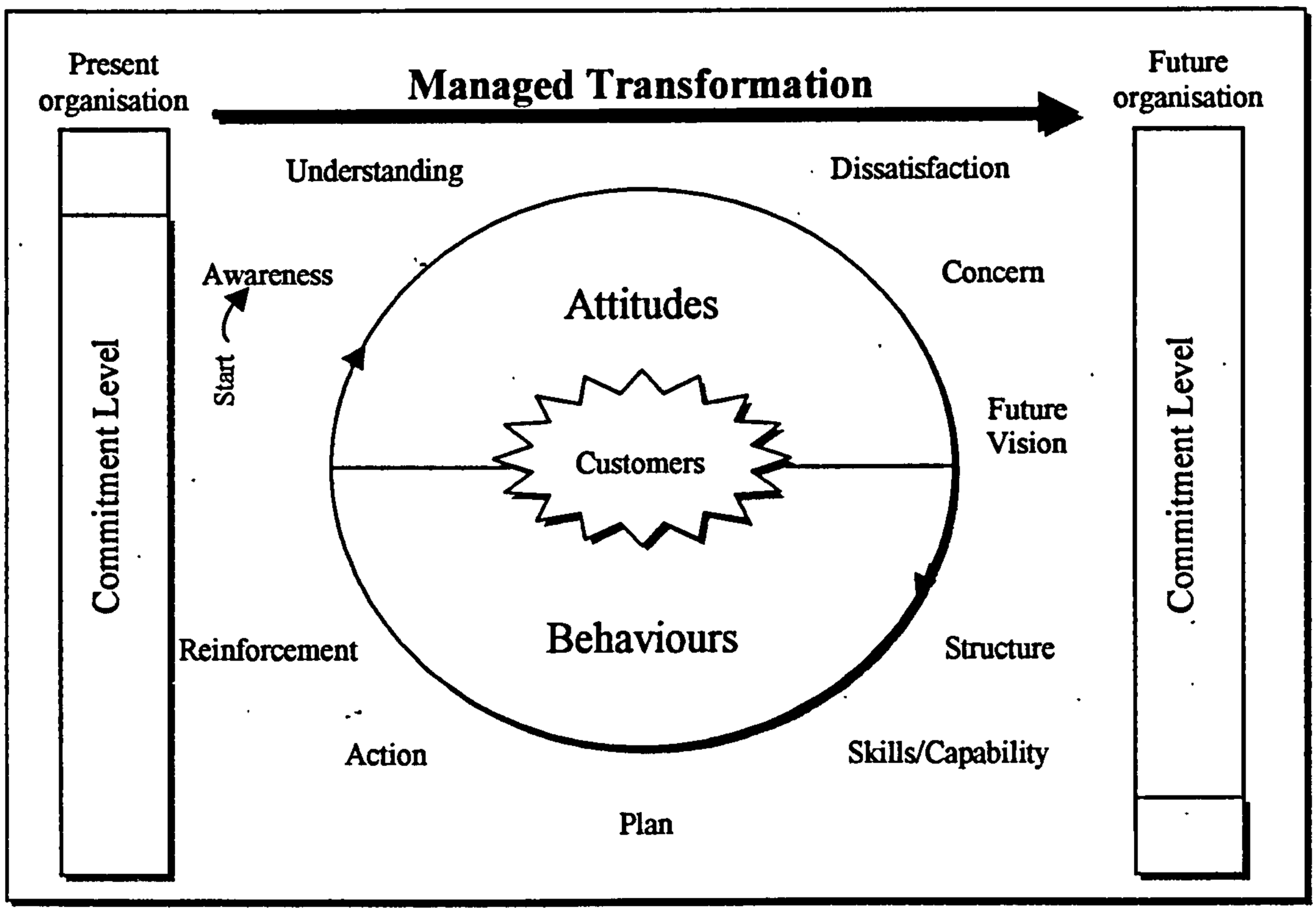

Figure 2.7: Managed transformation model (Fredrick and Christman, 1997)

2.2.2.2 Enriching Customers, Products and Solutions (Providing Total Solutions)

The traditional manufacturer of goods, according to Nagel *et al*, (1992), often misses the opportunity for customisation, convenience services, education and training, ongoing maintenance, enhancements and upgrades thus not providing the total solutions aligned to the customers' needs. Enriching the customer with total solutions allows a new pricing strategy for products and services that is not based on the tradition of 'cost plus' but on customer perceived value (Goldman *et al*, 1994).

In aiming to enrich customers with what they want, when needed, the agile organisation integrates rapid prototyping, concurrent engineering, and information technology through empowered teams, continuous improvement and marketing strategies. Such integrated strategies will enable the capture of niche markets providing customer focus and valued customised product and solutions. The ability of a company to respond to niche markets is related to their design proficiency, that is

their ability to readily adopt new designs into the organisation, whether this is a totally new product design or a new product to them.

The essence of enriching customers, products and solutions is the precipitation of opportunity, reading the signals for sales. Shulman (1997) has described this as, in effect, "...providing customers with solutions even before the customers know what their needs are." Hormozi (2001) on a review of agile manufacturing goes as far as to say: "Agile enterprises should look beyond internal cross-functional teams in order to aggressively and proactively pursue any market opportunity that arises." Thus indicating that an agile organisation must be proactive in surveying the external environment for both opportunity and threat to their operating and market domain. This therefore implies that management should be quick to recognise the strengths and weaknesses in their resources and find alternative means to overcome these weaknesses, as Hormozi suggests; "...sometimes through the cooperation of suppliers and sometimes even with competitors."

2.2.2.3 Leverage of People through Knowledge and Information

Continuous education and training enhances people's skills and knowledge so that empowered decision making can be made closest to the problems or opportunities being addressed. In an agile enterprise investment in human capital is seen as an enabler for future competitiveness and can be developed through effective utilisation of Information and knowledge-based systems. Prahalad and Hamel (1990) have defined core competencies as the collective learning processes focused on development and co-ordination of a diverse range of skills and capabilities. Agility is gained by reducing hierarchical control, supporting workers in teams and empowering them to make decisions. Good reliable communication and information systems enhance the success of self-directed work teams in a manufacturing environment (Irani *et al*, 1997).

Agile manufacturing takes into consideration the ability of a company to unlock the potential of its people and as discussed by Hormozi (2001) the agile organisation will encourage (if not require), creativity from employees. This notion is considered key to an agile organisations' ability to thrive in an agile environment and considered in the

book from an author in agile and virtual organisations, Gunnesson (1997), "Transitioning to Agility" as:

> *"In the agile environment, the ability of a company to unlock its people's potential is critical to its success. Processes, advanced technology, and strategy can be copied and copied quickly people cannot. Managing knowledge capital is a little-understood key to success. Acquiring, developing, retaining, and moving knowledge capital to the "moments of truth" the customer contact points will be the key in the 1990s to sustaining a competitive advantage." (Gunneson, 1997).*

The information technology and infrastructure needed to facilitate agile manufacturing needs to connect people from a network of suppliers, customers, partners and producers. An appropriate information and knowledge system would allow member organisations the advantages of real-time production through real-time sampling and analysis, and diagnostics (Nagel, 1993). Accordingly, Goldman *et al* (1995) have suggested an example of this type of communication is the recent development of the Boeing 777 airplane. This project was a combined effort of 250 cross-functional teams that were linked electronically. Goldman *et al* (1995) further said this particular alliance of domestic and international manufacturers completed the project using complementary core competencies.

2.2.2.4 Co-operating to Enhance Competitiveness–Virtual Organisation/Partnerships

In an agile organisation co-operation and collaboration in a virtual enterprise enhances the competitive capability bringing together the competencies required for a specific period of time and then dissolves these alliances as the partners move on to other projects (Handley, 1997). Agile organisations foster collaboration internally across departments and divisions as well as externally, bringing together empowered cross-functional teams to solve problems or seize opportunities. Commonly, company cultures are often oriented towards devaluing – seeking out weaknesses and faults, looking for mistakes and acting on the basis of distrust (Savage, 1996). This is in

contrast to an agile culture that strives to build creativity and innovation throughout the organisation and across organisational boundaries to the virtual enterprise.

These virtual corporations have been considered by Davidow and Malone (1992) who believe they capitalise upon their various pockets of excellence and draw into one fiercely competitive organisation the various skills of many independent firms. According to these authors this is against the capitalistic logic that dictates monopolies and trusts, which discourage competition. To be able to do this effectively managers should provide an infrastructure to support employee empowerment (Barkman, 1987 and Irani *et al* 1997a) and thus facilitate trust as a core organisational value. Similarly, Kovac (1993) considers agility, as being gained through effective collaboration or partnerships with suppliers and customers continually improving communication within the supply chain. Likewise McAdam and Brown (2001) have included an assessment of partnerships in their research in the supply chain of rapidly changing markets thus further suggesting partnering will improve agile responsiveness.

Without an industry's desire to forge new working relationships among multiple organisations successfully implementing agility will not be possible:

> *"Virtual partnering creates dynamic networks of opportunistic companies that can better take advantage of fast-changing opportunities collectively as an enterprise than any could operating as an individual organization. They leverage the competencies of others that are better than theirs. As an enterprise, they are in a real sense redefining the nature of business." (Gunneson, 1997).*

The concept of a virtual network of organisations consequently further enhances the ability of an organisation to survey the external environment and identify opportunities to enhance competitiveness. Thus without virtual networks an organisation is disadvantaged because it does not have the ability that an organisation that networks prolifically has to identify opportunities in the marketplace. Likewise in aerospace case study literature it is well documented that in the USA the experience of Boeing forming alliances with partners and suppliers has had great success, (Handley, 1997).

2.2.2.5 *The Agility Forum Framework for Manufacturing*

The agility forum has continued developing the seminal work on agility produced by the Iacocca Institute, Dove (1996), Dove *et al* (1996) and consequently produced and tested an infrastucture framework for agile manufacturing. The framework developed has been produced from a set of competitive foundations and common characteristics, systems elements and enabling subsystems for agility, that have been developed from industry led research. These are represented in figure 2.8 as an infrastructure for manufacturing and have been the issue of many research and industry improvement studies (Sutphin, 1995; Dove *et al*, 1996).

Agilty is not a concept without a great deal of depth to it, as figure 2.8 shows the agility forum have developed the theory of agility into a framework that incorporates concepts drawn form many disciplines, into a cohesive set of enterprise elements. Termini (1996) has reviewed these enterprise elements and suggests these contribute to the core competencies of:

- Timely and consistent technological innovation
- The ability to quickly identify potential market opportunities
- The ability to develop and maintain a broad-based, well-educated workforce
- Enhanced communication and data processing networks
- The ability to provide low cost customised market products
- The ability to provide products that are market driven

Hooper and Steeple (1996) show the structure of agile manufacturing and its interrelationships with other manufacturing methodologies and in a similar way to the agility forum framework figure 2.8, suggest that agile manufacturing should be seen as an umbrella phrase which encompasses the integration of a number of diverse systems, technologies and philosophies. This Hooper and Steeple structure of agile manufacturing is a customer focus model of manufacturing and is analogous in the main to Total Quality Management (TQM) models as presented in section 2.1.4, however the concept of virtual companies and the decentralised organisation are elements. Hooper and Steeple (1996) provide a model structure, figure 2.9 for agile manufacturing, which appears insufficient as a framework for entrepreneurial activity,

in that opportunity seeking in new markets is not represented but is given consideration in the agility forum model, figure 2.8 as implied enabling sub-systems.

COMPETITIVE FOUNDATION AND CHARACTERISITICS	MANUFACTURING ENTERPRISE ELEMENTS	IMPLIED ENABLING SUB-SYSTEMS
▪ COMPETITIVE FOUNDATION ▪ Continuous change ▪ Rapid response ▪ Evolving quality journey ▪ Environmental responsibility ▪ ENTERPRISE CHARACTERISTICS ▪ Concurrency ▪ Continuous education ▪ Customer response ▪ Dynamic multi-venturing ▪ Employee valued ▪ Empowered individuals in teams ▪ Environmentally benign ▪ Flexible (Re-) configurable ▪ Information accessible and used ▪ Knowledgeable employees ▪ Open architecture ▪ Optimum first time design ▪ Quality over product life ▪ Short cycle time ▪ Technology leadership ▪ Technology sensitivity ▪ Total enterprise integration ▪ Vision based management	Business environment Communication and information Cooperating and team factors Enterprise flexibility Enterprise wide concurrency Environmental enhancement Human elements Sub-contractor & supplier support Technology deployment	▪ Continuous education ▪ Customer interactive systems ▪ Distributed databases ▪ Empowered individuals and teams ▪ Energy conservation ▪ Enterprise integration ▪ Evolving standards ▪ Factory America net ▪ Global broadband network ▪ Global multi-venturing ▪ Groupware ▪ Human-technology interface ▪ Integration methodology ▪ Intelligent control ▪ Intelligent sensors ▪ Knowledge based systems ▪ Modular reconfigurable process hardware ▪ Organisational practices ▪ Performance metrics& benchmarks ▪ Pre-qualified partnering ▪ Rapid co-operation mechanisms ▪ Representation methods ▪ Simulation and modelling ▪ Software prototyping & productivity ▪ Streamlined legal role ▪ Supportive accounting mechanisms ▪ Technology adaption and transfer ▪ Waste management & elimination ▪ Zero accident methodology

Figure 2.8: The Agile Enterprise (Dove, 1996)

It is necessary for an organisation to continually be aware of the operating environment to assess potential risk to the business as shown in the framework for the agile enterprise illustrated by Dove (1996) and shown in figure 2.8. Additionally, Meredith and Francis (1999) have discussed this as wide deep scanning of the environment, which is necessary for organisations to seek out niche market opportunities.

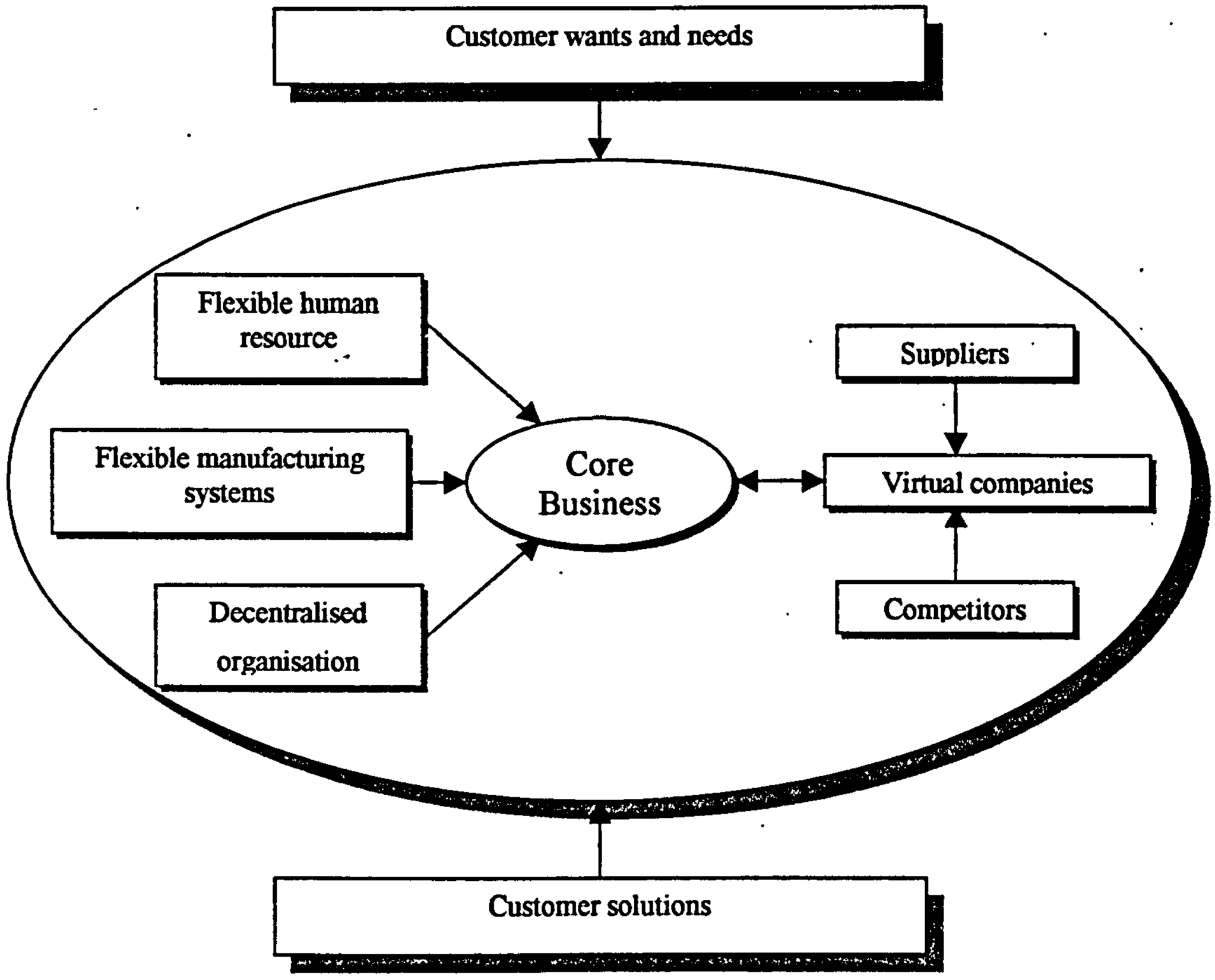

Figure 2.9: The Hooper and Steeple Structure of Manufacturing
(Hooper and Steeple, 1996)

The Hooper and Steeple (1996) model, figure 2.9, does however show that an appropriate structure for manufacturing includes the concept of virtual companies that have input from suppliers and competitors.

2.2.3 The Work of Kidd

Paul Kidd, a UK consultant and researcher, has done much in the UK and Europe to develop the understanding of what are the operational requirements of agility,

producing several books on the subject, leading the European Agility Forum and organising many conferences and symposiums on the subject of agility and next generation manufacturing. A key focus of the work of Kidd is agile competencies brought together in networks of organisations, hence he suggests:

> *"The concept of Agile Manufacturing is built around the synthesis of a number of enterprises that each have some core skills or competencies which they bring to a joint venturing operation, which is based on using each partners' facilities and resources. For this reason, these joint venture enterprises are called virtual corporations, because they do not own significant capital resources of their own. This helps to make them Agile, as they can be formed and changed very rapidly." (Kidd 1994).*

In the book, Agile manufacturing: Forging New Frontiers, and other publications, Kidd advocates the integration of technology, organisation and people as critical to the success of an organisation:

> *"An agile corporation is a fast moving, adaptable and robust business enterprise capable of rapid reconfiguration in response to market opportunities. Such a corporation is founded on appropriate processes and structures and the integration of technology, organization and people into a coordinated system in order to achieve a quantum leap forward in competitive performance by delivering capabilities that surpass those obtained from current enterprise practices." (Kidd 1994, 1995).*

According to Kidd the fundamental resource for an agile organisation is "knowledge" and similar to the US agile forum principal dimension of agility, "Leverage of people through knowledge and information," he suggests that if people and knowledge are leveraged then:

> *"The Agility that arises can be used for competitive advantage, by being able to respond rapidly to changes occurring in the market environment and through the ability to use and exploit a fundamental resource - knowledge. People need to be brought together, in dynamic teams formed around clearly defined market*

opportunities, so that it becomes possible to lever one another's knowledge. Through this process is sought the transformation of knowledge into new products and services." (Kidd, 1994).

Moreover, on people and organisation integration, Kidd (1997a) has said there is a need for most organisations to develop a culture that is capable of dealing with continual change in technology, organisational structure and systems. Although this issue of integration and culture has been discussed by Peters and Waterman referring to the McKinsey 7-S framework for organisational analysis, which is discussed later in section 3.1.3.1.1. Some of the key words and phrases linked with the agile paradigm expressed by Kidd (1996a) are:

- Fast - a very high speed of response, for example, to new market opportunities.
- Adaptable - the capability to change direction with ease, for example, to enter completely new markets or product areas.
- Robust - avoiding and withstanding variations and disturbances, for example, products that lose market appeal owing to changes in customer preferences.
- Virtual corporations - the combining of talents between companies through (short term) joint ventures.
- Reconfiguration - the ability to very quickly reconfigure corporate structures, facilities, people, organization and technology to meet (often) unexpected and (probably) short lived market opportunities.
- Dynamic teaming - actively looking for and building off the creative and innovative talents of other team members.
- Transformation of knowledge - explicitly transforming raw ideas into a range of capabilities, which are then embodied in both products and services.
- Kidd (1994) has suggested that agile manufacturing can be considered as the integration of organisation, 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 product. This concept is the focus

of his book "Agile Manufacturing: Forging New Frontiers" and is illustrated in figure 2.10.

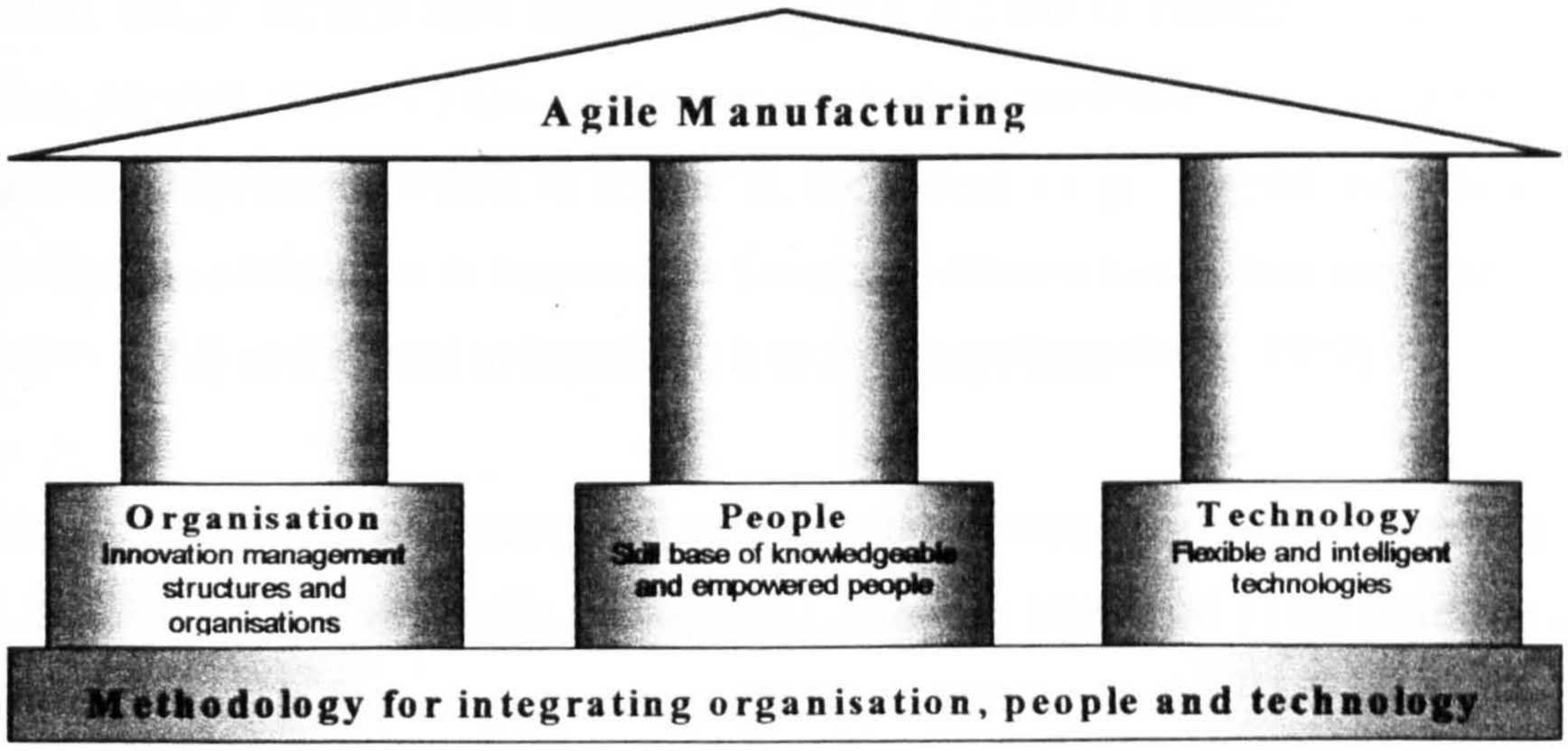

Figure 2.10: The structure of a Agile Manufacturing Enterprise (Kidd, 1994)

Accordingly Kidd (1994) advocates that each organisation should develop a methodology for integrating organisation, people and technology to enable these three primary resources to achieve agility from a co-ordinated, interdependent system.

2.3 Aerospace Manufacturing Management

In 1998 a number of aerospace companies in the south-west USA were visited to assess their progress in improving manufacturing processes and the following Department of Trade and Industry (DTI) report by Clifford *et al* (1998):

> *"Many of these companies in California and Arizona, such as Boeing (Long Beach), Allied Signal Engines (Phoenix), Rohr (San Diego), and Simula (Los Angeles), have introduced lean manufacturing based on the Lean Aircraft Initiative and developed from the Toyota Production System."*

However the DTI report further suggests that the results were not impressive as in each case, there was little recognition that lean manufacturing is an intermediate stage en route to agile manufacturing. Similarly the report indicated that the initial stages of waste reduction, progress has stalled to such an extent that there was little ongoing continuous improvement.

In contrast, the report made comment that Boeing Helicopters (Mesa) and Kaynar (LA), have made significant progress by developing continuous improvement methods, which include lean manufacturing but are aimed beyond that phase, whilst Hughes Aircraft (Tucson) are a prime example of a company that has introduced an integrated programme which is aimed at the outset to go beyond lean to an agile capability. In addition, it is known that Lockheed-Martin have taken the Lean Aircraft Initiative (LAI) and started to introduce it to their suppliers (MIT, 1997).

Similarly, within the UK, many aerospace prime contractors and first-tier suppliers, such as BAE SYSTEMS, Rolls Royce and Lucas, are interested in the development of lean and agile manufacturing processes (Phillips, 1999). Although it is argued in this thesis that there is not a clear differentiation between lean and agile in aerospace and the concepts are closely tied together. This view is supported by Phillips (1999) who claims to consider agile manufacturing in aerospace, has in reality discussed in the main the concepts advocated by a lean manufacturer, hence the concept of lean and agile are inappropriately used synonymously. Although some authors do discuss agility appropriately such as Lockheed Martin researcher and US aerospace experts on agility Bipin Chadha *et al* (1996) suggesting " ... culture as a core element of the infrastucture of agile manufacturing".

The UK Lean Aerospace Initiative advocates the principles of lean, supported by SBAC and EPSRC and based upon the MIT Lean Aircraft Initiative (MIT, 1997). This UKLAI sought to develop a lean framework for the UK aerospace industry at the higher tiers of the industry, with some input from SMEs. According to Woodhead and Sharp (1998) in 1993 US labour unions, defence aerospace businesses and MIT formally launched the Lean Aircraft Initiative (LAI) with the goal of transferring the lean practices that had seen success in the automotive industry to US aircraft industries. During the first phase of the LAI a systematic framework, referred to as the Lean Enterprise Model (LEM†), was designed to organise and disseminate research results to LAI consortium members (figure 2.11).

† Further details of the LEM are available to LAI consortium members. The LEM consists of a hierarchical structure. At its top are six principles that define lean philosophy, followed by 12 overarching practices, with 30 specific metrics at the base that support the top level lean philosophies.

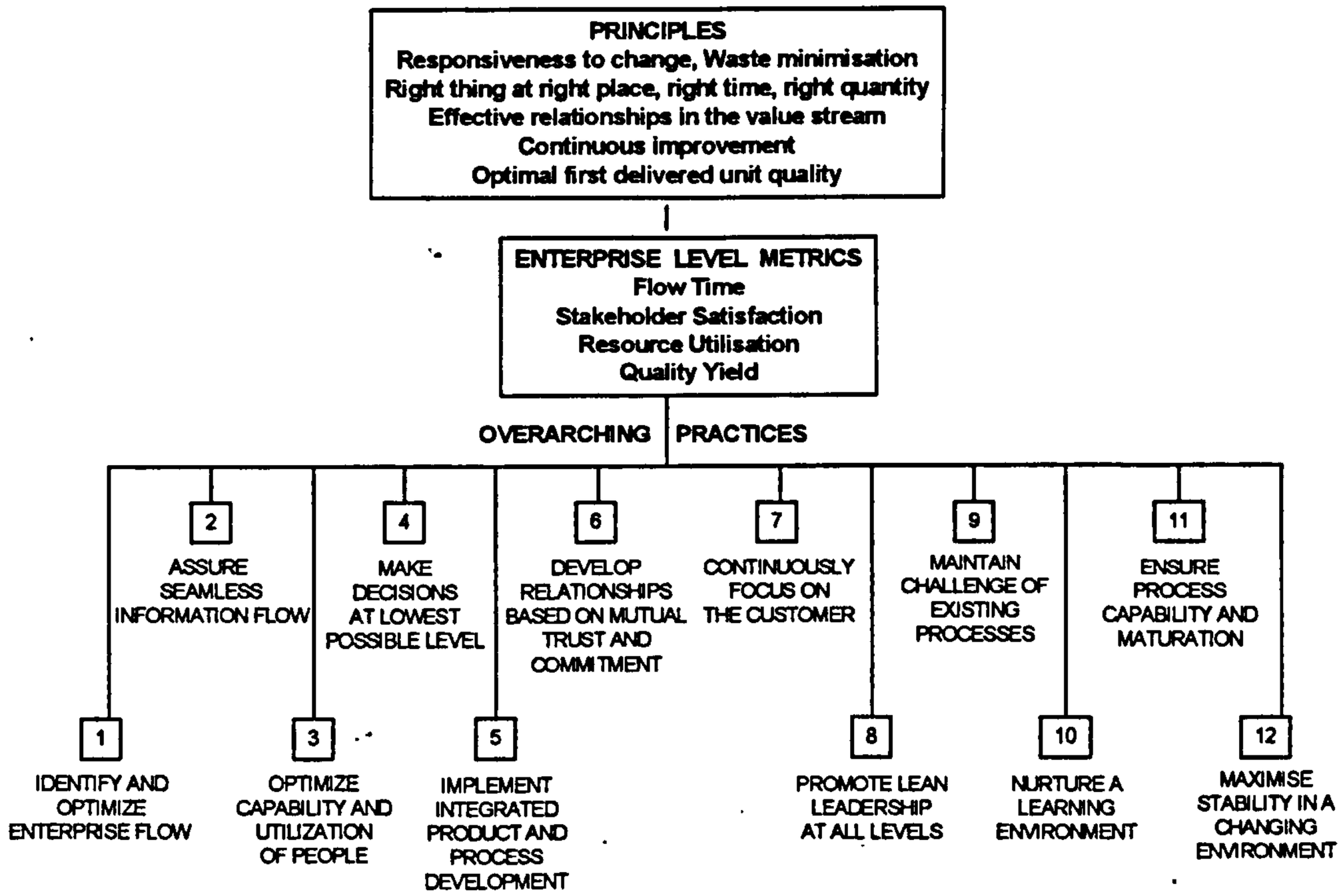

Figure 2.11 The Lean Enterprise Model (LEM)

This Lean Enterprise Model (LEM) model according to the US Lean Aircraft Initiative (USLAI) was to serve as a reference to help consortium members better understand the leanness of their own organisations and processes and to provide insights as to where they might direct lean efforts. The LEM encompasses lean enterprise principles and practices and is populated by research-based benchmarking data derived from surveys, case studies, and other research activities.

In contrast to the automotive industry, most aerospace industries do not have roots in mass production and continuous line environments. Unlike the automotive reference base of the Toyota Productive System, there is no lean "best practice" aerospace company example (Clifford *et al*, 1998). Indeed, it is already shown that the application of lean manufacturing in the US Aircraft Industry has had mixed success, often because companies adopt lean in order to impose even tighter restrictions on their suppliers (Velocci, 1999). The result has been that some already efficient suppliers have been squeezed into 'business anorexia' and bankruptcy whilst other companies introducing lean manufacturing have faced significant labour problems and reduced

capability to adapt and manoeuvre in a changing and unpredictable business environment (Clifford *et al,* 1998).

The UK aerospace industry also differs from many high technology industries that have effectively achieved efficiency improvements throughout their supply chain, in that its products are super-high value, highly-integrated systems with long lead times, specific system integrity issues, and extensive certification demands and are often produced for just one customer. Consequently, very few components are mass-produced (indeed, many components are ordered in single figure batch sizes) and the business environment for the product introduction process (and, indeed, the whole product life-cycle) is very changeable, due to numerous factors including changes in customer requirements, component obsolescence, demands for new technology inserts, and imposed regulatory amendments resulting in a lack of stability for the suppliers to develop more efficient processes. As a result the aerospace industry has to be sufficiently agile and flexible to accommodate these environmental perturbations whilst becoming leaner to meet reductions in cost and delivery time demanded by the same customers who repeatedly modify their requirements.

Bamber *et al* (1998a) on a review of lean and agile capabilities in aerospace manufacturing small to medium sized UK (SMEs) has discussed their agileness:

> *"Many SMEs within the aerospace industry sector are capable of adapting to change faster and more effectively than larger prime contractors, and have effectively become lean as a requirement of the pressures within the industry to be cost competitive. Likewise, many SMEs within the aerospace sector have to be adaptable and responsive due to the nature of the business environment and the unpredictability seen lower down the aerospace supply chain. Therefore, it is recognised that many of these companies are, to some extent, agile, since they are companies which have had to be very responsive to customer needs in order to survive the cyclical depressions which have characterised the industry over the last 40 years."*

Bamber *et al* (1998a) have provided further discussion on the comparison of lean and agile within UK aerospace and the following section is predominantly taken from these discussions.

2.3.1 An Evolution of Management in the UK Aerospace Manufacturing Sector

The historical evolution from craft based production, through mass and lean, and on towards agile manufacturing, as perceived by Dove (1996) for the US automotive industry is shown in figure 2.12.

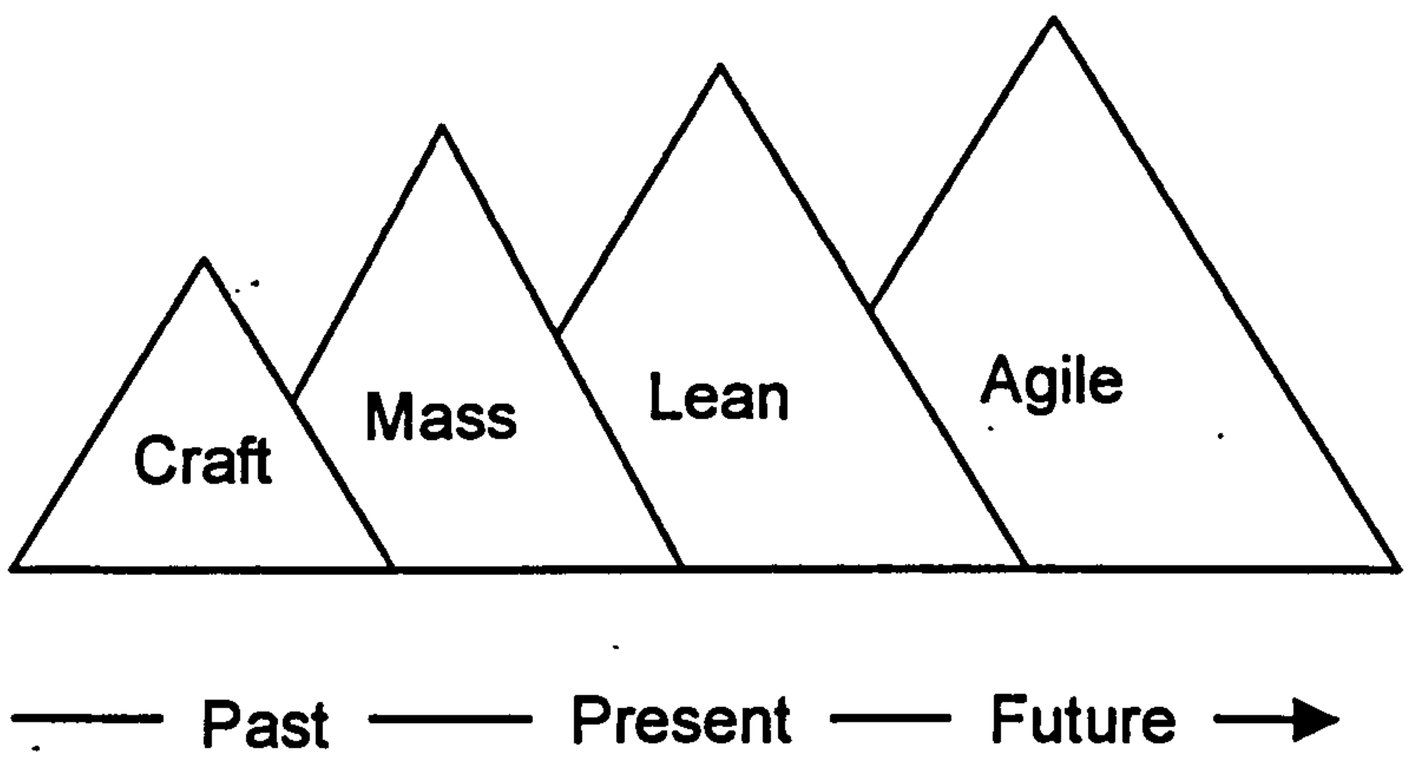

Figure 2.12: A progression of manufacturing paradigms within the automotive industry (Dove 1996)

This however, is not representative of a historical progression within the aerospace industry. The roots of aerospace industry are more related to the craft production enterprise while there are only small elements of mass production and continuous flow practice. As opposed to the automotive industry, the aerospace industry has not seen the economies of scale in production runs, capacity planning and capital expenditure inherent in a 'make to forecast' industry. In fact, the aerospace industry has been predominantly a 'make to order' environment. Therefore, a more accurate comparative representation of the historical evolution of manufacturing in the aerospace industry, is shown in figure 2.13, which indicates that the aerospace industry did not progress from craft through mass to lean, but progressed directly to lean from craft.

Consequently, there are emerging needs, which are placing added pressures on the aerospace industry and must be considered by the UK aerospace Small to Medium Size Enterprises (SMEs) in order to ensure their continued longevity. These companies must be responsive to a business environment that is changing and unpredictable with respect to the increasing demands of prime contractors who, through preferred supplier initiatives, are shifting a larger proportion of business risk on to their suppliers. They must also be aware of potential benefits to be made from collaboration with other SMEs, where combined resource and capabilities are utilised to form effective competitive alliances. These considerations imply that there is a need for SMEs to invest in the continuous improvement of their capabilities whilst still managing to satisfy current demands and deliver small-batch production on time and at lower cost.

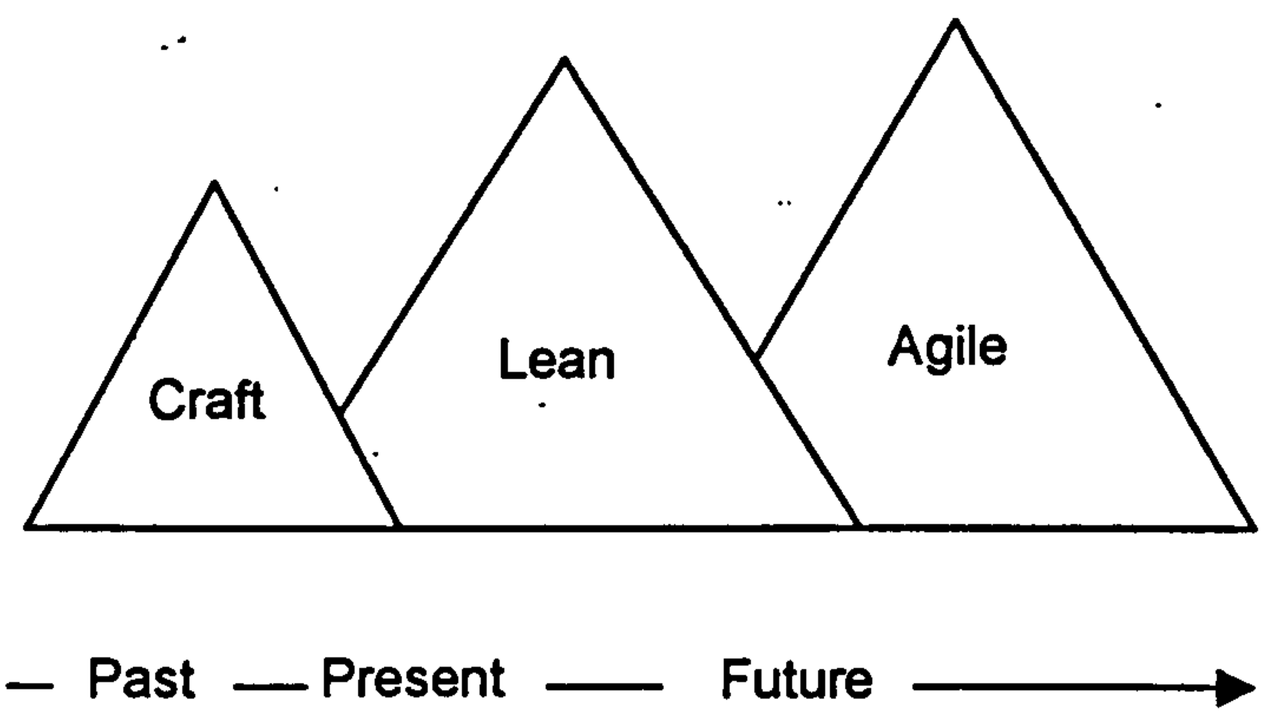

Figure 2.13: A progression of manufacturing paradigms within the aerospace industry (Bamber *et al,* 1998a)

As discussed in previous paragraphs nevertheless, it is lean manufacturing with its origins in the automotive industry, which has been introduced into the US aircraft sector with varying degrees of success and is currently being introduced into the UK aerospace industry with large prime aerospace companies working toward reducing their approved/preferred supplier base, typically from several hundred to below fifty, in line with lean thinking. However, the comparison of lean and agile concepts with respect to the aerospace industry suggests that:

1. Less of lean can be readily transferred and accepted into the aerospace sector than into the automotive industry.

2. More of a craft based production enterprise is present within aerospace industries and can be developed to give a sound foundation for multi-skilled flexibility, and improved capability.

Subsequently, with recent trends showing that the amount of work required by the primes is likely to be on the increase and subsequently, with prime contractors adopting lean manufacturing practices, it is anticipated that:

1. The Small Medium Enterprises (SMEs), out of necessity, will look toward forming alliances, in order to maintain business through collaboration and core competence/capability and capacity sharing.
2. Some aerospace SMEs will not survive in their present organisational form due to increased competition and upturn in business.
3. Interfaces and communication between prime and sub-contractors and suppliers will need to take on different dimensions due to a reduction in the supplier base.

Combined with the widely differing enterprise characteristics such as capability, size of facilities, capacity, core competencies and percentage turnover in aerospace business, a prescriptive approach with defined metrics, such as the Lean Enterprise Model (LEM) may not wholly be suited or relevant to SMEs within the industry. Hence, customised programmes or metrics may be developed and comparisons of aerospace industry best practice may reveal different metrics for different situations.

It is recognised that there is a proportion of craft capability within both lean and agile although more multi-skilled craft capability is required by agile to ensure it remains flexible and effective than by lean (Bamber *et al* 1998a). Figure 2.14 aims to show this relationship of craft, lean and agile competencies. It is also recognised that there is a great deal of commonality between lean and agile, such as the effective use of best practice tools and techniques in order to improve the overall efficiency and effectiveness of the business. This commonality is illustrated in figure 2.14, where, for example, elimination of wasteful activities and processes, improved supplier relations (both internal and external) and team-working philosophies are important aspects of lean and agile organisations.

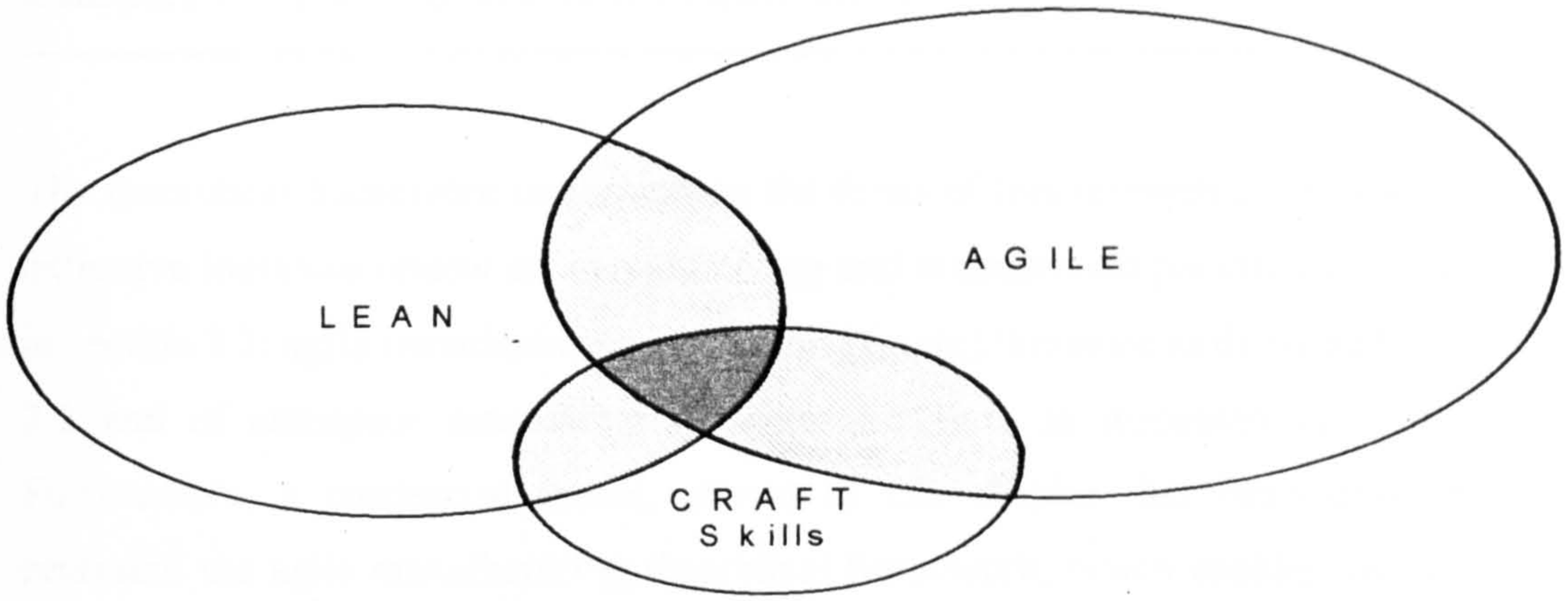

Figure 2.14: Commonality of attributes and skills (Bamber *et al* 1998a)

Figure 2.14 also illustrates that the skills brought forward from traditional production environments are required by both lean and agile organisations, although it is anticipated that agile practice will require a higher proportion of skills/ multi-skilling. This is a view supported by Dove (1996) who, with reference to his eight agile change domains, states that lean manufacturing only deals very directly with variation, augmentation and correction. Therefore their are two arguments rising from this section which state; firstly that agile manufacturing in aerospace is not currently seen as a priority issue because there is a preoccupation with lean aerospace/aircraft principles; secondly the aerospace sector has not progressed historically through the same manufacturing paradigms apparent in the motor trade.

Chapter 3 The Theoretical Framework

The theoretical framework underpinning the focus of this research is derived from an extensive literature review of; manufacturing and management paradigms as discussed in section 2.1; agile manufacturing (and management) literature as discussed in section 2.2 and of aerospace manufacturing sector literature as discussed in section 2.3. Furthermore, a conceptual model, shown in this chapter, has been developed to represent the agile manufacturing theoretical framework, which enables the reader to understand the relationships of the various parts of the model from a systems perspective.

3.1 The Conceptual Model of Agility

The conceptual model is presented in the form of a mechanical system with gears (operational characteristics), lubrication to the mechanics (organisational psychology), a driving power system (external motivators) and a governing system (the agile strategy cycle). This mechanical system analogy is further expanded upon in section 3.2.2, which provides a detailed discussion of the conceptual model and all its parts.

This conceptual model at a macro-systems level, as shown in figure 3.1, essentially includes the four agility enabling integrated sub-systems of:

- Agile manufacturing strategy
- External motivators
- Organisational psychology
- Operational characteristics

The macro-system view of the conceptual model represented by figure 3.1 is provided to show the relationship of the agility enabling macro sub-systems that are considered from the review of literature in chapter 2, necessary and fundamental to an SME's agile manufacturing system operating in UK aerospace sector. The four agility-enabling sub-systems are interdependent and interrelated bringing together the operational aspects and strategic requirements of agility as illustrated in figure 3.2.

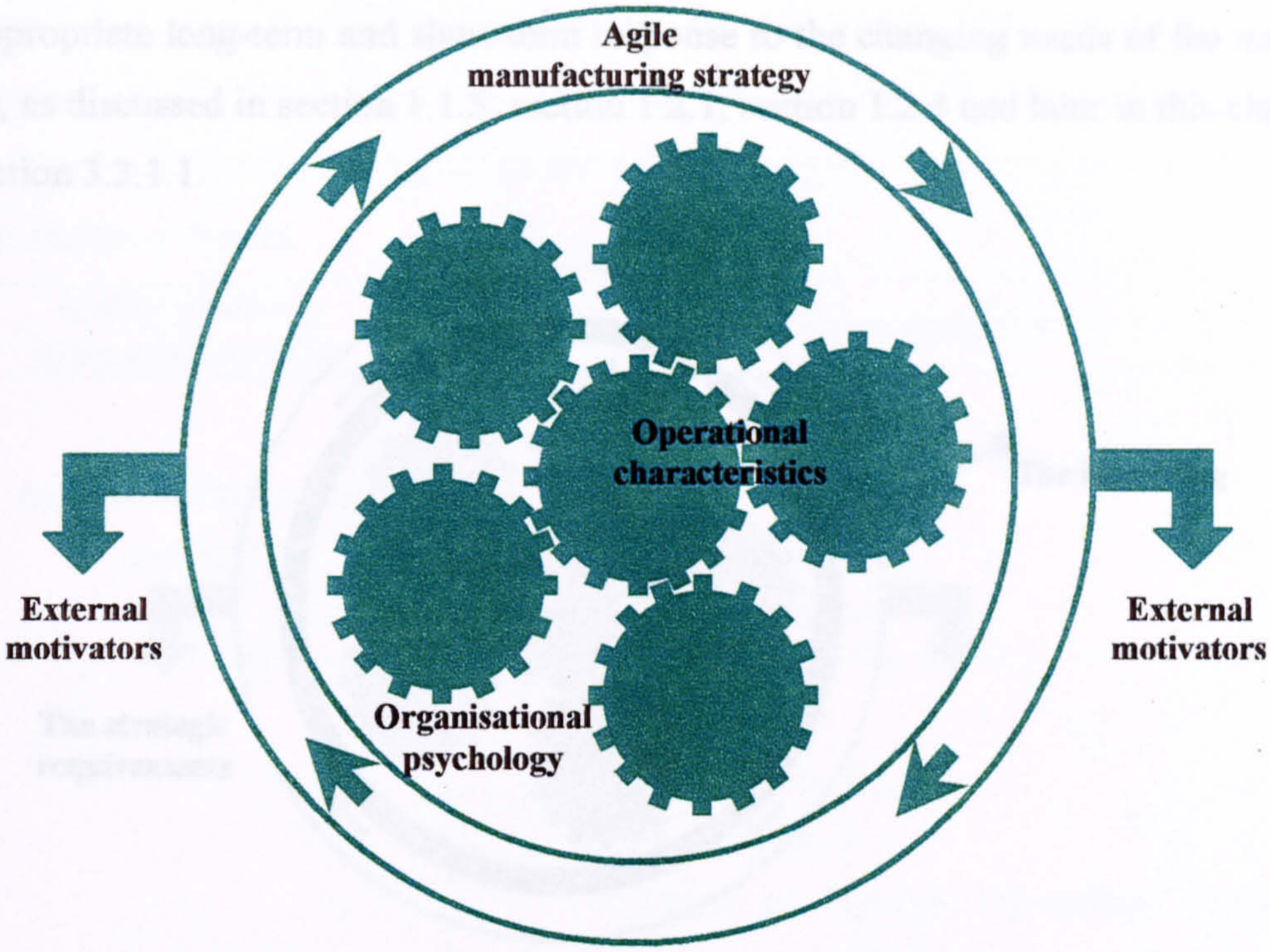

Figure 3.1: Agility enabling macro sub-systems

The inner ring shown in figure 3.2 encompasses the operational aspects of organisational psychology and operational characteristics, while outside of this relates to the strategic requirements of an agile enterprise, namely an agile strategy cycle and an outward looking approach or external motivators of the agile enterprise. Moreover figure 3.2 indicates that the driving forces of agile manufacturing operations are at a strategic organisational level, which is some what similar to "the strategy driven approach" to agility presented in detail by Kidd (1994, p 37) and shown in section 2.2.3 from Kidd (1994a) and Kidd (1997c) and discussed in more detail in section 3.3.1.1 of this chapter.

The strategic requirements and operational aspects of an agile enterprise are depicted separately in figure 3.2 but it is recognised that each have a profound influence on the other. Nevertheless, strategy is recognised as being influenced from the operations and this is discussed in section 3.1.2.1. However the operational aspects are those systems and activities that are directly in the control of the agile enterprise and thus provide the manufacturing paradigm. On the other hand the strategic requirements are those systems and activities that influence the manufacturing paradigm in order to activate

an appropriate long-term and short-term response to the changing needs of the market place, as discussed in section 1.1.5, section 1.2.1, section 1.2.4 and later in this chapter in section 3.3.1.1.

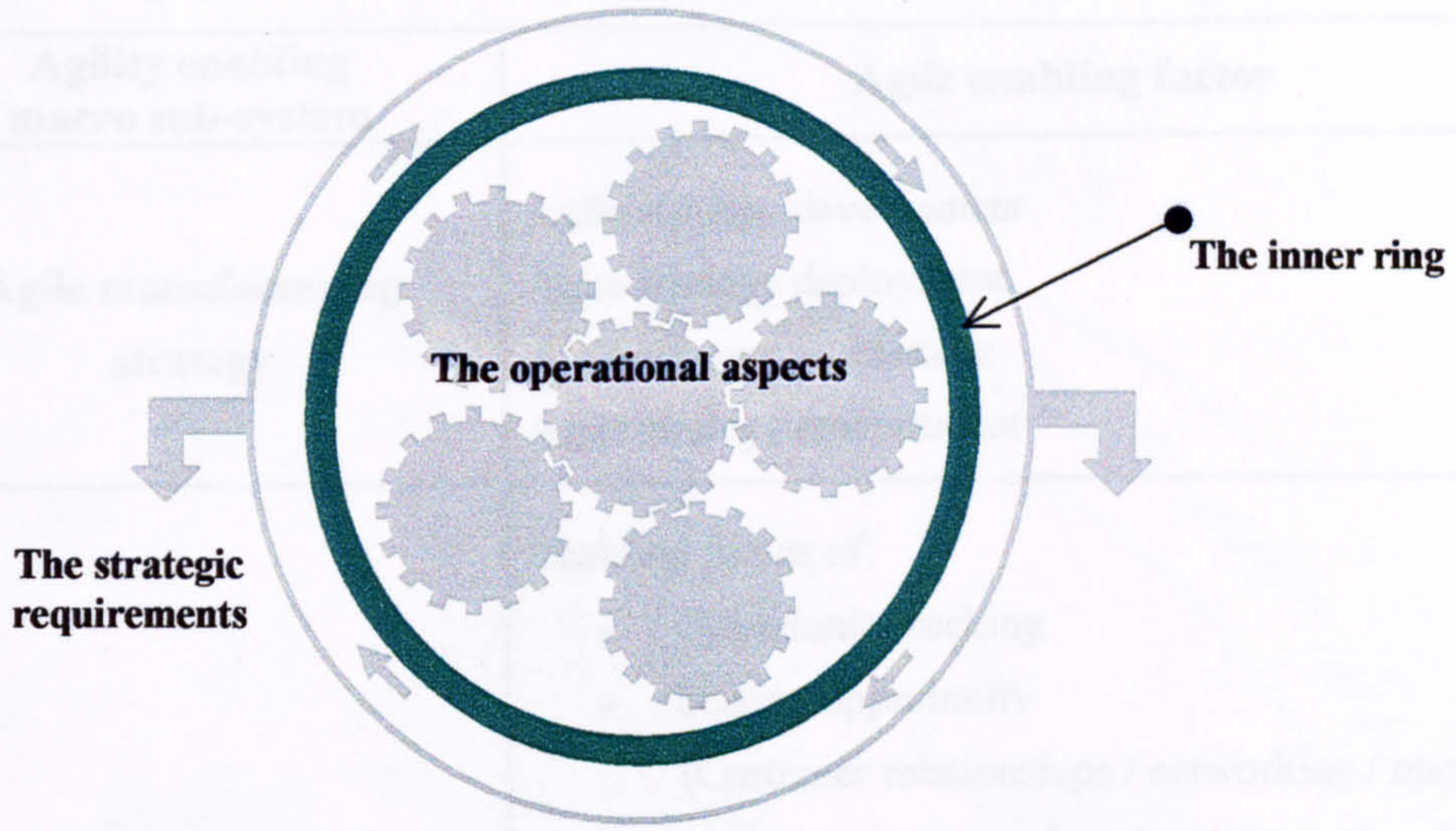

Figure 3.2: Operational and strategic aspects of the conceptual model

Thus operational aspects are driven by the strategic requirements of an agile enterprise which means (as presented in figure 3.1) that in this conceptual model the manufacturing strategy drives the organisational psychology and the agile enabling factors of culture, beliefs, values, understanding and shared vision of the agile enterprise system as shown in figure 3.3.

3.2 The Enabling Factors for Agility in the UK Aerospace SMEs

This conceptual model (figures 3.1, 2 and 3), encompassing the four agility enabling integrated sub-systems, provides the framework for the literature survey identified enabling factors of agility in aerospace small to medium size enterprises (SMEs) operating in the UK. The conceptual model is comprehensive in that it is a synthesis and development of the theory represented in chapter 2 and presented in pictorial form, within which are the agility enabling integrated macro sub-systems, as shown in figure 3.1 as the enabling factors for agility in UK aerospace SMEs. The enabling factors as represented in figure 3.1 are also tabulated in table 3.1 to provide further clarity of the key groupings (agile enabling sub-systems and agile enabling factors). The enabling factors for agility in UK aerospace SMEs provide the assessment categories for this

research and thus fundamentally provide the aerospace SME agile framework generated and discussed in section 3.3 while section 3.2.2 is aimed at discussing the conceptual model and all the parts of the model to provide the reader an understanding of the enabling factors.

Agility enabling macro sub-system	Agile enabling factor
Agile manufacturing strategy	Agile strategy development Agile strategy deployment Agile strategy assessment Agile strategy commitment
External motivators	Enabling forces of: • Opportunity seeking • Seizing opportunity (Customer relationships / networking / marketing / venturing / new product development) Resisting forces of: • Environmental • Social • Economic • New entrants • Partners • Customers • Suppliers • Competition
Organisational psychology	Organisational culture Core values Deep rooted beliefs Real world understanding Shared vision
Operational characteristics	Effective information systems Effective enterprise integration Real time production Waste management and elimination Knowledge management Change and risk management

Table 3.1: Enabling factors for agility in the UK aerospace SMEs

Figure 3.3: The conceptual model of agile manufacturing

3.3 The Conceptual Model of Agile Manufacturing in Aerospace

The conceptual model illustrated by figure 3.3 shows a generic representation of agile manufacturing enabling systems and sub-systems. The interpretation of the model, however, is in the context of an aerospace manufacturing small to medium size enterprise (SME) domain. This requires that for this research to fulfil the aims and objectives outlined in chapter 1.0 the interpretation of the conceptual model is aerospace specific, moreover relevant to manufacturing small to medium size enterprises. Similarly, as described in section 1.4.4, established researchers such as Pugh *et al* (1963 and 1969) and Bryman (1989 and 1995) describe this contextual interpretation of concepts as "operationalisation" which provides "operational definitions" which according to Bryman (1995) will incorporate; "...the specification of the steps to be used in the measurement of the concepts under consideration." Likewise, for this research, the interpretation of the conceptual model has been performed in such a manner as to translate the concepts of agility into a set of operational definitions to be used within the context of agility in the aerospace SME manufacturing domain. Notwithstanding this, the generic configuration of the model is expected to be a useful theoretical framework when researching the concepts and application of agility in other manufacturing sectors and domains, but this is not to be considered in this thesis until chapter 5.

3.3.1 An Understanding of the Conceptual Model

Agile manufacturing is primarily seen as a business practice (Kidd, 1994a) aimed at putting the enterprise way ahead of its competitors. Thus the development of agile properties is essential to establish and maintain a competitive advantage, by being able to respond to changes occurring in the market environment and through the ability to exploit the fundamental real and virtual competencies. Consequently, the conceptual model of agile manufacturing shows a synthesis of a number of macro-sub systems (and theories), as shown by figure 3.1, that draw together the operational aspects and strategic requirements, as shown by figure 3.2. These macro-sub systems are needed for an agile enterprise to be capable of taking advantage of the windows of opportunities that arise, from time to time, hence the ability to rapidly respond to changes in the market place and changes in customer demands. Therefore the harmonious marriage of the strategic requirements with the operational aspects of the

organisation is essential for successful agility and hence the integration of all the agile enabling factors is critical, none of these elements can be bolt on, they all work together dependent on each other. Similarly, Senge (1997) articulates on discussing organisational systems:

> *"We have to develop a sense of connectedness, a sense of working together as part of a system, where each part of the system is affecting, being affected by the others, and where the whole is greater than the sum of the parts."*

Therefore the first thing when using the conceptual model of agility is to realise everything is interrelated, complex and dynamic; nevertheless, to help understand the conceptual model, a representation of the system parts is discussed under the agility enabling macro-sub system headings below.

3.3.1.1 Agile Manufacturing Strategy

To achieve a purpose in competition with other organisations, there needs to be a strategy, which provides commercial logic, as suggested by (Cambell and Yeung, 1995) given in section 1.2.4, and to the agile enterprise this requires a strategy that continually facilitates agile principles. Agile manufacturing strategy is hence defined within the conceptual model, figure 3.2, as one of the strategic requirements of an agile enterprise. Accordingly, Kidd (1994) affirms:

> *"We can only benefit from agile manufacturing if we have a strategy of agility which will allow us to formulate a change plan to implement agile manufacturing and be competitive"*

The conceptual model follows the principle of plan-do-check-act as popularised by Deming (1986), which builds upon the Kidd (1994) affirmation above in that, it recognises an agile strategy is not static but must follow a continuous learning cycle and consequently be dynamic. Hence, agile strategy is characterised as a cycle of agile strategy development; agile strategy deployment; agile strategy assessment and agile strategy commitment as shown in figure 3.4. While Meredith and Francis (1999) have described the agile organisations strategy in terms of wide deep scanning, strategic commitment, full deployment and the use of an agile scoreboard, the conceptual model

includes the principles of wide deep scanning within the external motivators agility enabling macro sub-system part of the model.

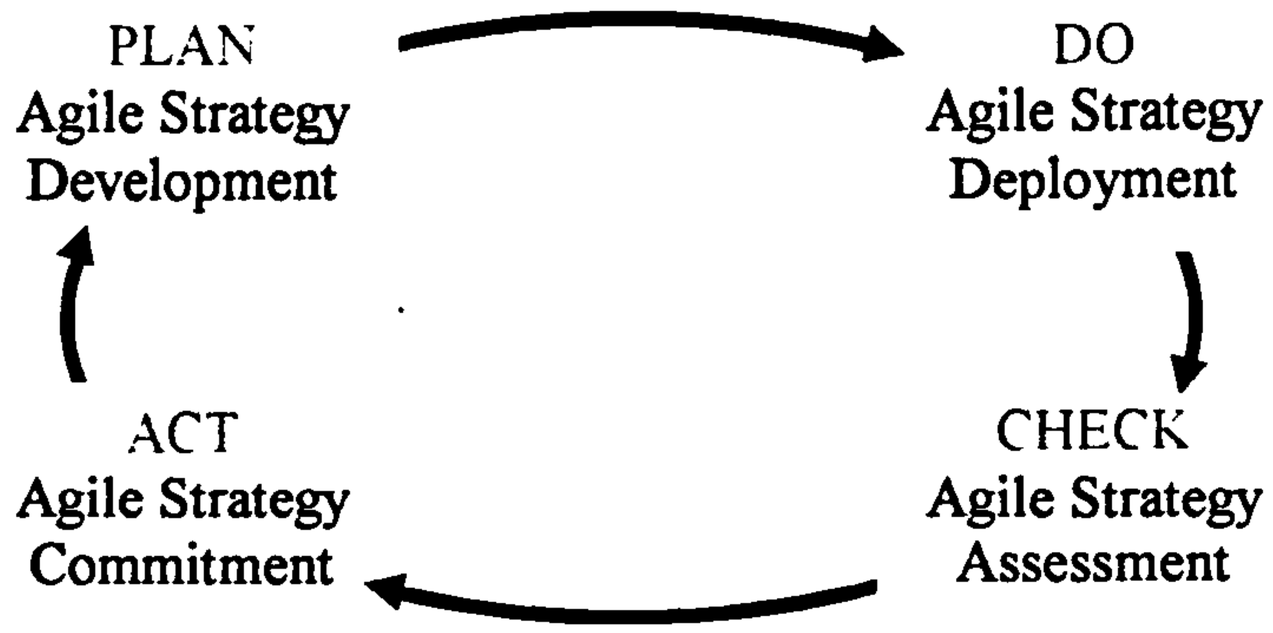

Figure 3.4: Agile strategy enabling factors aligned to the Plan-Do-Check-Act cycle

Johnson and Scholes (1999) have considered a basic three-stage model of the strategic management process as including strategic analysis, strategic choice and strategy implementation, whereas the conceptual model of agility as shown in part by figure 3.4 has four stages. The four stages recognise the work of Gunneson (1997) and Kidd (1994) presented in the sections 2.2.2.3 and 2.2.3 literature, in the respect of the commitment to building agile competencies must be part of the organisations' strategy process. This essentially means as described by Gunneson (1997) that: "The overall culture of the organisation must support risk taking" and hence the commitment to continually assess and amend the strategy, in terms of risk, is an important part of an agile strategy process.

Furthermore, the approach in an agile organisation to the strategy process must include both concepts of incremental strategic change and more radical or fundamental shifts in direction as explored by Johnson (1995) and as such, the conceptual model allows the strategy process to include this approach. Accordingly advocates of organisational continuous improvement and the lean manufacture approach Womack and Jones (1996), naturally use the plan-do-check-act process, while the conceptual model additionally recognises that radical change, hence radical strategic shift, is needed for agility. Consequently the commitment to change the organisational strategy is included in the 'act' part of the strategy cycle, which incorporates both incremental and radical change needs. The influence or facilitator of a commitment to a strategic

organisational shift is expected to come from the external motivators of agility while an incremental strategic shift is more likely to come from the operational characteristics of agility (see figure 3.1). The view that adopting incrementalism in strategic change will lead sooner or later to "strategic drift" is presented by Johnson (1988) and explains this emerges from business practice that is internally constructed rather than objectively experienced. Furthermore, Sadler (1995) on discussing strategic drift states:

> *"Over a period of years the strategy becomes increasingly out of line with the environment. Performance declines in consequence and eventually a more fundamental strategic change becomes essential if the business is to survive."*

In contrast agility requires the competence for spontaneous and radical shifts in organisational strategy as a result of wide deep scanning as described by Meredith and Francis (1999), which in terms of the conceptual model is represented by the external motivators of resisting and enabling forces shown in figure 3.3 and described below in section 3.3.1.2.

3.3.1.2 External Motivators

The conceptual model represented by both table 3.1 and figure 3.3 provides taxonomy of external motivators that are categorised into the agile enabling forces of:

- Opportunity seeking
- Seizing opportunity

This opportunity seeking and seizing of opportunity is through activities such as: customer relationships; supply chain networking and partnering; marketing developments; corporate venturing and new product development. While the agility resisting forces have been identified as consisting of the following issues:

- Environmental
- Social
- Economic
- New entrants
- Customers
- Suppliers
- Competition/competitors.

This taxonomy of external motivators has been drawn from the agile literature presented in section 2.2.2.1 and section 1.2.4 from the work of Porter (1980) and literature available from such publications devoted to venturing (Lloyd, 1992; Block and MacMillan, 1995), marketing (Goldman *et al,* 1994; Kotler, 1997; Ries, 1996) and business development activities (Magretta, 1998; Goldman *et al,* 1995) and also from new product development and innovation processes (Cooper, 1993; Tidd, Bessant and Pavitt, 1997).

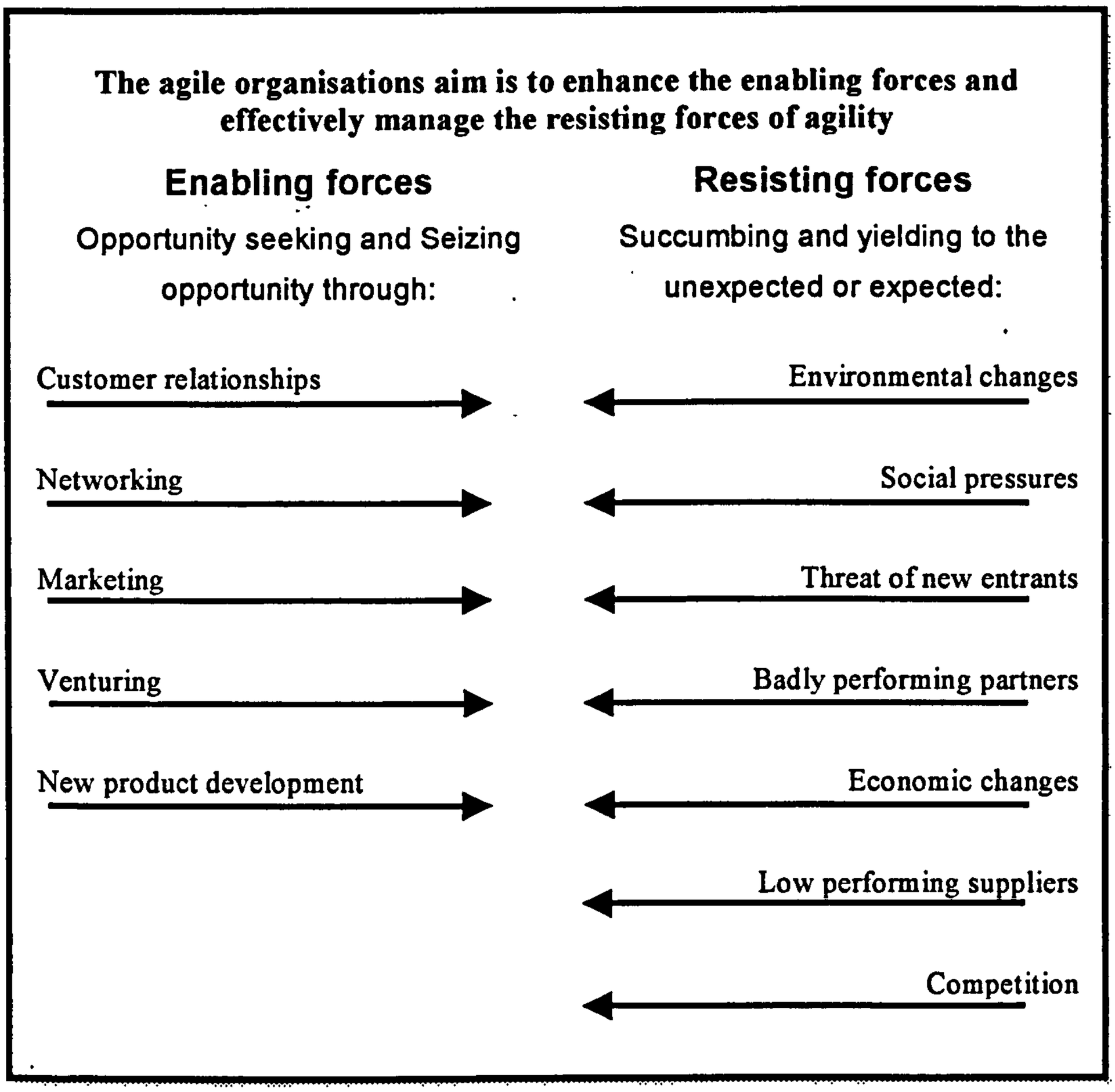

Figure 3.5: The external motivators of agile manufacturing represented as enabling and resisting forces

While the taxonomy is divided into the two categories of enabling and resisting forces, it should be recognised that an enabler handled badly could be a resisting force to

While the taxonomy is divided into the two categories of enabling and resisting forces, it should be recognised that an enabler handled badly could be a resisting force to agility and *vice-versa* a resisting force that is handled appropriately would become an enabler. Figure 3.5 therefore represents these forces in a force field analysis diagram to illustrate the opportunity to an agile organisation to firstly recognise and then make the most of the external motivators.

The need for a new manufacturing paradigm has been discussed throughout section 2.2, and in part, the reason being that lean manufacturing, world class manufacturing, and Total Quality Management (TQM) philosophies focus on the internal organisation and on things that can be controlled and on existing products and customers. Section 2.2 identified a need to include scanning the environment for new opportunities and threats to the organisation (Meredith and Francis, 1999). Hence, the external motivators of the conceptual model have been considered as an integral part of the framework of an agile aerospace enterprise.

3.3.1.2.1 Assessing the Strategic Requirements of Agility

The ethnographic studies, as mentioned in detail in chapter 4 the case study organisations' section of this thesis, play an important role in assessing the strategic requirements of an agile aerospace organisation as mentioned in the above sections. Alongside the ethnographic studies the author has gained a great deal of knowledge of the aerospace sector strategic position. This strategic knowledge of the industry is shown throughout the thesis and particular reference is made of the sector positioning and status in chapter 1, while current changes in the environment have been discussed in section 2.1.4.3 and knowledge of aerospace management is shown in section 2.3 and the publications of Bamber *et al* (1999 and 2001a). Additionally close contact is maintained with North West Aerospace Alliance (NWAA) and likewise meetings and seminars are held by the NWAA regularly.

In addition to observations made during the ethnographic studies a series of topics relating to strategy issues is addressed by a questionnaire that has been developed, which is discussed in more detail in chapter 4, thus providing respondent attitudinal data on the perception of the organisations' strategic maturity.

3.3.1.3 Organisational Psychology

The conceptual model at a macro level, as shown in figure 3.1, includes the agility enabling sub-system of organisational psychology. This sub-system of organisational psychology is integrated with the three other agility enabling sub-systems of external motivators, agile manufacturing strategy and operational characteristics and is therefore seen as a core interdependent variable in an agile system. Within this enabler of organisational psychology the conceptual model presented within this thesis shows the five agile enabling factors of organisational culture; core values; deep-rooted beliefs; real world understanding and shared vision as shown in figure 3.3 and table 3.1. The essential premise of this enabling macro sub-system, of organisational psychology, is that the vision, values, beliefs, understanding and culture of the organisation, promotes agility and does not oppose the agile manufacturing strategy.

Retaining competitive advantage, according to The Agile Manufacturing Research Group (AMRG) relies on being aware of, and creatively responding to, many elements within the business environment, (Merdeith and Francis, 1999). Creativity, it is argued, can only come from people, likewise, Goldman (1995) recognises "leveraging the impact of people and information" as one of the dimensions of agility discussed in section 2.3, "... people - what they know, the skills they possess, the initiative they display - and information are the differentiators between companies in an agile competitive environment ..." (Goldman *et al.*, 1995).

3.3.1.3.1 Organisational Culture

Lockheed Martin researcher and US aerospace experts on agility Bipin Chadha *et al* (1996) discuss culture as a core element of the infrastucture of agile manufacturing mentioned in section 2.3. Cultural issues are represented in section 2.2.2.3 and Kidd (1997a) section 2.4, implied that, a need for a massive culture change is necessary for most organisations to become agile and suggested the need to develop a culture [work force behaviours] that is capable of operating in an agile environment and consequently suggested several areas need to be addressed:

- Training and education.
- Living in a world of permanent change.
- Gaining leverage from people's skills, knowledge and creativity.
- Working together.

Commonly, company cultures are often oriented towards devaluing – seeking out weaknesses and faults, looking for mistakes and acting on the basis of distrust (Savage, 1996). This is in contrast to an agile culture as described by Kidd (1997a) that strives to build creativity and innovation throughout the organisation. According to Clarke (1994) organisational culture "is considered by many as the way things are done around here", hence culture is driven by a shared vision and core values of the organisation and can therefore be best observed rather than tested or analysed through questionnaires. The ethnographic studies have played a major role in observing, collecting and analyzing the information related to this topic. On discussing culture Cole (1995), said there are several focal points that groups can home in on when assessing organisational culture:

> *"(e.g. office/factory layout, people's dress, published lists of values, observable rituals and behaviour trends) and then the espoused values of the organisation (e.g. the values promulgated by the founders and/or senior management, and the values expressed by individual managers and other employees)."*

Peters and Waterman (1987) on the other hand, in their study of 'excellence' chose to follow a so called McKinsey 7-S framework of organisational analysis. This framework is based on the parameters shown in table 3.2 below. This Mckinsey 7-S framework provides an indication how difficult culture is to assess within an organisation and indicates the interdependence of the operational aspects of organsational psychology and operational characteristics.

▪ Shared values (i.e. the essential culture of the organisation)
▪ Style (i.e. management style)
▪ Strategy (i.e. goals and corporate strategic plans)
▪ Structure (i.e. organizational structure)
▪ Systems and procedures and protocols
▪ Staff (all employees)
▪ Skills (i.e. people's talents, levels of competence etc.)

Table 3.2: The McKinsey 7-S framework (adapted from Peters and Waterman, 1987)

3.3.1.3.2 Shared vision

An agile culture therefore rewards creativity and tolerates risk, has well established values and principles of conduct, has absolute clarity about mission and purpose and this can only come about through a shared vision facilitated by organisational leaders. The Total Quality Management (TQM) philosophy as discussed in section 2.1.4.1 has leadership and total involvement at its core. The TQM literature (section 2.1.4.1) and change management literature (section 2.1.4.3) emphasise the importance of mission statements. In addition, DuBon and McGuire (1996) discuss the subject emotively: "In an agile organisation where integrity abounds, there is an attitude of limitless potential and unification of energy in pursuit of opportunity. Organisational mission and vision is a shared reality in the culture."

A mission of an organisation (purpose) and it's vision (direction) only come alive in the organisations' commitment to action therefore the shared vision of an agile organisation as represented in figure 3.3 provides input to strategy issues. As discussed in learning organisation literature and presented in section 2.1.4.2. shared mental models can direct an organisation: where leaders encourage a shared vision and understanding of the direction in which the organisation is trying to move and the environment in which this is taking place. Informal interviews with members of the case study organisations have been carried out to assess whether a shared vision exists within these case study aerospace SMEs. Additionally, two questions of a larger set of questions directly relating to this feature are part of a questionnaire mainly aimed at assessing the agile operational characteristics, which is further discussed in detail in section 3.3.1.4 of this chapter.

3.3.1.3.3 Core Values and Deep Rooted Beliefs

Values are those enduring principles held dear to people and directly influence their behaviour. Hence, agile enterprise core values are those values, both at organisational and individual levels, which enable agile practices [behaviour]. If the organisation or individuals' core values, or value set, is at odds with an organisation strategy or direction then unnecessary barriers to effective change will be present. For instance if sub-ordinates do not respect managers then how can they efficiently manage an organisation. Core values and deep-rooted beliefs contribute to the existing

organisational paradigm: such values and beliefs are said, in section 2.1.4.3, to be reinforced through custom and practice, procedures - written or implied, rituals and ceremonies and socializing revolving around the organisation. These softer, organisational psychology issues have been discussed in more detail by Bessant and Francis (1999) in section 2.1.4.3, as providing a strategic advantage to innovative companies.

3.3.1.3.4 Real World Understanding

A knowledgeable workforce is described in section 2.3.3 as necessary for the support of agile systems and practice. Literature relating to organisational learning is provided in section 2.1.4.2 that states trust, openness and honesty are factors directly related to effective learning of organisations. A real world understanding is necessary for managed transformation and this is shown in figure 2.6, in section 2.3.1 as awareness and understanding stages of a transformation cycle. A truly integrated system that enables agility is one that is rich, in up to date information, to enable appropriate and rapid decision-making. Therefore, real world understanding is facilitated by, the operational characteristics of effective knowledge management, effective information systems and effective enterprise integration (see figure 3.3). However, information alone is insufficient; decision makers must be well equipped and skilled to interpret information, and fully supported by the organisational systems. Teams foster a real world understanding and as organisations develop the ability and competence in team development, both multi-functional and inter-organisational, either virtual or physical, improvements in the human and organisational decision process will take place as true knowledge develops (Castka *et al* 2001). In this respect real world understanding is analogous to systems thinking as expressed by Senge (1990) and shown in section 2.1.4.2 and therefore the five disciplines of the learning organisation promote this agile sub-factor.

3.3.1.3.5 Assessing the Organisational Psychology

Senge (1990) has used systems modelling techniques, while others such as Middleton (2000) have suggested interview, group work and the use of soft systems methodology (SSM) to assess worldviews through the use of rich data. This research in a similar manner to systems analysis techniques has used process mapping and process flow-charting techniques to elicit knowledge from organisational personnel. Accordingly,

process mapping exercises have been performed during ethnographic studies as mentioned in section 1.1.2 and detailed information can be seen in the final EPSRC report IMI/A/05/004. Moreover the use of system modelling techniques in ethnographic studies is well documented in systems design and configuration literature such as Cooper *et al* (1995), and conversely, the value of ethnography in systems design is discussed by Anderson *et al* (1994).

Furthermore, during the ethnographic research, as a participative observer the author has been able to gain insight into project and team based activities within these organisations, of which one case example assessment has been published in a journal by authors Castka *et al* (2001). This has provided the opportunity at varying levels to gain knowledge of the level of 'real world understanding' and how this affects performance to customer requirements, (see also Economou, 1999). The use of ethnographic approaches to eliciting social phenomena is accepted by Benson and Hughes (1991) who discuss the issue of understanding and documenting cultural issues: "Its [ethnography] objective is to display the social organisation of activities as they are revealed through involvement in the natural setting of the activity." Hence, the findings relating to this section, and this part of the conceptual model for this thesis, are predominantly from ethnographic and participant observation as discussed in chapter 4 of the thesis.

3.3.1.4 Operational Characteristics

The operational characteristics shown in figure 3.1 and represented by the system cogs within the conceptual model shown in figure 3.3 and listed in figure 3.1 and shown below for clarity in figure 3.7. These operational characteristics have been derived from an extensive review of literature relating to agile manufacturing as discussed in section 2.2.1. The selection of these six operating characteristics was from a review of literature by Bamber *et al* (1999) carried out within the framework of Engineering and Physical Science Research (EPSRC) funded research as described in section 1.1.2 and referred to in the appendix II project document.

These operational characteristics are recognised as being dependant and interrelated as discussed in section 3.2. An acceptance of these operational characteristics has been recognised through the EPSRC steering group members. The industrialists present at

steering group meetings for the EPSRC work represent leading UK aerospace organisations operating in the North West of England. These industrialists included four Chief Executive Officers (CEOs) of aerospace groups, two aerospace manufacturing company directors, two aerospace manufacturing managers, two aerospace professors and two research assistants over the period of the project.

Figure 3.6: Agile operational characteristics

The final report for the EPSRC research IMI/A/05/004 provides a more detailed description of these characteristics [referred to as the six agile enablers] while below presents an overview description of each characteristic:

1. Knowledge management pertains to how a company effectively manages, utilises, retains and enhances relevant corporate knowledge in line with company strategy. This allows an organisation to mobilize a real world understanding to respond to unanticipated opportunities in an appropriate manner.

2. Effective information systems relates to the timely delivery of appropriate information and data to appropriate points of delivery. This includes communication between people and between systems within organisations and between organisations both locally and globally. It also relates to the capability of the information system infrastructure to support such communication.

3. Change and risk management relates to the ability to effectively implement change in all aspects of the business as required by customers, suppliers, environmental pressures and organisational goals and strategies while assessing all risk to the business.

4. Effective enterprise integration is described as the ability of two or more companies to work together as a virtual enterprise in order to provide the necessary core competencies that will most effectively fulfil customer requirements known or unknown. This characteristic essentially includes the ability of an organisation to sustain team-work across functions and across organisational boundaries.

5. Real-time production management pertains to the capability to manage product, process, people and technology, on a real-time basis, to most effectively meet customer demands and company goals. This ensures that an organisation's production unit is optimised to deliver total customer satisfaction.

6. Waste management and elimination pertains to the effective management and appropriate elimination of all waste (material, effort, motion, time, space, inventory and production). This is sometimes referred to as continuous improvement in TQM organisations and Total Productive Maintenance paradigms.

3.3.1.4.1 Measuring the Operational Characteristics

Having identified the six agile operational characteristics, predominantly through the literature survey, a means by which these characteristics could be practically measured within the collaborating companies was developed, by expanding each of the characteristics into increasing levels of detail. This expanding source of information was enriched by the knowledge being gained working on-site at each of the companies. Subsequently over a hundred factors had been identified as being of potential use in

assessing the agility of an aerospace manufacturing Small Medium sized Enterprise (SME) in relation to the six agile operational characteristics.

Through a categorisation process (see figure 3.8) of the factors identified as being of potential use in assessing SME agile operational characteristics were distilled into 30 key topic areas (appendix III). These key topic areas, alongside two assessment frameworks relating to business strategy and agility measurement issues, formed the basis of the agile assessment questionnaire (appendix IV) that was developed as a means by which agile data relating to the operational characteristics could be elicited from each of the collaborating companies from respondents.

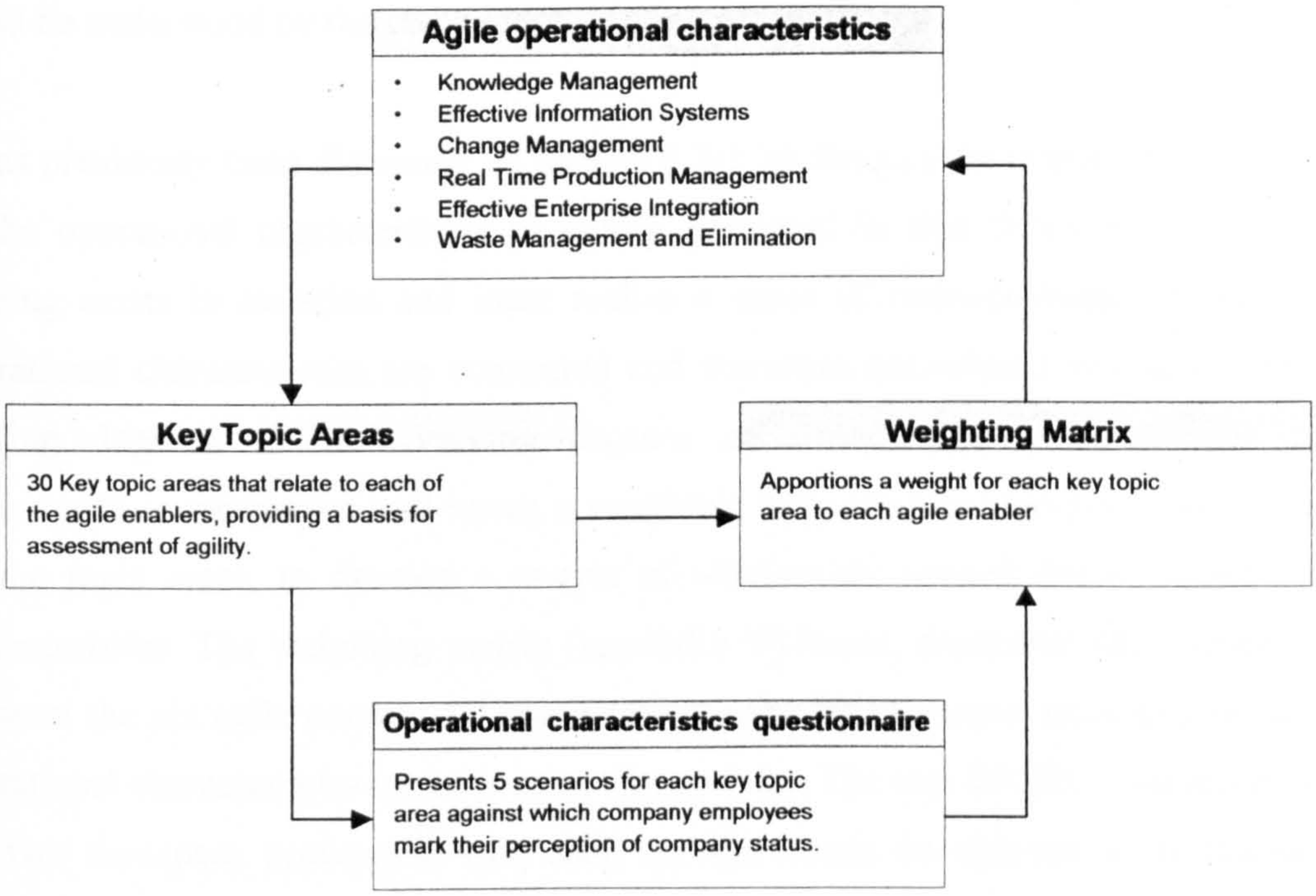

Figure 3.8: Entity relationship diagram for agile operational characteristics, key topic areas, the agile questionnaire and the weighting matrix.

This questionnaire has been developed in the style of the quality maturity grid first published by Crosby (1979), which he advocated was to be used as a self-assessment tool for organisations assessing opportunities for quality improvement. Wireman (1991) provides further support for this technique within manufacturing organisations in developing and extensively using in his research and organisational assessments a "maintenance organisation maturity grid." These organisational maturity grids

typically have five stages of a developing enterprise and Wiremen (1991) discusses the use of the tool suggesting it: "... is truly an examination of attitudes of the company toward maintenance." In the case for agility, thus, the agility assessment matrix is an assessment of the companies' attitudes toward agile characteristics.

Likewise, the questionnaire (appendix IV) presents five scenarios for each topic area, the first being a bad practice scenario and the fifth being a good practice scenario. Individuals completing the questionnaire shall be instructed to indicate the scenario that best represented their perception of their company with regards to the topic area, thereby providing a score between 1 and 5. This method has been chosen to provide a set of "operational definitions", as discussed in the first paragraph of section 3.3, that could be understood by the respondents.

It has previously been discussed, in section 3.3.1 by Senge (1997) and with reference to the operational characteristics of agility presented in this thesis in 3.3.1.4, that nothing exists in isolation and must realise a sense of connectedness. Hence, the operational characteristics are connected and therefore interrelated and dependent to varying degrees. These varying degrees of connectedness, interrelation and dependence is recognised and hence a weighting exercise has been performed across all the topic areas, to develop a matrix of relationship toward the six operational characteristics. The weighting matrix (appendix V) hence, completes the relationship between the six agile operational characteristics the 30 key topic areas and the agile operational characteristics questionnaire (figure 3.8). The two EPSRC researchers and the two aerospace professors, who shall for this thesis be referred to as the agile operational characteristics assessment panel (OCAP), (see IMI/A/05/004 EPSRC report for details) carried out this weighting exercise and therefore correlated each topic area to each of the operational characteristics.

The lengthy process of assessment of each characteristic (i.e. OCAP agreeing a notional 1, 2 or a 3 against each topic area, which is relating to each operational characteristic; that has been correlated to a number 1, 32 [$=2^5$] or 243 [$=3^5$]) provides the weighting matrix. Figure 3.9 shows part of the matrix for clarification only, and shows for examples; topic two, waste time, has more to do with the operational characteristic of "waste management and elimination" than has to do with "knowledge

management" and that; "multi-disciplinary teams" has more to do with "change management" than to do with any of the other operational characteristics.

	Weighting matrices						
	Agile operational characteristic / Topic	Knowledge Management	Effective Information Systems	Risk and Change Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination
1	Working environment	1	32	32	32	243	243
2	Waste Time	1	32	32	32	243	243
3	Waste Space	1	1	32	1	32	243
4	Waste Materials						
	Maximum possible score	22,280	22,745	26,065	31,185	25,010	15,175
	Minimum possible score	4,456	4,549	5,213	6,237	5,002	3,035
	Max-Min	17,824	18,196	20,852	24,948	20,008	12,140

Figure 3.9: Part of the weighting matrix (appendix V)

This method of weighting has naturally provided a ranking of the operational characteristics, to each, but only in terms of their relationship to the 32 topic areas assessed and weighted. This is shown in figure 3.9, where the total is the summation of all the ranks per operational characteristic; the maximum possible score and the minimum possible score relate to the agility assessment questionnaire (appendix IV) e.g. if a respondent scores a five in topic four "waste materials" [see figure 3.9] then the "knowledge management" characteristic receives a score of only five (5x1) because the weighting of this topic against this characteristic is only a one; while this scoring would provide a score of one hundred and sixty (32x5) against the operational characteristic of "real time production management."

The operational characteristic that is able to receive the most points from a respondent is therefore "change management", which can receive a total of 26,065 if all fives where given in all of the assessment topics in the questionnaire (see figure 3.10). Similarly the lowest ranking category (agile operational characteristic) given as a result of this method of weighting is "waste management and elimination".

The lowest scoring of "waste management and elimination" is not entirely surprising, as this, in the main, is the principle of lean manufacturing as discussed in the literature review, section 2.1.2, while "effective enterprise integration" in terms of agility is to do with integrating, in the main, cross-organisational issues such as the virtual enterprise, which has no reference base in lean literature.

Weighting matrices

	Agile operational characteristic / Topic	Knowledge Management	Effective Information Systems	Risk and Change Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination
1	Working environment	1	3 2	3 2	3 2	2 4 3	2 4 3
.....	.....	.....	.....	.....	.....	.....	.....
32	Use of metrics	2 4 3	2 4 3	2 4 3	2 4 3	2 4 3	2 4 3
Total		4,456	4,549	5,213	6,237	5,002	3,035
Maximum possible score		22,280	22,745	26,065	31,185	25,010	15,175
Minimum possible score		4,456	4,549	5,213	6,237	5,002	3,035
Max-Min		17,824	18,196	20,852	24,948	20,008	12,140

Figure 3. 10: Part of the weighting matrix showing max-min possible score for each operational characteristic from the agility assessment questionnaire

Alternatively the weighting per topic area can be shown as in figure 3.11. It is clear from viewing figure 3.11 that topic twenty-five, thirty-one and thirty-two; information quality and management; integration with the business strategy and use of metrics, carry the highest weight across all the operational characteristics. These three topic areas each have a percentage contribution toward agile operational characteristics of 5.2%, while the lowest contributing topic areas are topics 3 and 4; waste space and waste material (1.09% and 0.98%). Acknowledging these figures it must be noted that, each topic area provides a separate weighting to each of the six operational characteristics (appendix V).

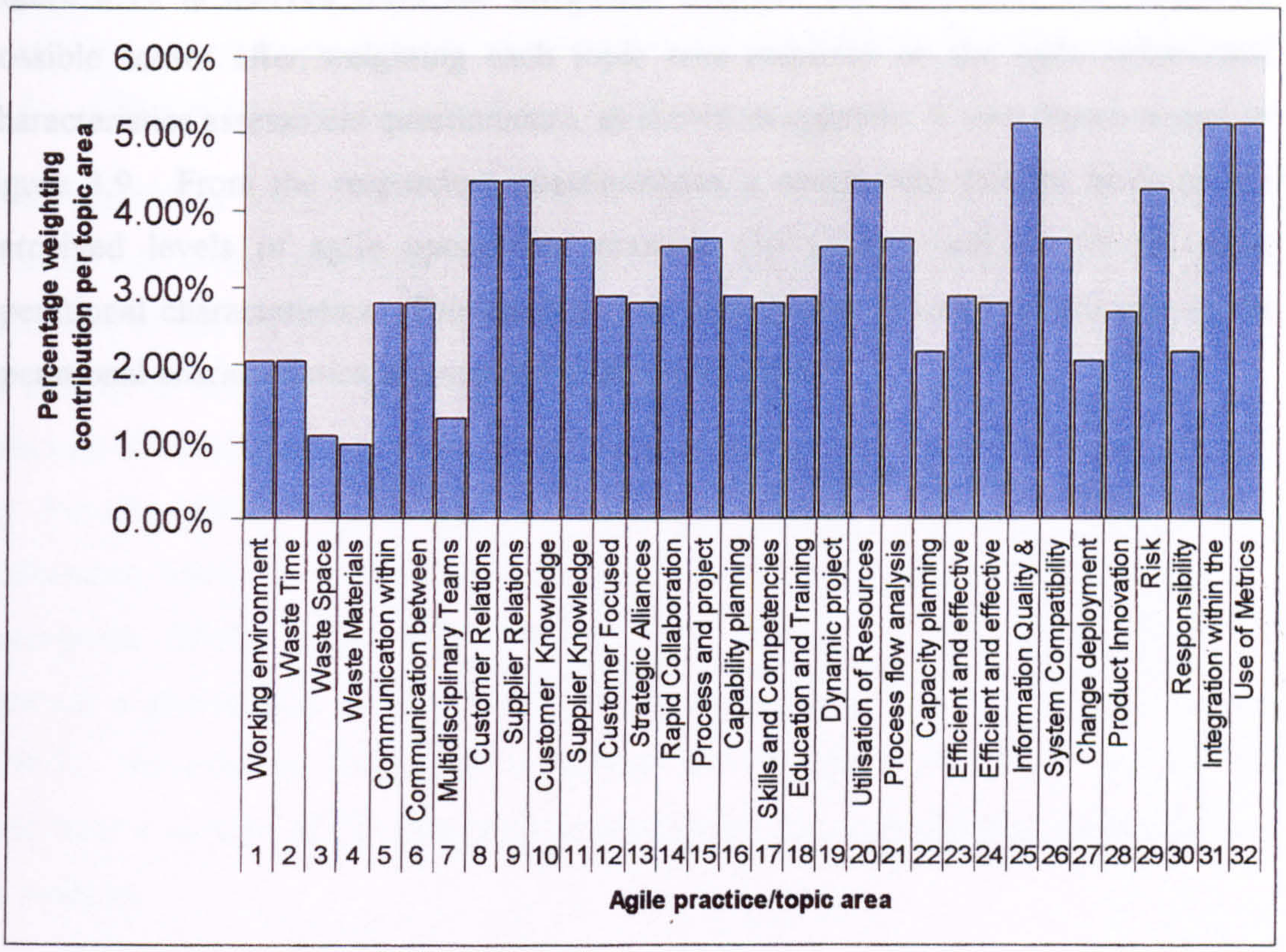

Figure 3.11: Percentage weighting contribution per topic area of agile practices/topic areas

The six operational characteristics that have been identified as; knowledge management, effective information systems, change and risk management, effective enterprise integration, real-time production management and waste management and elimination can be shown to have a range of possible scores from an agile operational characteristics questionnaire respondent as figure 3.12.

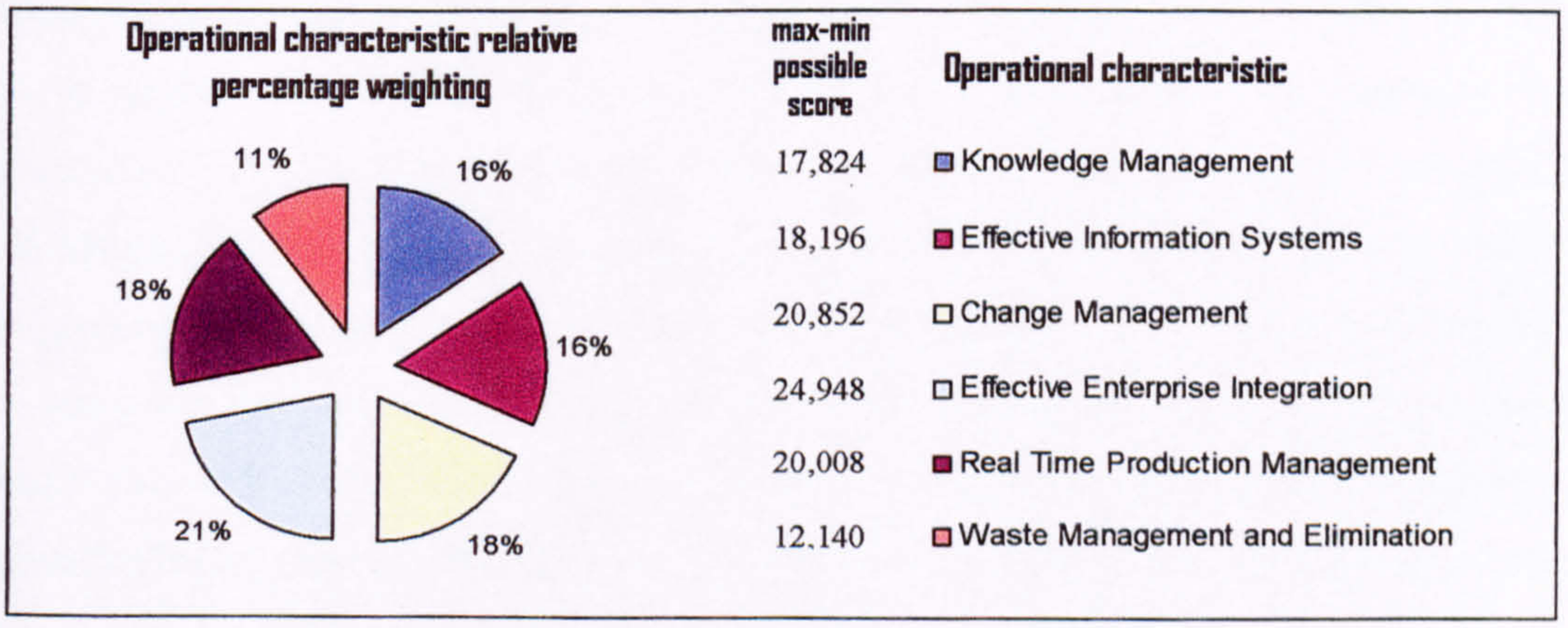

Figure 3.12: Relative weightings for each operational characteristic

Figure 3.12 is derived from the difference between the maximum and minimum possible scores after weighting each topic area response on the agile operational characteristics assessment questionnaire, as shown in appendix V and shown in part in figure 3.9. From the respondent questionnaires a comparison can be made of the perceived levels of agile operational practice (30 topic areas) to the six agile operational characteristics. This analysis and comparison of levels of practice to the operational characteristics is discussed in the next chapter.

Chapter 4 The Case Study Organisations

4.1 Characteristics of the Case Study Organisations

The reasons for adopting the case study research method have been discussed in section 1.4, while the reason for using more than one case study organisation is discussed in this section. The adoption of the multi-case study method in this research is mainly to enhance the generalisabilty of the research findings as indicated in previous research from researchers such as Sutton and Callahan (1987) or as described by Powell (1985). Additionally the research findings may indicate important differences when comparative contrasts are being made between small to medium size enterprises (SMEs), thus indicating important themes such as environmental or internal organisational factors as discovered from research carried out by Lupton (1963). Nevertheless, the aim is to generate rich qualitative data from a limited but informative number of UK case study organisations that manufacture aerospace parts, in order to:

- *Provide an understanding of agility in UK aerospace SMEs*

and hence bridge the knowledge gap between that of agile practice in non-aerospace companies drawn from literature, generalised agile theory, other aerospace manufacturing research in SMEs and that of agility in UK aerospace SMEs (see figure 1.2 in section 1.2.3).

The external validity of case study research has been questioned many times and discussed by Bryman (1995) (see also chapter 2), consequently within this research this is approached through the adoption of a multi-case approach as suggested by researchers Yin (1994) and Mitchell (1983 and 1985). The arguments of Yin (1994) and Mitchell (1983 and 1985) suggest that it is the purpose of the case study to permit the generation of theory, not to be considered a sample of one. In summary the reason for choosing four case study organisations is a balancing act between the needs to obtain rich informative data through rigorous investigation and the need to enhance generalisability, hence reliability, of the research findings while understanding and recognising the differences apparent in each case.

Therefore alongside the information gathered in a very structured manner, using the matrix approach as identified in section 3.3.1 and information gathered using archival evidence, an unstructured interview approach during ethnographic studies has been used in order to gather rich qualitative material. Each case study organisation is discussed separately in the sections 4.2 to 4.5 while the reason for choosing these case study organisations is presented in section 4.1.1 below.

4.1.1. Selecting the Case Study Organisations

In choosing the case study organisations certain characteristics have been identified as important and necessary to establish some equivalence as suggested by Bryman (1985) and some relevance to the research focus by matching these characteristics, namely the four case study organisations are:

- Suppliers to the UK aerospace sector (more than one aerospace customer).
- Manufacture aerospace components or sub-assemblies.
- Based in the Northwest of England (see figure 4.1).
- Operating autonomously as a small to medium size enterprise (SME).

(less than 250 employees per case study organisation site).

- Introducing new products on a regular basis (i.e. continuous change in production-involved in New Product Introduction activities).
- ISO 9000 quality management systems accredited or similar aerospace approval such as Technical Specification 157.
- In possession of at least one aerospace prime quality supply approval.
- Investing in new machining centres and working practice.

(CNCs introduced in the last 2 years, *from 1998*).

This research focus means that of the organisations subscribing to the EPSRC project mentioned in section 1.1.2 four can be selected for close examination and the other EPSRC case study organisations are omitted from this PhD research. This does not diminish the importance or validity of the results in any way, but rather enhances the opportunity to collect rich data through focusing on four case studies. As such the four case studies presented in this PhD research are the four organisations that the author has spent most time with, during the period of the EPSRC project work.

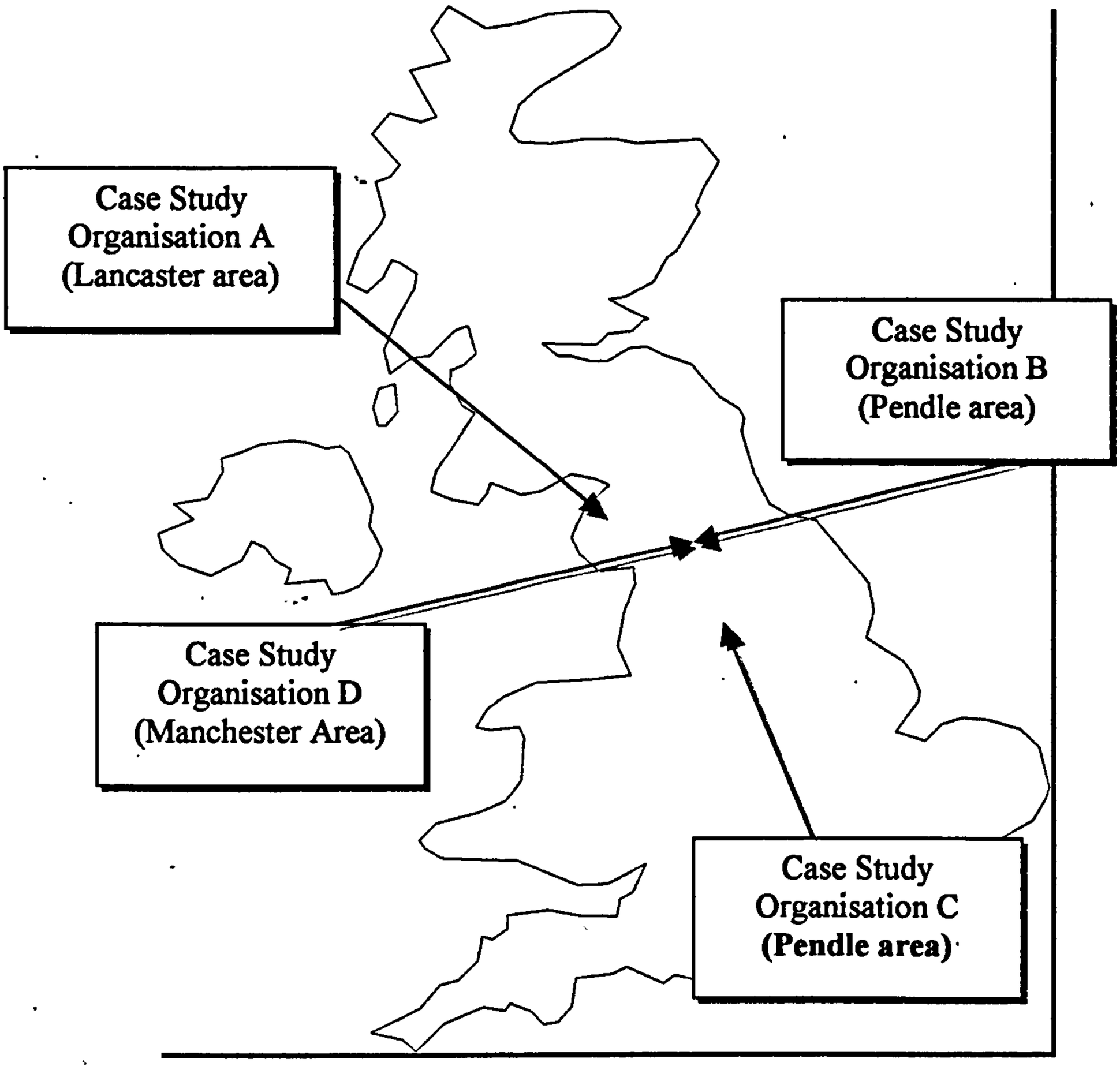

Figure 4.1: Geographical position of UK case study organisations

For each of the case study organisations certain characteristics that are relevant to the research have been identified and are given in the following sections. These characteristics are generally different for each of the case study organisations and are identified as:

- Company history which has led to the organisations' current:
    - Marketing and sector mix.
    - Product mix.
    - Customer base.
    - Supplier base.

- Partner organisations and relationships which would include a review of the organisation's situation regarding:
    - Sub-contractor relationships.
    - Ownership.
    - Collaborations.
    - Environmental awareness.
- Key production related processes, capacities and capabilities:
    - Core competence.
    - Floor space/facilities/premises.
    - Number of employees.
    - Planning and scheduling systems.
- Financial planning and control methods and status:
    - Company turnover.
    - Order book/profits.
    - Investment in capability and competencies.
- Organisational structure enabling agility:
    - Hierarchical management structure.
    - Cross-functional project management.
    - Levels of team development.
- Mission/vision/strategy and deployment efforts:
    - Change management competence.
    - Best practice initiatives.
    - Continuous improvement programs.
- Affiliations and memberships/including awards:
    - Professional membership.
    - Trade organisation membership.

In addition to the above characteristics, environmental factors that are unique to each organisation are identified. These environmental factors may include, local regulatory authority demands; specific needs of particular products or services offered by the organisation; imposed demands of shareholders or owners; legal requirements; specific customer needs; or market driven change.

4.2 Case Study Organisation A

Case study organisation A was founded in 1948. Operating from a 45,000 square foot facility on a six-acre site, in 1994 co-founders, acquired the Company and shareholders of Organisation A Group, which includes both case study organisation A, based in Lancaster and a sister company, based in Cambridge. The Lancaster operation employs 46 people of which 38 are considered direct workers (see figure 4.2). It has for many years been a sub-contract precision engineering company with a customer base centred on the aerospace, defence and nuclear industries. Case study organisation A provides a service in design, prototyping and management of heat treatments and plating, supplying finished components to the highest quality although this part of the business is very minor in terms of financial turnover.

Case study organisation A operations rely on two key customers (and market sectors), an aerospace prime and a large nuclear engineering company although the operations and marketing strategy is to develop key partnerships and deliver larger packages of work through the development of alliances. These two customers account for 85% of turnover of which 95%, of this 85%, is aerospace manufactured components and assemblies. Occasionally packages of work are taken on by the company from outside of the main two sectors of operation and include sub-assembly and component manufacture for special purpose machinery and transport systems (automotive, plant machinery, truck and bus). Therefore new product introduction is continuous and a large part of business is non-recurring orders, although repeat work is seen and strategic orders (maintenance of power station parts and assemblies; including replacement and repair) for the nuclear industry are placed currently representing approximately only 5% of revenue turnover. This means that very few products produced by case study organisation A are from forecasted sales.

The supplies to the aerospace sector are direct to a prime aerospace customer and also as a second and third tier supplier to other aerospace supply chain companies. These aerospace parts are manufactured in the main on CNC machine tools and bench worked, by a highly skilled work force and these parts are considered by the primes as small component parts and small sub-assemblies. The shop floor is organised in a traditionally functional arrangement of machines (i.e. milling machines together) and the main competence of the organisation is complex milling and this is augmented

with turning, while virtually all products go through a finishing centre. A small percent, in the region of 3% of the aerospace manufacture is for aircraft on ground (AOG) and as such rapid manufacture and turn round is necessary and higher rates can be charged.

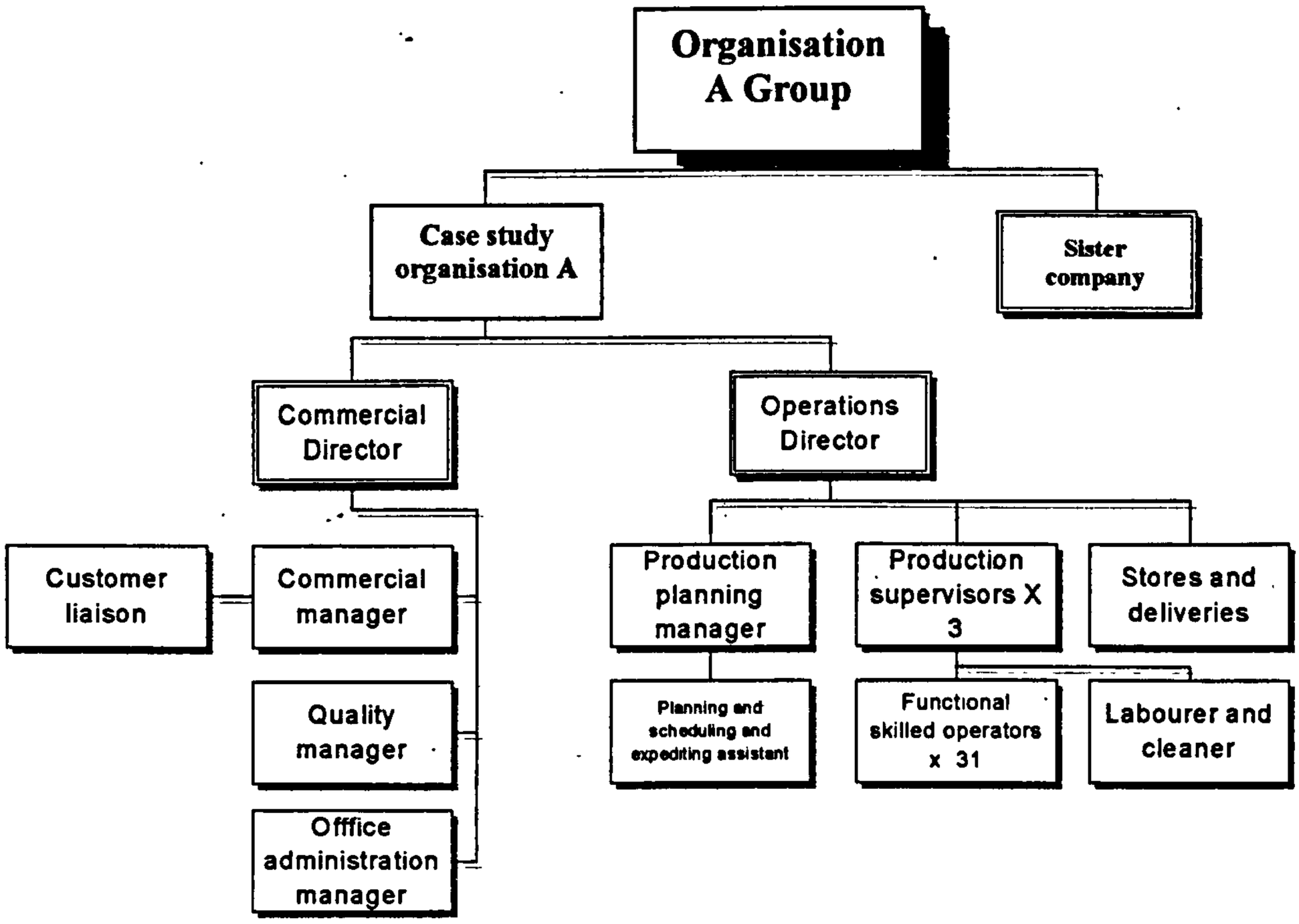

Figure 4.2: Case study organisation A organisational chart and The Organisation A Group structure

The organisation A group of companies operate within the framework of ISO 9001: 1994 and both case study organisation A and the Cambridge sister company quality management systems are assessed by the British Standards Institute. Additionally the requirement to move toward ISO 9001: 2000 and the additionally expectations of this revision is recognised by the quality and engineering professionals at the company and work to develop the quality system is underway.

Quality initiatives have accordingly been part of case study organisation A operating regime for some time and many initiatives have provided operating benefit to the company. Such initiatives include 5S training, Single Minute Exchange of Die, cost improvement exercises on particular products and an initiative to improve delivery performance of suppliers through supplier performance analysis methods. This work

has identified categorically that treatment house performance, which includes all types of treatments to case study organisation A, is poor, showing 45% of items reworked at treatments stage due to bad quality and deliveries overdue are at a rate close to 100%. This work has highlighted to case study organisation A the need to collaborate, monitor and work toward improvements in supplier performance and relations.

Initiatives to improve performance, in particular to focus on overall equipment effectiveness (OEE) as described within the Total Productive Maintenance (TPM) philosophy, at case study organisation A also include a world class manufacturing policy of continuous improvement of operations. Additionally investigations have been carried out to assess opportunities to reduce lead-time from receipt of order to delivery of product to the customer, in line with Lean Manufacturing philosophy. Within manufacturing departments functional cells and areas have been set up to focus on machine performance improvement and control. Similarly, customer satisfaction questionnaires have been initiated providing valuable information relating to customer satisfaction and therefore perceived performance of the company. Accordingly the widespread use of quality improvement tools and techniques has been seen at Case study organisation A as beneficial to the business.

In terms of plant and machinery case study organisation A have managed to persuade a major customer to contribute financial expenses to a dedicated machining cell producing strategic planned parts manufacture. A new turning centre in addition has been purchased in the last 18 months (from December 1999) to relieve an identified capacity constraint. Accordingly, the managing director explains, the capital expenditure approval process is one that requires a three-year maximum payback and guaranteed justification of work.

Information and data base systems at case study organisation A are very comprehensive and provide accurate real-time production data for decision-making purposes (see next section for detail). This information system has been the cornerstone for data collection for fact based decision making improvement programmes as mentioned above. Continual investment in upgrades and bespoke software to drive the effectiveness of the data management system is ongoing and seen as a major priority for maintaining and improving operations.

4.2.1 The Ethnographic Study Report (Case Study Organisation A)

The author worked at case study organisation A during the period of July 1999 to August 2000 [a nine week break from 1st October 1999 was taken]. The work carried out with the organisation was to understand the production operations, procedures and protocols aimed at assessing current measures of performance and establishing suitable measures of performance for the needs of the organisation. The work was carried out over one to two days a week, however in the first two weeks four working days were taken up getting familiar with the setting. A desk and computer with printer and networked connections was made available in the production planning and engineering control office. This office was situated above the main shop floor and was very spacious and relatively clean and tidy, however this was a very busy area with supervisors, managers and shop floor machinists interacting many times a day with the planning manager.

Additionally, the author assisted with the supervision of one MSc dissertation student working on his final project and two final year degree graduates working toward their dissertations. This work has led to the successful process mapping of the entire internal supply chain processes, which has led to identified areas of improvement in the lead-time performance of the business (Thabet, 2000 and Coupe, 2000). It was also noted that previous involvement with university students on placement at case study A was quite normal, in fact the managing director is very keen to use academics to analyse information and data throughout the organisation, as this has been a very successful activity bringing about improvement in financial and operational performance. The performance improvement and potential improvement identified by student help has been discussed in the previous section.

The office area was a central meeting place for all the supervisors and the production-planning manager during breaks, lunchtime and early morning before the shift started. In addition to this operators or machinists from the shop floor frequented this office area to discuss either engineering issues or logistical problems with the work to be or being carried out. More often than not the production-planning manager would handle these types of queries in a very sympathetic and yet efficient manner, this ensured that decisions where made immediately regarding the necessary courses of action. The

necessary information to make decisions regarding machine and tooling, material, time scales and methods of work was on the production and control computer system, however if customers, partners or suppliers were needed to be contacted this was done by telephone more often than not.

The production-planning manager was responsible for processing quotations and detailing the estimating of packages of work. This was as well as detailing the production scheduling and utilisation of machines. Here it was noticed a key feature of the aerospace work is the need to attend to details such as tooling, methods of manufacture and methods of inspection and testing, which is reflected in the amount of paper work necessary to process a quote and maintain the appropriate information to progress if the order proceeds. The work of the production planning manager, in this case, was described by himself as "... balancing the computer work, paper work and people work ....."

In certain areas 5Ss, a Total Productive Maintenance (TPM) principle as described by Bamber (1998), have been attempted but in reality, the observations showed that in truth only the first three Ss had been implemented. This means that the last two Ss of this principle, namely standardisation and self-discipline were not implemented, which meant that procedures and practice for continually maintaining the cleanliness of all areas was not achieved. Nevertheless there are pockets of excellent work place cleanliness practice, particularly in the maintenance and control of cutting tools. Additionally a 5S programme was being planned for introduction throughout the factory area and in some areas painting of walls and floor has started.

In terms of innovation and creativity the main areas that were observed for this were in the engineering aspect of the business. For instance the production supervisors were continually looking at state of the art cutting and machine tools and practice, this was augmented with visits from many tool representatives sharing stories of best practice with the case study A engineering people. Machining times are a challenge for the supervisors and a great deal of effort is afforded in monitoring and correcting machining time issues. Further to this, innovative clamping arrangements have been created alongside maximised tooling paths and increased cutting speeds making case study company A truly innovative in machining practice. However, when the author

calculated the true overall equipment effectiveness (OEE) rate it was noted that a lot of improvement potential was possible, see figure 4.3. The data shown by figure 4.3 clearly shows that the productivity rate [performance rate] and the quality rates are approaching world-class levels (OEE = 85%), however availability rates are comparatively poor. Further to this it is shown in figure 4.3 that on one machine case study organisation A has improved the productivity performance beyond that of the machine manufacturers' stated capability.

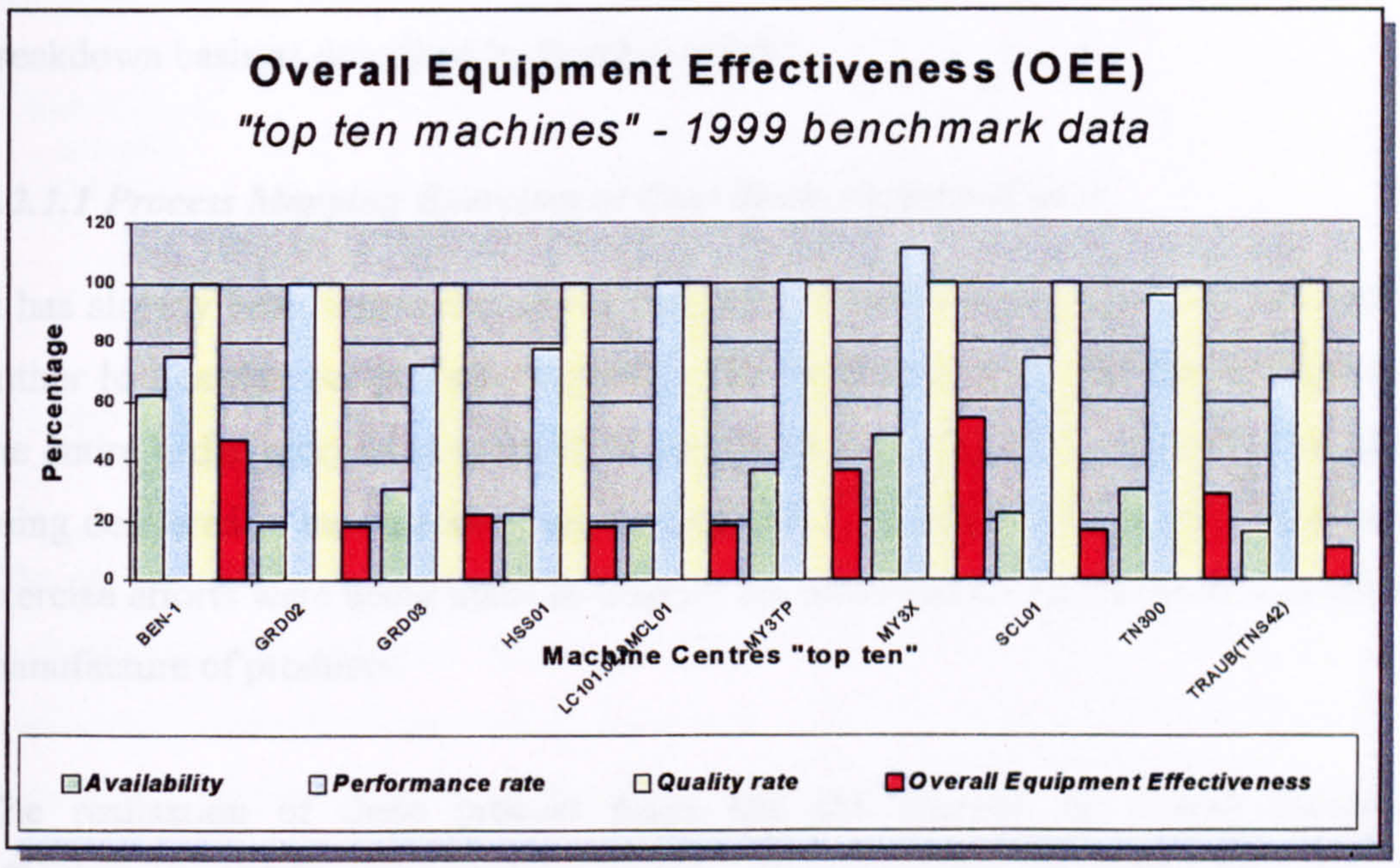

Figure 4.3: Overall equipment effectiveness chart for the "top ten" machines at case study organisation A

It was observed that the accuracy and availability of data in case study organisation A was unequalled across the case study organisations reviewed and, as mentioned earlier, the information and data systems were being continually improved and tailored to the needs of the company. This knowledge can only be obtained from comparison to other case study organisations and it would be unlikely obtained from a survey or questionnaire approach.

The author presented the OEE rates, to the supervisors and management team and this was immediately discussed and a cause and effect diagram was produced. The author

assessed this cause and effect diagram and it was noted that the main areas for concern were the availability of materials and jigs and fixtures, which brought the OEE rates down. This was cause for concern by the organisation as their efforts, in terms of performance measures, focus and action had been nearly entirely on productivity rates. The company had previously realised that obtaining promised tooling from their customer was very difficult, but did not realise that this was a major contributor to the loss of effectiveness of the system of operations and hence effected the customer deliver performance. Additionally it is noted there is no planned or preventive maintenance activities for machine centres and consequently maintenance is on a breakdown basis as described by Bamber (1998).

4.2.1.1 Process Mapping Exercises at Case Study Organisation A

It has already been mentioned above that other students under the supervision of the author had carried out process mapping. This work had led to the detail mapping of the entire order processing methods from receipt of a request for quotation to goods being delivered to the customer, see appendix VI. Alongside of this process mapping exercise efforts were being made to identify opportunities for reduction in lead-time to manufacture of products.

The realisation of these process maps and the analysis of overall equipment effectiveness (OEE), see previous section, at case study organisation A led to an understanding of the main issues during manufacture of products that prevented machine performance being optimised. Accordingly, during a brainstorming session, the management and shop floor supervisory personnel at the case study A organisation developed a cause and effect diagram (figure 4.4) that identified possible and very likely causes of poor Overall Equipment Effectiveness (OEE) rates and less than 100% on time delivery performance.

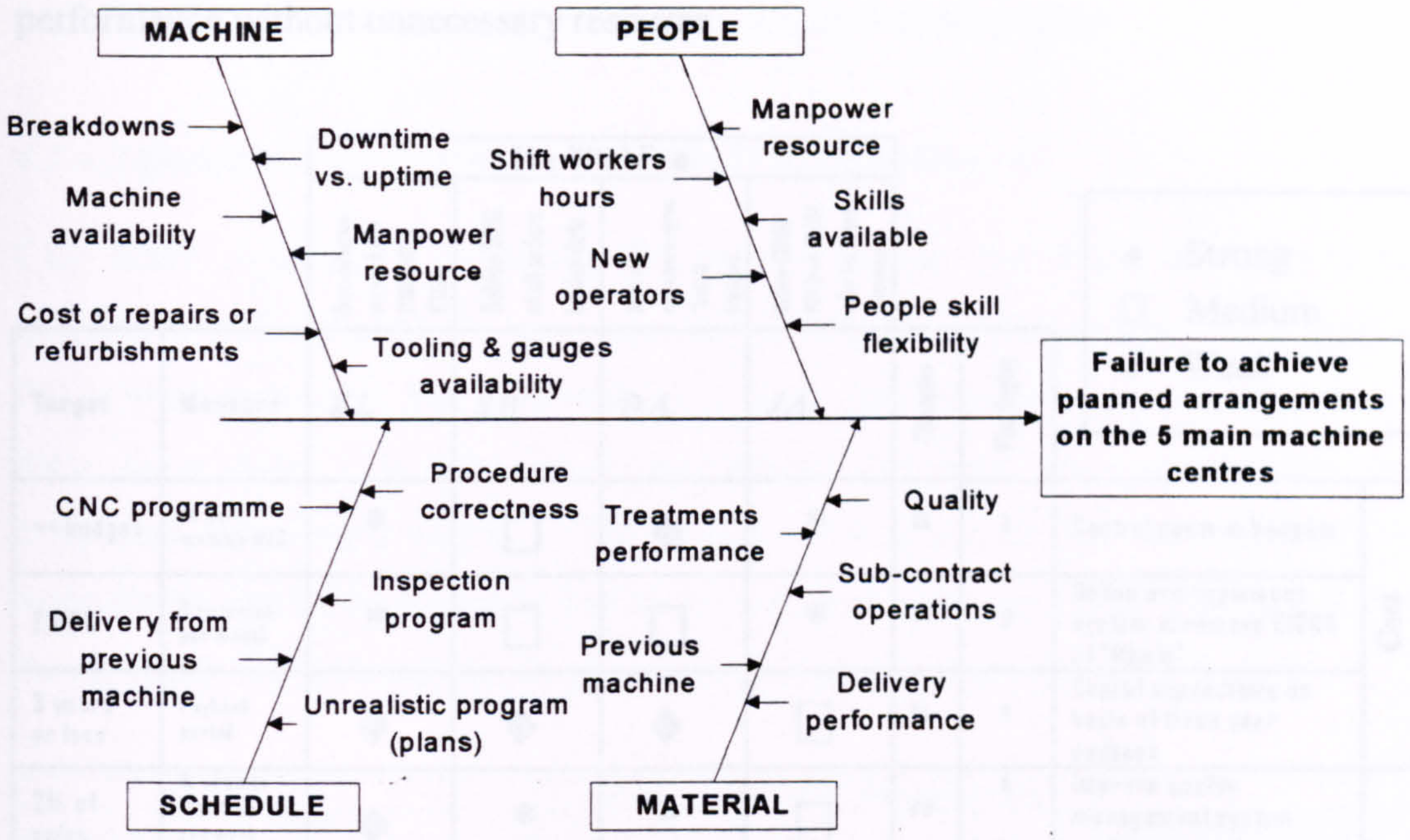

Figure 4.4: Factors affecting successful production performance at case study organisation A

The above figure 4.4 shows some of the issues affecting successful production performance and indicates that some of the issues are causes from outside the traditionally thought of production boundary. Likewise, the performance of external suppliers of materials and special tools are seen to have a major impact on delivery performance, moreover this has already been discussed in section 4.2, and the performance of treatment houses is a concern highlighted in previous case study organisation A internal reports. The availability of tooling, gauges and fixtures is seen as both an issue of internal/work shop housekeeping and also as a concern that the customer needs to be aware of, as many tools and fixtures are manufactured and held by the customer.

4.2.1.2 Other Activities and Findings

Case study organisation A is driven by an enthusiastic managing director who actively aims to create a shared vision of the future for the company. This is shown not just during weekly production meetings but has been the subject of visioning workshops led by an external consultant in December 1998. A plan for improvements (see table 4.1) was produced which in the terms of the management team was to address the

"vital few" that could improve major issues and therefore reach higher levels of performance without unnecessary resource.

		The Vital Few							
		Dept reduction overdraft to < £350K MTL < £320K	Deliver 90% of all orders by due date	55% of customers agree "best in business"	Deliver £330K PBT from £3.6M sales inc. 3 new customers				
Target	Measure	*KL*	*SW*	*DA*	*JA*	Champion	Plan Deploy		
=< budget	As per monthly A/C	*	□	◆	*	KL	1	Control costs to budgets	Cost
£100K	£ reported per month	*	□	□	*	DT	2	Define and implement system to remove £100K of "Waste"	
3 years or less	Payback period	◆	◆	◆	□	KL	3	Capital expenditure on basis of three year payback	
2% of sales	% of sales plus failures per work centre	◆	*	*	□	RD	4	Improve quality management system performance measures	Quality
June 1999	Training plan	◆	*	*	*	PP	5	Align all skills to business needs	
June '99 CNC turning 1st/y	Deployment of team work practices	◆	*	*	*	PP	6	Identify and implement best practice shop management	
March '99 for the mgt team	Published organisat-ional chart	◆	*	□	*	SW	7	To review and implement effective organisational structure	
All customers by the end of '99	Identify the AP tool set	◆	*	*	*	IC	8	Replicate AP project management structure for all cases	Delivery
February 1999	Pull on shipment time	*	*	*	*	IC	9	Develop and implement a delivery performance monitoring system	
March 1999	Transparency "enquiry to invoice"	*	*	*	*	JS	10	Confirm that jobshop gives full transparency through the plant	
£1.3m	T/O by customer	◆	*	□	*	JA	11	Develop and implement sales strategy to deliver £1.3M in aerospace	Compet-itive

* Strong
□ Medium
◆ Weak

Table 4.1: Case study organisation A deployment chart aimed at addressing "the vital few"

These interactive work shops had been attended by all managers of the organisation and the first tier shop floor supervisory level managers. It was very clear from observations that these workshops had given a better business understanding to the managers and supervisors and consequently the ability to plan collectively for the future. At the same time as the workshops a customer survey had been completed, which indicated: "55% of customers agree that [case study organisation A's] quality is

the highest in the business." Certainly for each of the deployment plans, as shown in table 4.1, activities were seen to verify active perusal of these plans.

4.2.1.3 Questionnaire Results for Case Study Organisation A

Case study organisation A decided that each individual that would take part in the question would complete the agile operational characteristics matrices (see appendix IV) in their own time, that is, neither at a given time and place nor together in one place as a group. In total seven respondents delivered the questionnaire with completed assessment scores. The names were provided for only two of the respondents, but all respondents' names are removed from any of the data used in this thesis. Table 4.2 is the tabulation of results from the respondents.

		Respondent reference and assessment score										
	TOPIC	A	B	C	D	E	F	G	Ave.	high	low	diff.
1	Working environment	3	3	3	3	2	2	3	2	3	2	1
2	Waste Time	3	2	4	2	4	3	3	3	4	2	2
3	Waste Space	3	2	4	3	3	3	3	3	4	2	2
4	Waste Materials	4	3	4	3	3	3	3	3	4	3	1
5	Communication within Groups/Teams	3	2	4	3	2	1	2	2	4	1	3
6	Communication between Groups/Teams	2	2	3	3	2	2	2	2	3	2	1
7	Multidisciplinary Teams	1	1	3	2	2	2	3	2	3	1	2
8	Customer Relations	2	2	4	3	4	3	3	3	4	2	2
9	Supplier Relations	2	2	3	2	1	1	2	1	3	1	1
10	Customer Knowledge	2	2	3	3	2	2	2	2	3	2	1
11	Supplier Knowledge	2	1	3	3	1	1	1	1	3	1	2
12	Customer Focused Production	2	3	4	3	2	2	3	2	4	2	2
13	Strategic Alliances	3	2	4	3	3	3	3	3	4	2	2
14	Rapid Collaboration	1	1	4	3	1	2	1	1	4	1	3
15	Process and project visibility	3	2	3	3	3	3	3	2	3	2	1
16	Capability planning	3	2	3	3	3	3	3	2	3	2	1
17	Skills and Competencies	3	2	4	4	3	3	3	3	4	2	2
18	Education and Training	2	2	3	3	2	2	2	2	3	2	1
19	Dynamic project scheduling	2	3	4	3	3	3	3	3	4	2	2
20	Utilisation of Resources	3	2	4	1	3	2	3	2	4	1	3
21	Process flow analysis	3	1	4	1	5	5	4	3	5	1	4
22	Capacity planning	3	3	4	4	4	4	4	3	4	3	1
23	Efficient and effective maintenance	3	2	3	2	2	2	1	2	3	1	2
24	Efficient and effective administration	4	2	3	4	1	2	2	2	4	1	3
25	Information Quality & Management	5	2	4	4	4	4	4	3	5	2	3
26	System Compatibility (standards, protocols & metrics)	4	3	3	3	4	3	3	3	4	3	1
27	Change deployment	3	3	3	3	2	3	2	2	3	2	1
28	Product Innovation	4	3	4	3	3	3	3	3	4	3	1
29	Risk	1	2	3	3	3	3	3	2	3	1	2
30	Responsibility	3	3	4	3	3	3	3	3	4	3	1
31	Integration within the Business Strategy	3	2	4	3	2	3	3	2	4	2	2
32	Use of Metrics	2	1	4	2	2	3	2	2	4	1	3

Table 4.2: The questionnaire results from case study organisation A

The "Ave." column is the mean average of columns A to G rounded down to the nearest whole number. The "high" and "low" columns represent the highest score found against a particular topic and the "diff." column represents the difference between the highest score and the lowest score from any respondent against each of the topics. Figure 4.5 shows the combined scores per topic area.

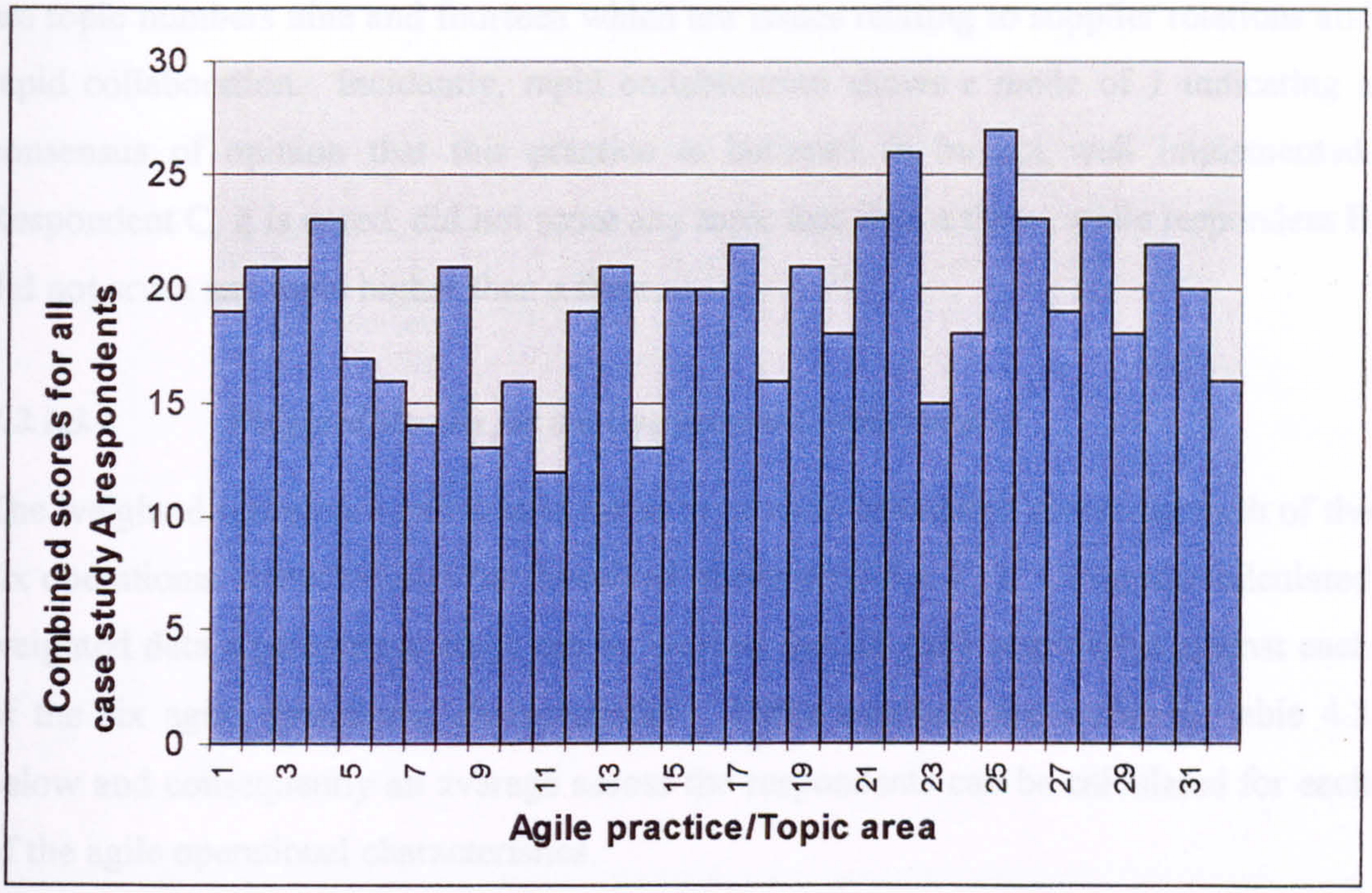

Figure 4.5: Combined scores of all case study A respondents per topic area

The highest combined score of 27 which is topic number twenty five is concerning information quality and management. Significantly, the mode average for this topic area is at level 4, this gives a consensus of opinion from the respondents that the management of information and quality is well developed in this organisation. Following topic number twenty five as the highest combined score of 26 is topic number twenty two related to capacity planning activities where the consensus of opinion is also at level 4. The next four highest scored topic numbers each at a combined score of 23 are topic numbers twenty eight, twenty six, twenty one and four which are the four issues relating to product innovation; system compatibility (standards, protocols and metrics); process flow analysis and waste materials. However, process flow analysis (topic 21) across the seven respondents scores is noticed the greatest difference between highest and lowest score for this topic. It is noticed the only three fives scored, have been scored on the two topic areas of "process flow" and "information quality and management."

The lowest combined score however, is topic number eleven concerning supplier knowledge where the consensus of opinion infers this practice to be at level 1. Following topic number eleven as the lowest combined scores the next two practices

are topic numbers nine and fourteen which are issues relating to supplier relations and rapid collaboration. Incidently, rapid collaboration shows a mode of 1 indicating a consensus of opinion that this practice is believed to be not well implemented. Respondent C, it is noted, did not score any topic less than a three, while respondent B did not score any topic higher than a three.

4.2.1.3.1 Weighted Results for the Operational Characteristics

The weighted score per topic area is taken to provide calculated scores for each of the six operational characteristics (as described in section 3.3.1.4.1). Using this calculated weighted data a percentage score can be worked out for each respondent against each of the six agile operational characteristics. These averages are shown in table 4.3 below and consequently an average across the respondents can be calculated for each of the agile operational characteristics.

Case study organisation A respondent reference / Agile operational characteristic	Knowledge Management	Effective Information Systems	Change and Risk Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination
A	54%	51%	50%	54%	54%	64%
B	42%	39%	39%	42%	42%	41%
C	72%	70%	71%	71%	72%	74%
D	57%	59%	55%	57%	55%	52%
E	53%	48%	50%	52%	57%	56%
F	52%	49%	51%	53%	56%	57%
G	54%	49%	51%	52%	56%	56%
Highest	72%	70%	71%	71%	72%	74%
Lowest	42%	39%	39%	42%	42%	41%
Average	55%	52%	53%	54%	56%	57%

Table 4.3: Case study organisation A percentage weight score per respondent for each agile operational characteristic

Accordingly, the data from table 4.4 can be plotted on charts to show the current position of the organisation in terms of their own respondents' perceived agile operational characteristics and operational practices. Figures 4.6 and 4.7 therefore show the weighted results taken from table 4.4, which are calculated from the respondents' questionnaire answers.

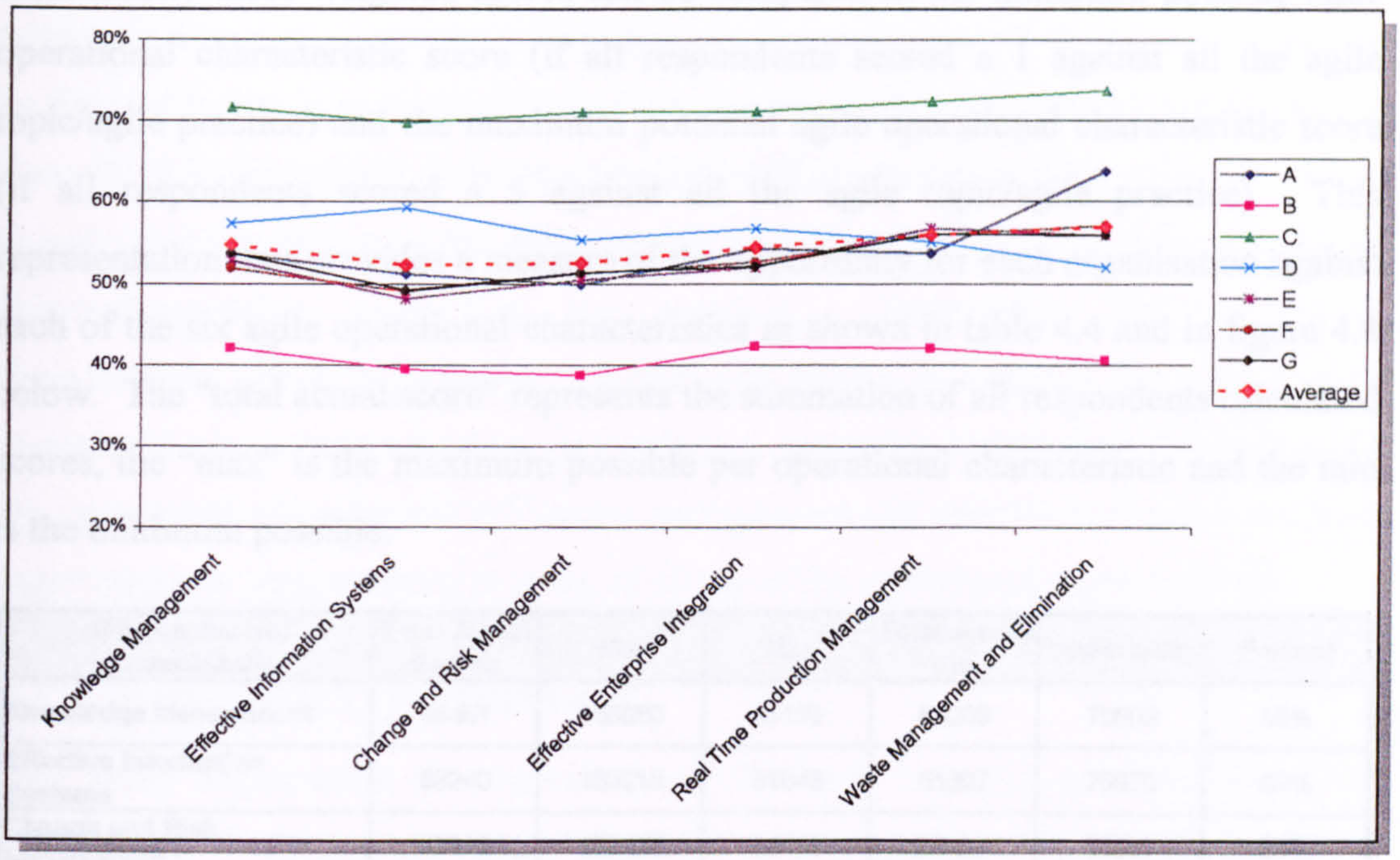

Figure 4.6: Case study organisation A percentage weighted scores per respondent for each agile operational characteristic

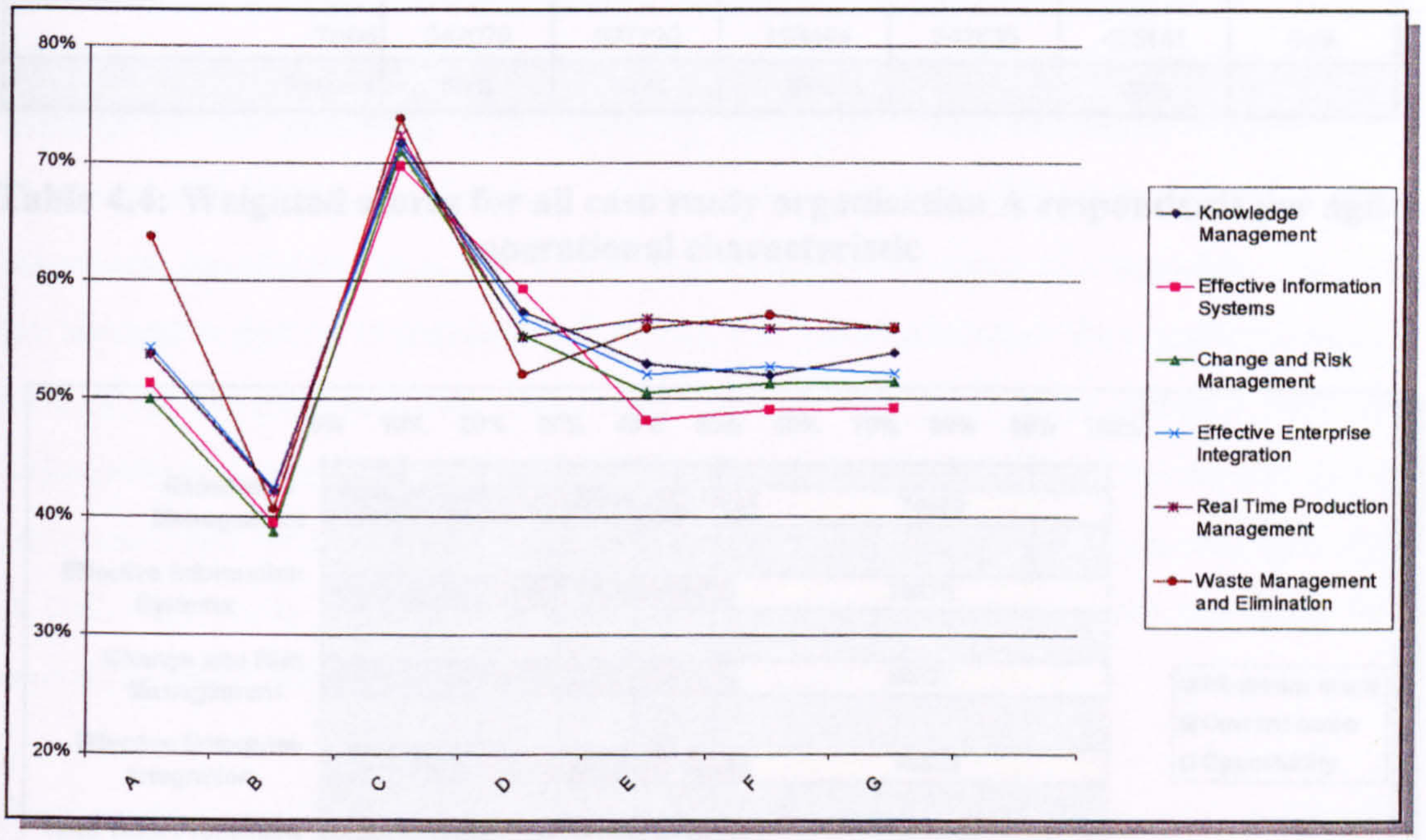

Figure 4.7: Case study organisation A percentage weighted scores per agile operational characteristic for each respondent

Additionally these weighted scores can be compared to the minimum possible agile operational characteristic score (if all respondents scored a 1 against all the agile topic/agile practice) and the maximum potential agile operational characteristic score (if all respondents scored a 5 against all the agile topic/agile practice). This representation thus provides a measure of the opportunity for each organisation against each of the six agile operational characteristics as shown in table 4.4 and in figure 4.8 below. The "total actual score" represents the summation of all respondents calculated scores, the "max" is the maximum possible per operational characteristic and the min is the minimum possible.

Agile operational characteristic	Total Actual Scores	Max	Min	Total scores-min	Opportunity	Percent
Knowledge Management	85451	155960	31192	54259	70509	55%
Effective Information Systems	83240	159215	31843	51397	75975	52%
Change and Risk Management	95918	182455	36491	59427	86537	53%
Effective Enterprise Integration	118899	218295	43659	75240	99396	54%
Real Time Production Management	98028	175070	35014	63014	77042	56%
Waste Management and Elimination	60543	106225	21245	39298	45682	57%
Total	542079	997220	199444	342635	455141	54%
Percent	54%	100%	20%		46%	

Table 4.4: Weighted scores for all case study organisation A respondents per agile operational characteristic

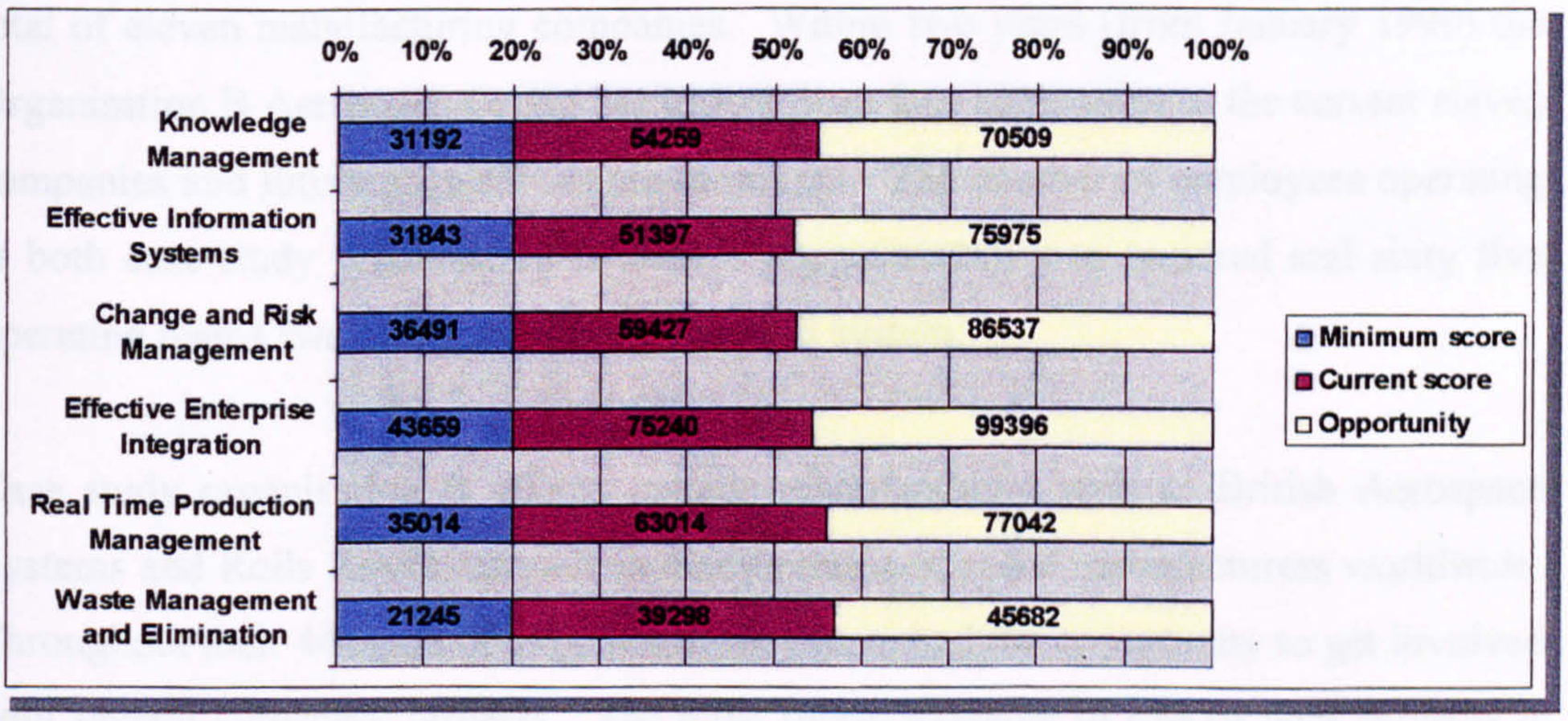

Figure 4.8: Case study organisation A agile operational characteristics weighted scores showing opportunity

Table 4.4 therefore indicates the potential opportunity for improvement for each of the agile operational characteristics. For case study organisation A it is therefore shown by figure 4.8 that, in percentage terms, the greatest opportunity for improving a single operational characteristic, is to improve their "effective information systems". Even though, this is contrary to the ethnographic report, which shows an effective use of information drives production and planning. Nevertheless the operational characteristic, which provides the greatest opportunity to improve the overall agile operational characteristics' score, is "effective enterprise integration". Additionally the operational characteristic of "waste management and elimination" gives the least opportunity for improvement in terms of all six of the operational characteristics.

4.3 Case Study Organisation B

Case study organisation B established in 1955 and currently operating under the organisation B Group plc. since 1998, is an aerospace sub-contractor company specialising in precision machined aircraft components; assemblies/sub-assemblies and kitted parts. Organsiation B Group plc, which is an engineering group specialising in the aerospace and mass transit markets, operates under two divisions, Organisation B Aerospace and Organisation B Automotive (see figure 4.9). Organisation B Aerospace consists of the following four operating divisions: Aerostructures; Aeroengines; Electrical and Spares and Services. Case study organisation B alongside three other aerospace manufacturers is part of the Aerostructures division of companies. In total the aerospace part of Organsiation B Group plc. now consists of four divisions with a total of eleven manufacturing companies. Within two years (from January 1999) the Organisation B Aerospace Group has grown from four companies to the current eleven companies and future acquisitions are imminent. The number of employees operating at both case study organisation B sites is approximately one hundred and sixty five operating over a two and sometimes three shift system.

Case study organisation B clients include manufacturers such as British Aerospace Systems and Rolls Royce, as well as many other aerospace manufacturers worldwide. Throughout their 44 years of experience, they have had the opportunity to get involved with several aerospace projects. The most recent example of one of their projects is the production of structural components for the Airbus series and the Eurofighter/Typhoon. For the completion of these projects they use the latest

technology in machining centres, programming and engineering facilities. Case study organisation B consists of two plants, the main plant is located at Colne (Lancashire region) and the second newer plant is located at a nearby industrial park, which is 5 miles from the main plant. The main plant produces aircraft components for all their customers while the industrial park site plant is mostly dedicated to the needs of British Aerospace.

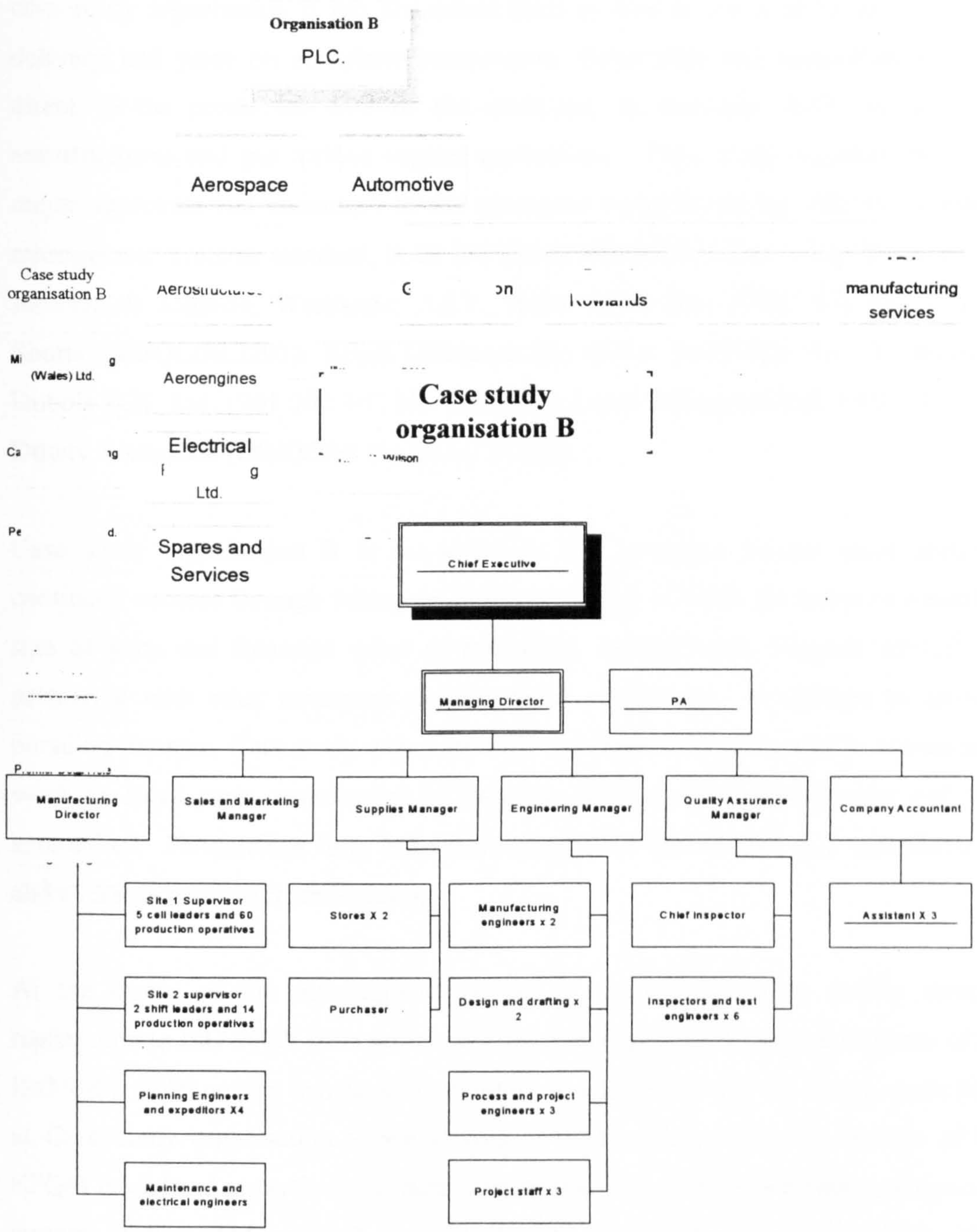

Figure 4.9: Case study organisation B organisational chart and Organisation B Group PLC.

The company produces airframe components and assemblies, engine, thrust reverser and landing gear components, employing extensive Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). The company's focus is on the establishment and retention of long-term partnerships, utilising dedicated manufacturing cells for individual customer projects and programmes. Accordingly case study organisation B has positioned itself as best in sector in terms of quality, delivery and price on aeroplane components, fitted parts and assemblies supplied direct to the production line of the customer, in this case BAE Systems, for aerostructures and gas turbine engine applications. Case study organisation B has major approvals and customers in the aerospace sector including: ISO 9002 quality management systems standard; BAE Plc (BAE/AG/QC/SCI Part 1 No. WAR 1016): Johnson & Johnson; Westlands; A.I.T.; Rolls Royce Plc. (CQC 103 No. 01175); Shorts (SB/QC/AC/293); Royal Ordnance Plc. (QRP 13-7F-001 No. 00726);Hurel Dubois U.K. Ltd. (901 202 102 No. HD1056); Lucas Aerospace Ltd. (901 402 005); Dowty Aerospace (DR/QC/67 No. MAC 31090).

Case study organisation B is pro-active in the aerospace market place ensuring continued success through taking on larger packages of work (in terms of assembly size of parts and financial value of packages), on the latest designed aircraft, by partnering with other aerospace manufacturing companies. In addition to actively pursuing partners, Case study organisation B has been very successful in maintaining work on small parts manufacture for ongoing sales of older aircraft parts and sub-assemblies. Partnerships have been maintained with UK aircraft part manufacturers and overseas partners from Malaysia.

At the centre of the management system is a commitment to quality through registration to ISO 9002: 1994 and a clear commitment to fulfil the requirements of the ISO 9001: 2000 quality management system. In addition to this the management team at Case study organisation B are interested in developing their knowledge of the EFQM model and are actively working toward building an environmental management system in line, and certified in time, to the requirements of ISO 14001: 1996 environmental management systems standard. Quality improvements have included the use of Statistical Process Control (SPC) methods as a requirement of supply of

certain parts. In addition lead-time reduction and delivery performance improvement projects have taken place using lean production methods and reduction in waste from the internal processes. Case study organisation B have been assessed to the Investors in People (IIP) scheme and been awarded a certificate indicating their commitment to the employees' education and development.

The industrial park site manufacturing site was a major investment for the company, introducing new "state-of-the-art" CNC machine tools and centres for world-class performance capability. The main site has also seen a continued investment in CNC and other machine tools to keep pace with increasing complexity and increasing orders for machining capabilities. Alongside introduction of new machine tools has been a move toward dedicated customer cells which are in operation to provide a customer focused production environment employing 5S principles and real time production scheduling techniques using visual systems and software based data management.

4.3.1 The Ethnographic Study Report (Case Study Organisation B)

The setting for the ethnographic study work at case study organisation B included the author working on two different but interrelated issues; work toward the development of statistical techniques for production improvement and control and process mapping work to understand the technical and planning engineering functions. In effect these two areas of work gave the author free access to personnel and data on both Colne, Lancashire manufacturing sites. The study started in December 1998 after negotiation with the managing director the focus of activities, reporting structure for access and possible benefits from collaborations.

The research fieldwork within case study organisation B continued for the following eighteen months until mid July 2000 [a nine week break from 1st October 1999 was taken]. The author additionally became involved in visioning exercises with the senior management team and continuous improvement initiatives aimed at production cell developments toward reducing lead-time and improving delivery performance. The initial two months of work was four days a week and the remainder of the time was for two to three days a week. A desk and computer was provided situated in the engineering planning office. This office was at the heart of operations with

responsibility for engineering processes, tools and machines as well as the detail development of drawings and specifications for production (see flowcharts). Other work carried out in this area included project management of packages of work, which included liaison with partner organisations, and accordingly direct links had been created via ISDN connections.

The process mapping work was carried out early in the ethnographic study and gave the author the opportunity to get to know the majority of the work force. Additionally the research work was assisted by two students on final year project dissertations; one working towards a final year degree dissertation that focused on communication aspects related to total quality control principles and the other was an MSc. dissertation student investigating the concept of agility in the aerospace industries, (Economou, 1999). Consequently the process mapping as discussed in the next section was incorporated in the work of the MSc. dissertation student.

The case study organisation B had in the last two years totally re-arranged the shop floor machinery and changed practices to provide two methods of operation under one roof; "small parts and single components" and "large components and assembly work". Everyone in the factory did not accept this change and practice soon reverted back to the old ways of doing things. In a similar way, it was noticed that in one particular area on the shop floor dramatic reduction in set-up (of machines) was seen and the practice continued well for two years, however the set-up reduction philosophy was tried elsewhere in the factory but no improvements seen.

There have been a series of improvement activities [case study organisation B call these development plans] that the organisation has struggled to get off the ground and implement successfully. One such project was the introduction and development of statistical process control (SPC). The research fieldwork helped facilitate the development of the SPC activities, which had been requested by a major aerospace prime. This work led to the creation of a process for SPC development (see figure 4.10). While further brainstorming activity, during a team work exercise, noted (see figure 4.11) that the perceived main areas of improvement were actually in house keeping and work place organisation principles of 5Ss as discussed by Ho (2000) and in section 2.1 of this thesis. Improvements in house keeping, particular of machines

and tooling for machines provided improvements in both quality and productivity, but for only a limited number of shop floor areas.

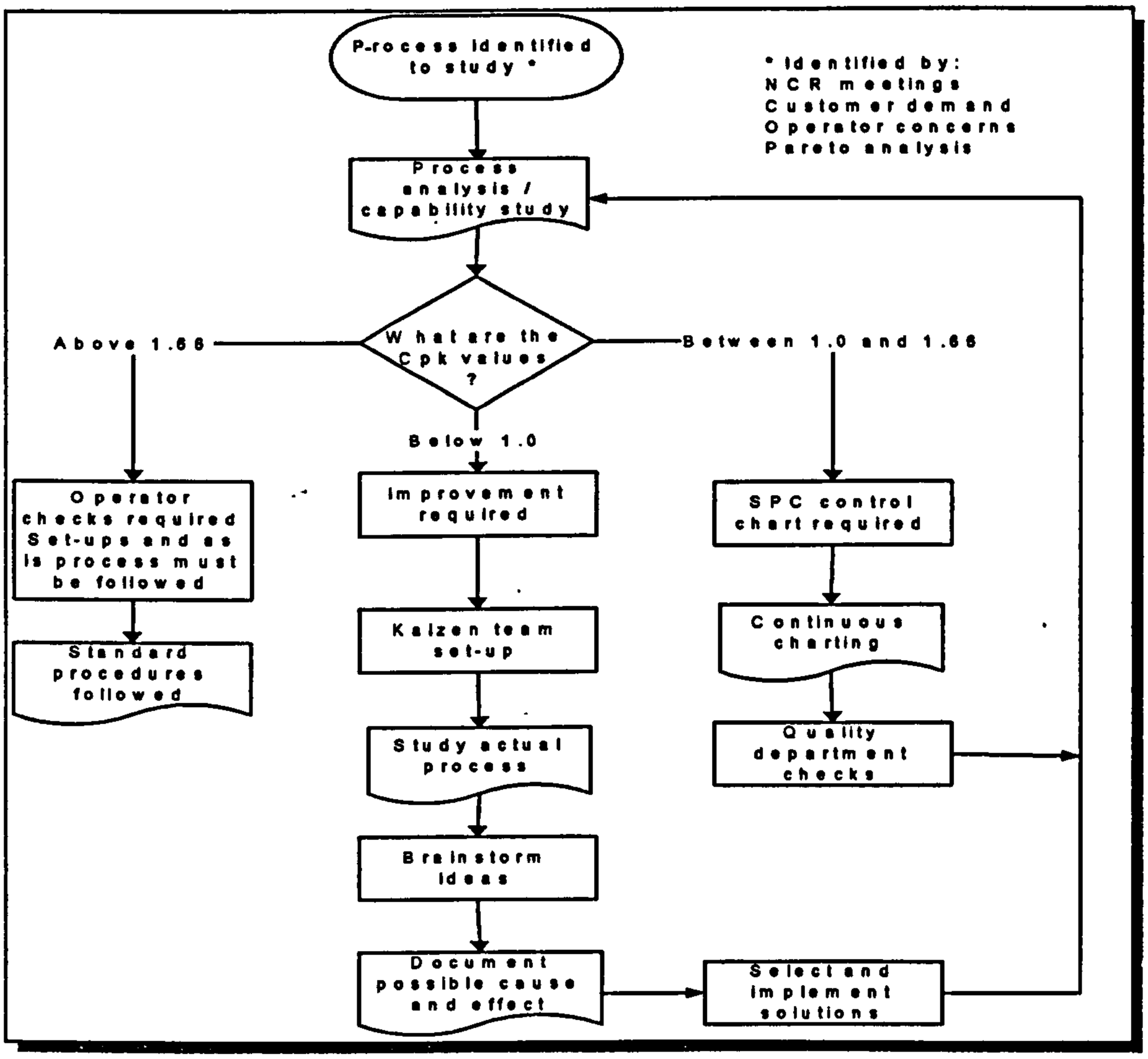

Figure 4.10: SPC development process at case study organisation B

The senior management team had committed to employ a continuous business improvement manager that would facilitate improvement projects. This was achieved and the new member of staff is currently responsible for managing and improving production performance in order to satisfy ever-changing customer demands. Several improvement projects were taken up aimed at improving scheduled adherence. These projects for the first time included operators, engineers, planners and purchasing officers i.e. cross-functional teamwork.

The company had tried to continue to inform employees of changes in business circumstances and practices at briefing sessions. These briefing sessions were

scheduled once per month but in effect the company only managed to deliver these three times a year. Nevertheless case study organisation B is a profitable and growing concern with many satisfied and returning customers. Additionally the managing director and dedicated sales manager are actively seeking and obtaining new business, both of strategic importance and of tactical short-term benefit.

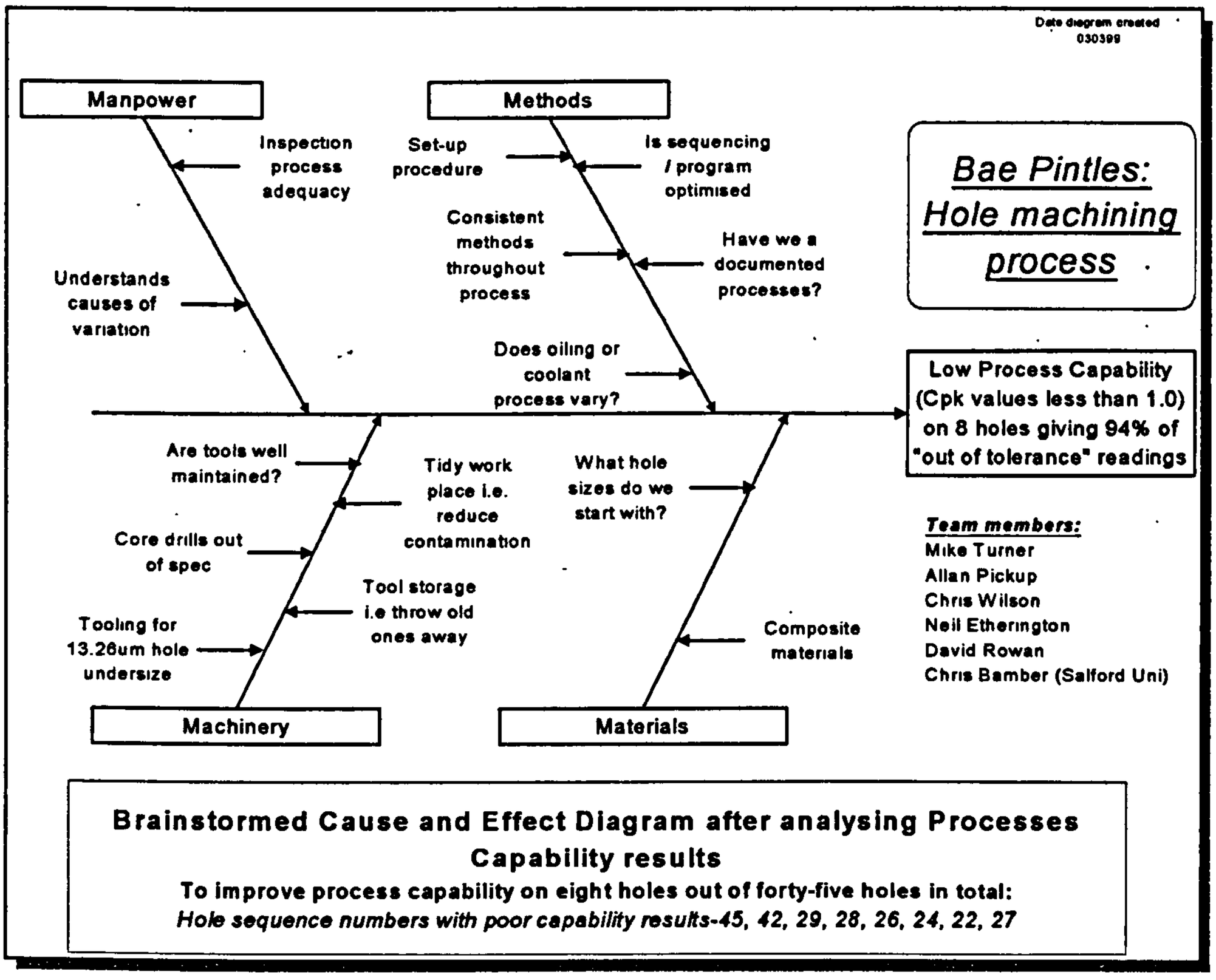

Figure 4.11: Case study organisation B brainstormed list of possible improvements in process capability

Currently case study organisation B is operating at above the expected profit margins and achieving sales better than budgeted. This work has come from a series of enterprising activities including working to develop partnerships to create an improved shared capability, networking within the group of companies to look at shared packages of work delivered through the most efficient operating units and actively pursuing new customers. Consequently, case study organisation B had been (November 1998) assessed and approved to supply components direct to the Boeing

Corporation, one of the few companies in the country to receive this, however as yet [June, 2001] no orders had been received.

4.3.1.1 Process Mapping Exercises at Case Study Organisation B

During the time spent at case study organisation B several processes were mapped out with the help of personnel at the company (see figure 4.12 as an example).

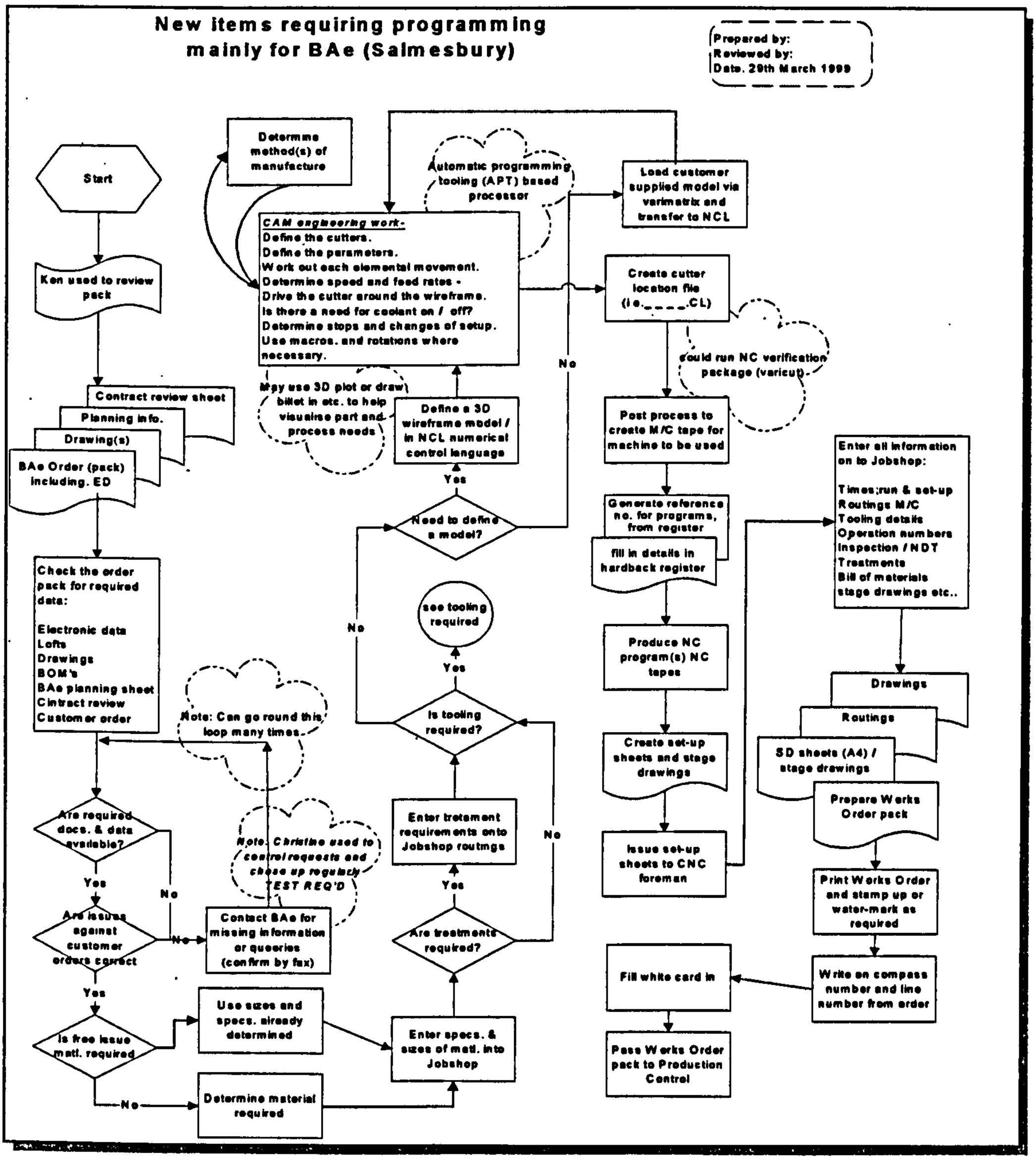

Figure 4.12: Example process map for case study organisation B showing rework loops and engineering design requirements

It was noticed from this exercise that key individuals that fully understood the requirements for key activities carried out these key activities very effectively and efficiently. In fact when key people from a process moved to other tasks or responsibilities a knowledge gap existed, for instance figure 4.12 shows that 'Christine' played a vital role in ensuring documentation was up to date and when she moved on there was obvious confusion causing unnecessary re-iteration in the process (see 'note: can go round this loop many times' in figure 4.12).

Consequently, there is very little multi-skilling within certain administrative, project management and engineering roles. This had caused considerable problems on occasion, for instance when personnel were on holiday or off work from illness it appears to be difficult to find cover. Additionally, the knowledge and understanding of what key processes and consequently key activities are, was little understood and process visibility was not necessarily a key issue, although project management activities for new customer work packages is a high priority. The organisation was set up as a traditional and functional based organisation but efforts to introducing cross-functional team-work as mentioned above are underway.

Additionally, it was particularly noted from the process mapping exercise that computer aided manufacturing was not optimised. For example all drawings from customers, whether electronic, 2D or 3D and whatever format, where redrawn to provide information for the CNC machines to understand (see figure 4.12: 'CAM engineering work section'). In fact there was only one occasion that CNC programmes supplied by the customer had been used, which unfortunately caused tooling to crash on machines and work pieces thus being very costly to rectify. Since this incident no other attempts had been made to use customer supplied programmes or drawings directly on CNC machines without first being redrawn in house.

4.3.1.2 Other Activities and Findings

The case study organisation B senior management team had developed a vision for the future. The vision is documented as a series of bullet points as shown in the table 4.5 below. Although the vision had been developed at the same time that many improvement projects had taken place a clear link between the vision and activities had

not been made by the management team. Therefore, how in detail, the new organisational vision was going to be actioned was not well known and consequently how individuals in the organisation contributed or could contribute to achieving the vision of the future for case study organisation B was not well understood.

• The company should be the first choice for the customer
• Customers are happy/satisfied from the service that they receive from The company
• Supplier satisfaction/closer supplier links
• Competitors should "fear" The company
• Everyone in the company knows how to satisfy their customers (internal, external)
• A role model within the industry
• Consistently beat and set benchmark performance levels
• Culture-attitude/atmosphere
• The company should be ready to give 110% when needed
• Behave internally to customers as if they were external
• Workplace organisation "5S" factory
• The company should not receive any calls from the customer concerning complaints or chasing orders
• The company should not have an inspection department
• Anyone should be able to stop the process of a job if they see that something is wrong
• The company should create a "no blame" culture
• Honesty
• New machining
• Training structure

Table 4.5: The vision for case study organisation B

The newly appointed business improvement manager prepared a series of short presentations to give to the entire workshop that outlined the vision. In addition to presenting the vision, the new manager highlighted some of the recent major successes of the organisation, explained the current work load and expected orders from the major suppliers.

4.3.1.3 Questionnaire Results for Case Study Organisation B

Case study organisation B decided that each individual that would take part in the question would complete the agile operational characteristics matrices (see appendix IV) in a single sitting in a group setting. The author was asked to be available during the completion of the questionnaires to answer any queries that may arise from the respondents' interpretation of the 32 topic areas. In total six respondents delivered the questionnaire with completed assessment scores. The names were provided for all of the respondents, but all respondents' names are removed from any of the data used in this thesis. Table 4.6 is the tabulation of results from the respondents.

		Respondent reference and assessment score									
	TOPIC	A	B	C	D	E	F	Ave.	High	Low	diff
1	Working environment	2	1	2	1	1	1	1	2	1	1
2	Waste Time	2	2	1	1	1	2	1	2	1	1
3	Waste Space	1	2	2	1	1	2	1	2	1	1
4	Waste Materials	2	2	3	1	1	2	1	3	1	2
5	Communication within Groups/Teams	2	2	2	1	1	2	1	2	1	1
6	Communication between Groups/Teams	2	1	3	1	2	2	1	3	1	2
7	Multidisciplinary Teams	1	1	2	1	1	3	1	3	1	2
8	Customer Relations	1	1	2	2	1	2	1	2	1	1
9	Supplier Relations	2	3	2	1	1	2	1	3	1	2
10	Customer Knowledge	3	1	3	2	2	2	2	3	1	2
11	Supplier Knowledge	2	1	3	1	1	2	1	3	1	2
12	Customer Focused Production	4	2	4	3	4	3	3	4	2	2
13	Strategic Alliances	3	3	4	4	2	4	3	4	2	2
14	Rapid Collaboration	2	2	3	3	1	4	2	4	1	3
15	Process and project visibility	3	3	3	3	2	3	2	3	2	1
16	Capability planning	2	3	2	1	2	3	2	3	1	2
17	Skills and Competences	2	2	2	1	2	2	1	2	1	1
18	Education and Training	3	3	2	1	1	2	2	3	1	2
19	Dynamic project scheduling	3	3	3	3	3	3	3	3	3	0
20	Utilisation of Resources	2	2	2	2	1	2	1	2	1	1
21	Process flow analysis	2	1	2	3	1	2	1	3	1	2
22	Capacity planning	2	2	3	2	1	3	2	3	1	2
23	Efficient and effective maintenance	2	3	1	3	2	2	2	3	1	2
24	Efficient and effective administration	1	3	2	2	1	3	2	3	1	2
25	Information Quality & Management	3	3	3	1	2	3	2	3	1	2
26	System Compatibility (standards, protocols and metrics)	2	2	1	3	1	3	2	3	1	2
27	Change deployment	2	2	2	2	2	2	2	2	2	0
28	Product Innovation	3	2	1	2	3	3	2	3	1	2
29	Risk	2	3	2	3	2	3	2	3	2	1
30	Responsibility	3	4	3	3	1	3	2	4	1	3
31	Integration within the Business Strategy	2	3	2	1	1	1	1	3	1	2
32	Use of Metrics	2	2	1	1	1	1	1	2	1	1

Table 4.6: The questionnaire results from case study organisation B

The "Ave." column is the mean average of columns A to G rounded down to the nearest whole number. The "high" and "low" columns represent the highest score found against a particular topic and the "diff." column represents the difference between the highest score and the lowest score from any respondent against each of the topics. Figure 4.13 shows the combined scores per topic area.

The highest combined scores of 20 are topic numbers twelve and thirteen concerning customer focused production and strategic alliances. These are the only two topics

with a mode of 4 from respondents, providing a consensus of opinion that this topic is implemented to a high level. Following these two topics as the highest combined score of 18 (mean average level 3), which is related to dynamic project scheduling. The next two highest scored topic numbers with a combined score of 17 are topic number fifteen, process and project visibility and topic number thirty which relates to responsibility. However, responsibility (topic 30) along with rapid collaboration (topic 14) across the six respondents scores are noticed to have the greatest difference between highest and lowest score for all topics (diff. = 3). It is also noticed that no fives were scored across any of the topics and for anyone of the respondents.

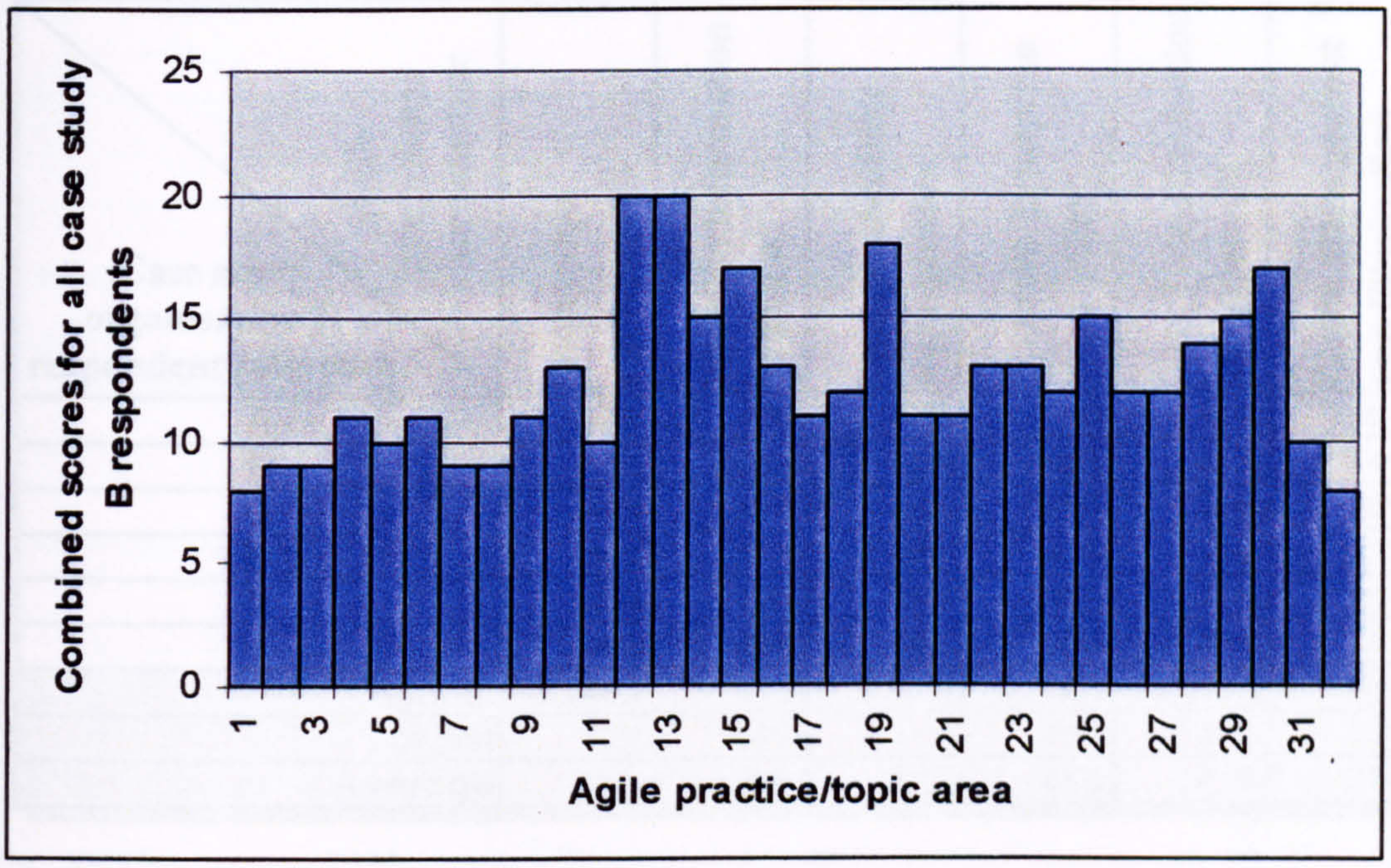

Figure 4.13: Combined scores of all case study B respondents per topic area

The lowest combined score for any topic area is seen in topic numbers one concerning working environment and topic number thirty-two use of metrics both with modes of 1 indicating a consensus of opinion. Following these topic numbers as the lowest average score, the next four lowest mean averages (four at 1.5) are topic numbers two, three, seven and eight which are issues relating to waste time and space, multidisciplinary teams and customer relations. Multidisciplinary teams being the only one topic of these four where responses are not bi-modal and the consensus of opinion (mode) is level 1 indicating a perceived low adoption level.

4.3.1.3.1 Weighted Results for the Operational Characteristics

The weighted score per topic area is taken to provide calculated scores for each of the six operational characteristics (as described in section 3.3.1.4.1). Using this calculated weighted data a percentage score can be worked out for each respondent against each of the six agile operational characteristics. These averages are shown in table 4.7 below and consequently an average across the respondents can be calculated for each of the agile operational characteristics.

Case study organisation B respondent reference / Agile operational characteristic	Knowledge Management	Effective Information Systems	Change and Risk Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination
A	48%	45%	44%	45%	44%	39%
B	47%	45%	42%	45%	45%	44%
C	46%	48%	45%	47%	44%	40%
D	38%	39%	36%	42%	39%	32%
E	33%	30%	31%	33%	31%	25%
F	48%	49%	46%	50%	47%	40%
Highest	48%	49%	46%	50%	47%	44%
Lowest	33%	30%	31%	33%	31%	25%
Average	43%	43%	41%	44%	42%	37%

Table 4.7: Case study organisation B percentage weight score per respondent for each agile operational characteristic

Accordingly the data from table 4.7 can be plotted on charts to show the current position of the organisation in terms of their own respondents' perceived agile operational characteristics and operational practices. Figures 4. 14 and 4.15 therefore show the weighted results from table 4.7, which are calculated from the respondents' questionnaire scores. For instance, table 4.7 shows that the "waste management and elimination" weighted score gives the lowest average score for any of the six agile operational characteristics for case study organisation B respondents.

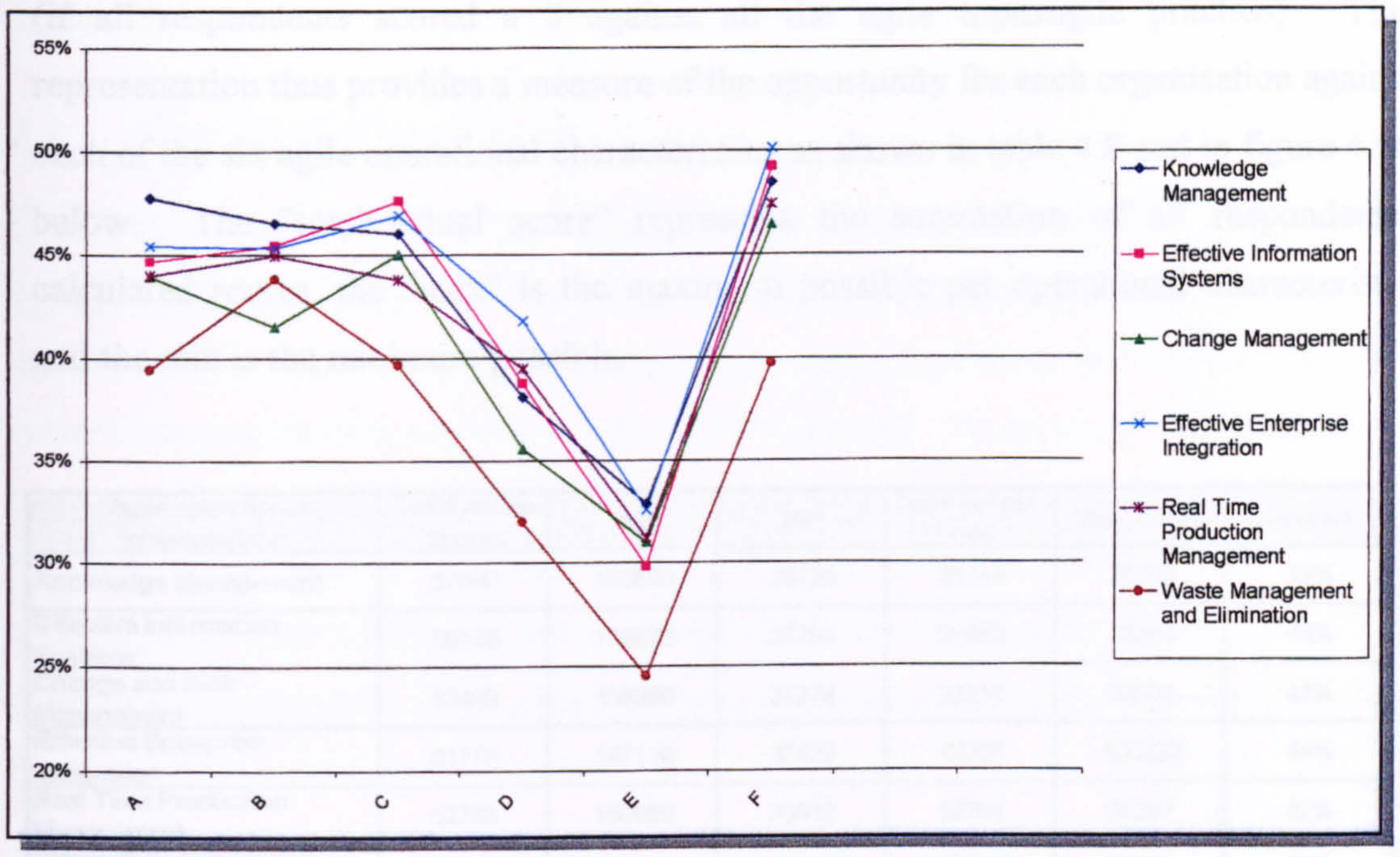

Figure 4.14: Case study organisation B percentage weighted scores per respondent for each agile operational characteristic

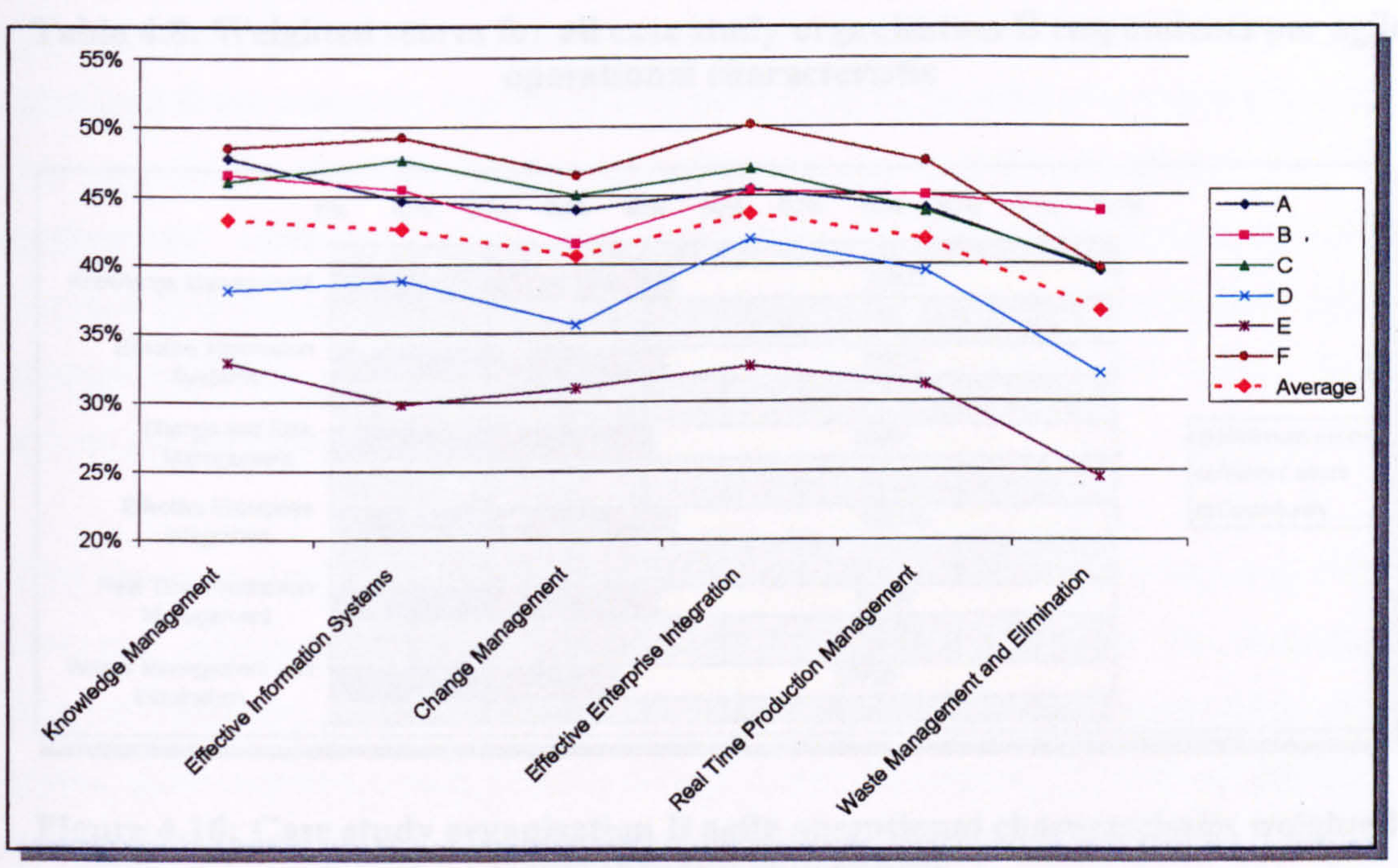

Figure 4.15: Case study organisation B percentage weighted scores per agile operational characteristic for each respondent

Additionally, these weighted scores can be compared to the minimum possible agile operational characteristic score (if all respondents scored a 1 against all the agile

topic/agile practice) and the maximum potential agile operational characteristic score (if all respondents scored a 5 against all the agile topic/agile practice). This representation thus provides a measure of the opportunity for each organisation against each of the six agile operational characteristics as shown in table 4.8 and in figure 4.16 below. The "total actual score" represents the summation of all respondents' calculated scores, the "max" is the maximum possible per operational characteristic and the min is the minimum possible.

Agile operational characteristic	Total Actual Scores	Max	Min	Total scores - min	Opportunity	Percent
Knowledge Management	57880	133680	26736	31144	75800	43%
Effective Information Systems	58146	136470	27294	30852	78324	43%
Change and Risk Management	63489	156390	31278	32211	92901	41%
Effective Enterprise Integration	81778	187110	37422	44356	105332	44%
Real Time Production Management	62763	150060	30012	32751	87297	42%
Waste Management and Elimination	33270	91050	18210	15060	57780	37%
Total	357326	854760	170952	186374	497434	42%
Percent	**42%**	**100%**	**20%**		**58%**	

Table 4.8: Weighted scores for all case study organisation B respondents per agile operational characteristic

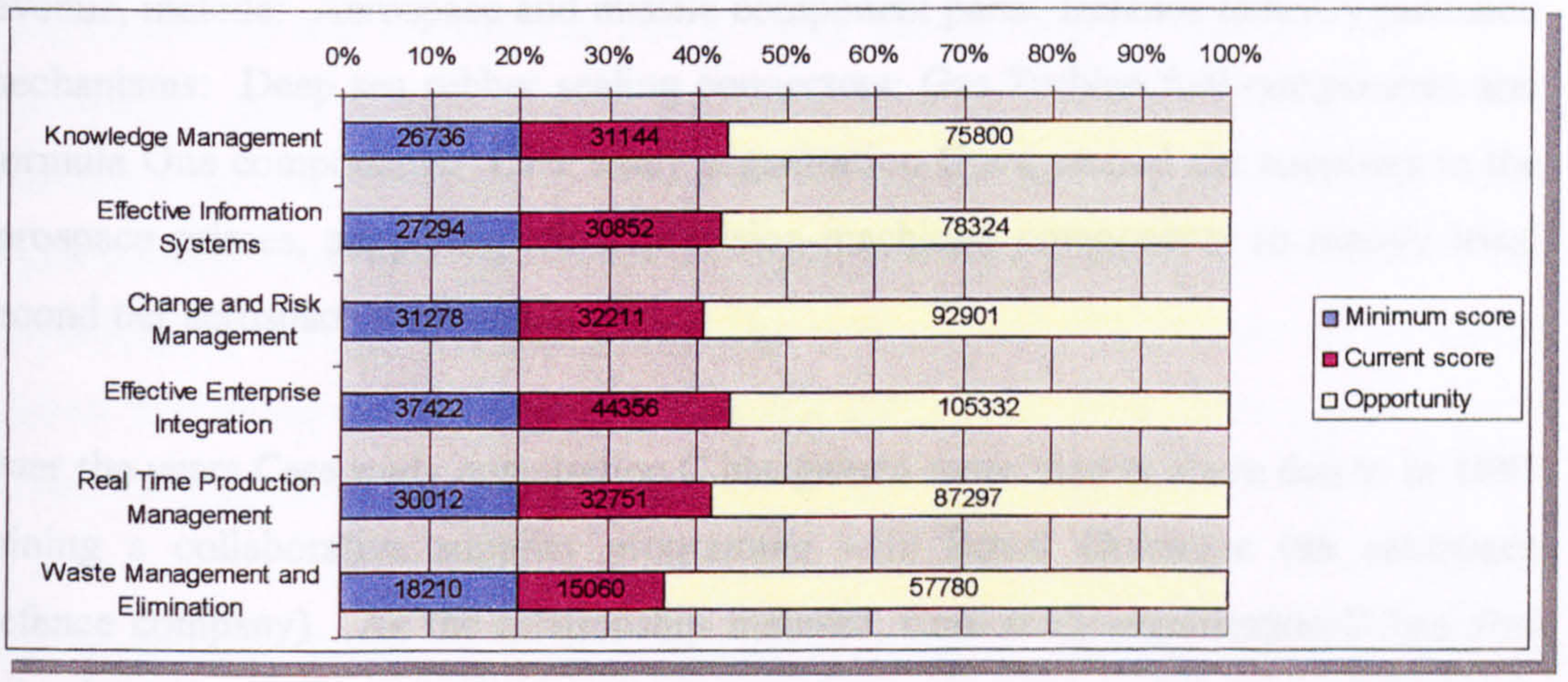

Figure 4.16: Case study organisation B agile operational characteristics weighted scores showing opportunity

Table 4.8 therefore indicates the potential opportunity for improvement for each of the agile operational characteristics. For instance "effective enterprise integration" provides the greatest opportunity to improve the overall agile operational

characteristics score while "waste management and elimination" has the greatest percentage opportunity increase of the six operational characteristics.

4.4 Case Study Organisation C

Case study organisation C, has operated as a sub-contract engineering company providing products and services to the defence, aerospace, motor sport and commercial market sectors. Case study organisation C is totally autonomous and has no sister or partner companies with any stake-hold of the company. Case study organisation C commenced trading in 1992 after a small engineering company was bought from the receivers, with a workforce of twenty, but now has increased to over fifty and operates a twenty-four hour production environment, consisting three shifts (see figure 4.17). Case study organisation C has operated, when necessary, during the weekend, giving the possibility to manufacture product seven days a week.

The company carries out prototype development, small batch work and the production machining of a wide range of precision components on both Computer Numerical Control (CNC) and conventional machinery. Case study organisation C deals with a customer base in the order of 70 companies, although 80% of revenue is from one missiles defence company, and the typical areas of work, in order of turnover and sales revenue, include: Aerospace and missile component parts: Defence industry precision mechanisms: Deep sea rubber sealing connectors: Gas Turbine fuel components and Formula One components. Case study organisation C are second tier suppliers to the aerospace primes, supplying small precision-machined components to mainly local second tier aerospace suppliers.

Over the years Case study organisation C has gained more market share due to in 1995 joining a collaborative supplier programme with Royal Ordnance (an aerospace defence company). As the relationship matured, Case study organisation C has also gained more customers such as Rolls Royce, Lucas Aerospace, Ministry of Defence, Aero and Industrial Technology and Rolls Royce Nuclear Engineering. Hence new product introduction is a core process, as new markets and new challenges are encountered regularly. Only a few repeat orders exist on the books, because of the product type and mix of work, therefore planning and scheduling is dynamic and often reactive when orders arrive necessitating very quick turn around.

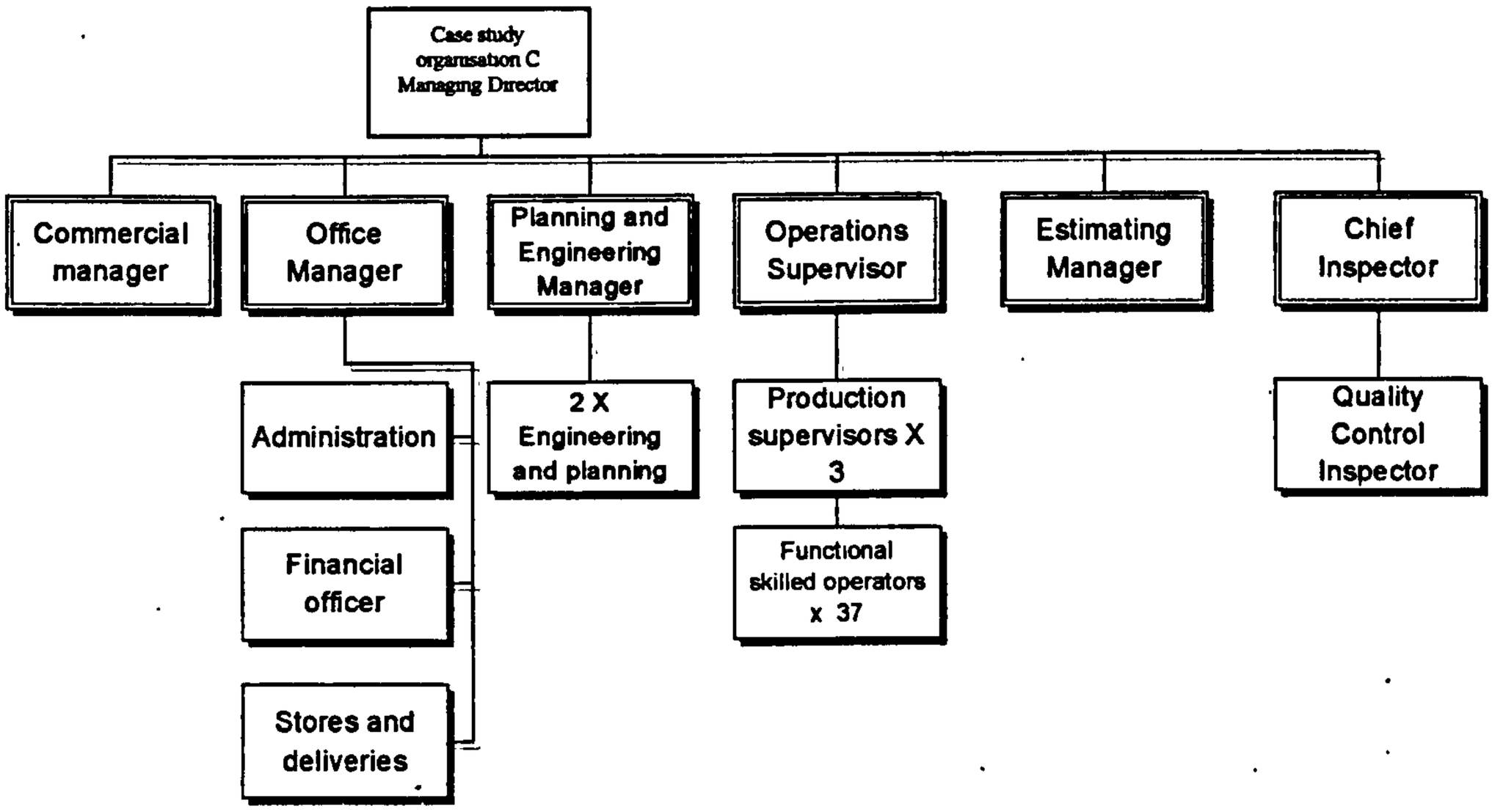

Figure 4.17: Case study organisation C organisation structure

Case study organisation C hold certificates for MOD quality approval and operate a quality management system certified to ISO 9001: 1994. The managing director ensures there are three initiatives ongoing at case study organisation C aimed at achieving World Class Manufacturing (WCM) status and hence improving competitiveness and maintaining and growing market share. These initiatives are maintaining; strict quality control standards; good inspection facilities; and CNC machinery to help reduce lead times. Alongside these initiatives case study organisation C have embarked on a major factory clean up exercise in line with the 5Ss philosophy of work place organisation. The main method of production planning and control is a visual management system using cards on a large board situated in the administrations office.

Several quality related initiatives have taken place to improve the efficiency of processes; particularly planning and scheduling of workloads, including the introduction of a new process oriented and bespoke data management system. Recent capital expenditure includes purchase of high speed turning machinery which has been recently commissioned to enable the efficient production of small turned components from bar. This new turning centre has the ability to produce large batches of very small components very fast and automatically with auto-bar feed facility. Further

investments in machine centres are being discussed and funding opportunities are being sought.

Customer satisfaction is perceived as low because delivery lead times are not maintained and the current performance for on time delivery is very poor for all customers. This problem is being addressed with the introduction of the new process and data management system and the development and continuation of the factory based 5Ss programme. Teamwork is a new philosophy for Case study organisation C and regular team meetings are held to develop ownership of processes and address opportunities for improvement in delivery performance although this is still early days and takes considerable effort to maintain focus on team development.

4.4.1 The Ethnographic Study Report (Case Study Organisation C)

The author worked at case study organisation C during the period December 1999 and December 2000. The work undertaken was in two parts, firstly to process map the existing operations from receipt of a request to quote to the delivery of product to the customer and secondly was to study the estimating process and methods of estimating and assess the accuracy of the estimates for the orders won compared to the actual costs of the job. The first part is discussed later in the next section.

The author was provided a small office adjacent to the engineering and production planning functions. From this position within the company many interactions were observed between the operators and the engineers, between the store men and engineers and between the production and quality control functions. Here it was noticed that the quality function within the company was of a very traditional nature, focusing on quality control and inspection aspects of quality management. In fact it was discussed that; "...the quality manager had no time at all to identify opportunities for improving quality matters because he was too busy inspecting first offs and final finished product." On asking the quality manager about the recent changes to ISO 9001: 1994 he replied: "I did not know that the standard was undergoing any changes so I cannot comment on the new standard."

It was noticed that the estimation function was based on a prediction of costs expected and then a percentage increase adding to that cost for profit, whereas agility theory discusses the concept of customer perceived value of products. The work carried out to compare estimates for jobs to actual costs showed clearly that expected performance (profit) on jobs was not being achieved on 95% of orders taken. The reason given was; " ... that the estimation process had not changed for 25 years and a lot of new customers were being sought and initially the first few jobs would be taken on at a loss." The explanations were obviously flawed as well-established customers were still providing new work to a loss making formula.

Within the management structure a new commercial manager had been appointed with the responsibility to develop customer relations by improving communications with existing customers and attracting new customers. The commercial manager had been in post for approximately six months and introduced two new customers to the company. Unfortunately these two new (super-high value motor sports parts) customers, in terms of delivery timescales, were not seeing the performance they had been promised from company C. Accordingly, the commercial managers' function became mainly involved in expediting orders through the factory and chasing materials purchased. The post had moved within the space of six months from that of a strategic role to a fire-fighting role, reacting to crisis.

Similarly, because of the up turn in business from new customers, an operations supervisor had been taken on to run the shop floor production, while the previous works manager became responsible for production planning and engineering activities. This role was predominantly aimed at pushing production through the factory as opposed to pulling it through as in a lean manufacturing environment. Additionally the managing director ensured that the customer that shouted the loudest got their jobs pulled through the production unit the quickest. This lead to a situation that many jobs were stopped part through a batch to make way for a perceived more important job; consequently preparation for quick change over was not seen as a possibility because there was very little confidence in the scheduling of machines and furthermore very little confidence throughout the operations that customer delivery dates could be achieved.

4.4.1.1 Process Mapping Exercises at Case Study Organisation C

The process mapping exercise at case study organisation C was primarily aimed at identification of duplication and identification of waste within the processes adopted by the organisation. It was considered by many in the organisation that because the computer systems adopted had evolved without a clear plan of improvement many activities that where carried out by individuals where being duplicated either on paper or by another person in another computer application. Examples of the process mapping activities are shown in appendix VII, while a particular example, the order processing function, is shown below in figure 4.18.

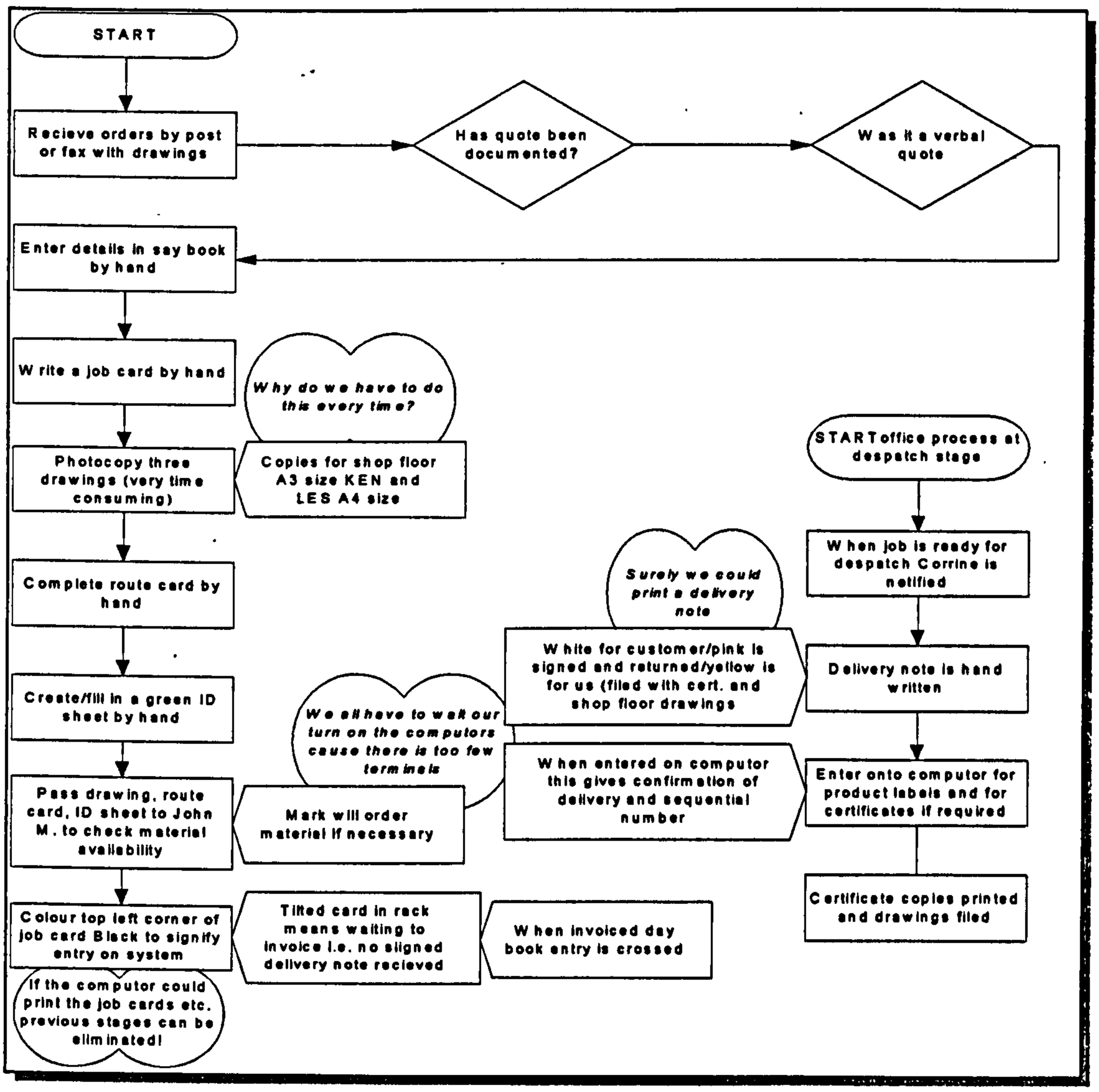

Figure 4.18: Process flowchart for case study organisation C showing order processing activities

The review of the order processing function, figure 4.18 shows that there are many time consuming and unnecessary activities that are being carried out. For instance while interviewing the order processor she indicated that if the information entered on to the computer could be printed off then completion of job cards by hand and associated activities could be eliminated, thus saving time. Additionally the order-processing map shows that many copies of engineering drawings and specifications are being printed and distributed throughout the organisation for not much benefit and a lot of effort.

Furthermore other process maps revealed that the computer-aided engineering and production planning activities where not linked to the estimating, order-processing, inspection, delivery or financial systems that operated in other functions. Thus the information systems and transfer of knowledge through the company was carried out on an ad-hoc basis at various crisis meetings throughout the day.

4.4.1.2 Other Activities and Findings

The Managing Director of case study organisation C recently (during the ethnographic study period) acquired a small (3 engineers and a turnover less than £125k per annum) engineering business that designs and builds special purpose semi-automatic machinery such as special purpose jigs, fixtures and basic assembly apparatus. This new business has provided the managing director a new interest and focus for his activities and time. Although the new business is set up to run autonomously, i.e. not financially linked to case study organisation C, it operates from the same premises and occasionally shares the same resources, such as the managing director, floor space and bench tops.

Similarly, that is in terms of the diverted effort of the managing director, he is pursuing the creation and development of a start-up business in the field of e-procurement. This start-up business requires a lot of time and effort, commitment and planning to secure both venture capital and commitment or enthusiasm from the potential market place and customer base. Hence the managing director affords a great deal of time to the activity (Observations show that approximately equivalent to half a day a week is spent directly attributed to this venture). This has been an activity lasting over six months during the end period of the ethnographic study.

4.4.1.3 Questionnaire Results for Case Study Organisation C

Case study organisation C decide that each individual that would take part in the question would complete the agile operational characteristics matrices (see appendix IV) in their own time, that is, neither at a given time and place nor together in one place as a group. In total seven respondents delivered the questionnaire with completed assessment scores. The names were provided for all of the respondents, but all respondents' names are removed from any of the data used in this thesis. Table 4.9 is the tabulation of results from the respondents.

The "Ave." column is the mean average of columns A to G rounded down to the nearest whole number. The "high" and "low" columns represent the highest score found against a particular topic and the "diff." column represents the difference between the highest score and the lowest score from any respondent against each of the topics. Figure 4.19 shows the combined scores per topic area. The highest combined scores of 19 are for topic numbers one and two concerning the working environment and the waste time topics although the consensus of opinion (mode average score) is for level 3 for topic one it is at level 2 for topic two. Following topic numbers one and two, as the next highest is topic number three with a combined score of 18 which is related to waste space issues which also has a consensus of opinion at level 3 adoption level.

		Respondent reference and assessment score										
	TOPIC	A	B	C	D	E	F	G	Ave.	High	Low	diff.
1	*Working environment*	1	3	4	3	1	3	4	2	4	1	3
2	*Waste Time*	3	2	3	2	2	2	5	2	5	2	3
3	*Waste Materials*	2	3	3	2	1	3	4	2	4	1	3
4	*Waste Materials*	3	3	1	2	2	1	3	2	3	1	2
5	*Communication within Groups/Teams*	3	2	2	2	1	3	2	2	3	1	2
6	*Communication between Groups/Teams*	4	2	1	1	1	2	2	1	4	1	3
7	*Multidisciplinary Teams*	1	1	2	1	1	1	1	1	2	1	1
8	*Customer Relations*	1	4	2	1	1	3	2	2	4	1	3
9	*Supplier Relations*	1	3	1	1	1	3	1	1	3	1	2
10	*Customer Knowledge*	1	4	1	1	2	3	3	2	4	1	3
11	*Supplier Knowledge*	1	2	1	1	2	3	3	1	3	1	2
12	*Customer Focused Production*	1	3	2	2	2	2	3	2	3	1	2
13	*Strategic Alliances*	1	2	1	3	3	5	2	2	5	1	4
14	*Rapid Collaboration*	1	1	1	2	2	3	2	1	3	1	2
15	*Process and project visibility*	1	3	1	1	3	2	2	1	3	1	2
16	*Capability planning*	1	3	2	2	2	3	4	2	4	1	3
17	*Skills and Competencies*	2	2	2	2	1	2	2	1	2	1	1
18	*Education and Training*	1	1	2	1	1	1	1	1	2	1	1
19	*Dynamic project scheduling*	1	3	1	2	2	2	3	2	3	1	2
20	*Utilisation of Resources*	1	3	2	1	1	2	2	1	3	1	2
21	*Process flow analysis*	1	1	3	1	1	1	2	1	3	1	2
22	*Capacity planning*	1	3	3	2	2	2	2	2	3	1	2
23	*Efficient and effective maintenance*	1	1	2	1	1	1	1	1	2	1	1
24	*Efficient and effective administration*	1	3	4	2	1	1	2	2	4	1	3
25	*Information Quality & Management*	1	2	2	2	2	3	2	2	3	1	2
26	*System Compatibility (standards, protocols and metrics)*	1	4	1	2	1	2	3	2	4	1	3
27	*Change deployment*	2	4	2	2	2	1	3	2	4	1	3
28	*Product Innovation*	1	3	1	3	3	3	1	2	3	1	2
29	*Risk*	1	1	1	1	1	1	4	1	4	1	3
30	*Responsibility*	1	3	1	2	2	4	3	2	4	1	3
31	*Integration within the Business Strategy*	1	1	1	2	2	1	2	1	2	1	1
32	*Use of Metrics*	1	1	1	1	1	1	5	1	5	1	4

Table 4.9: The questionnaire results from case study organisation C

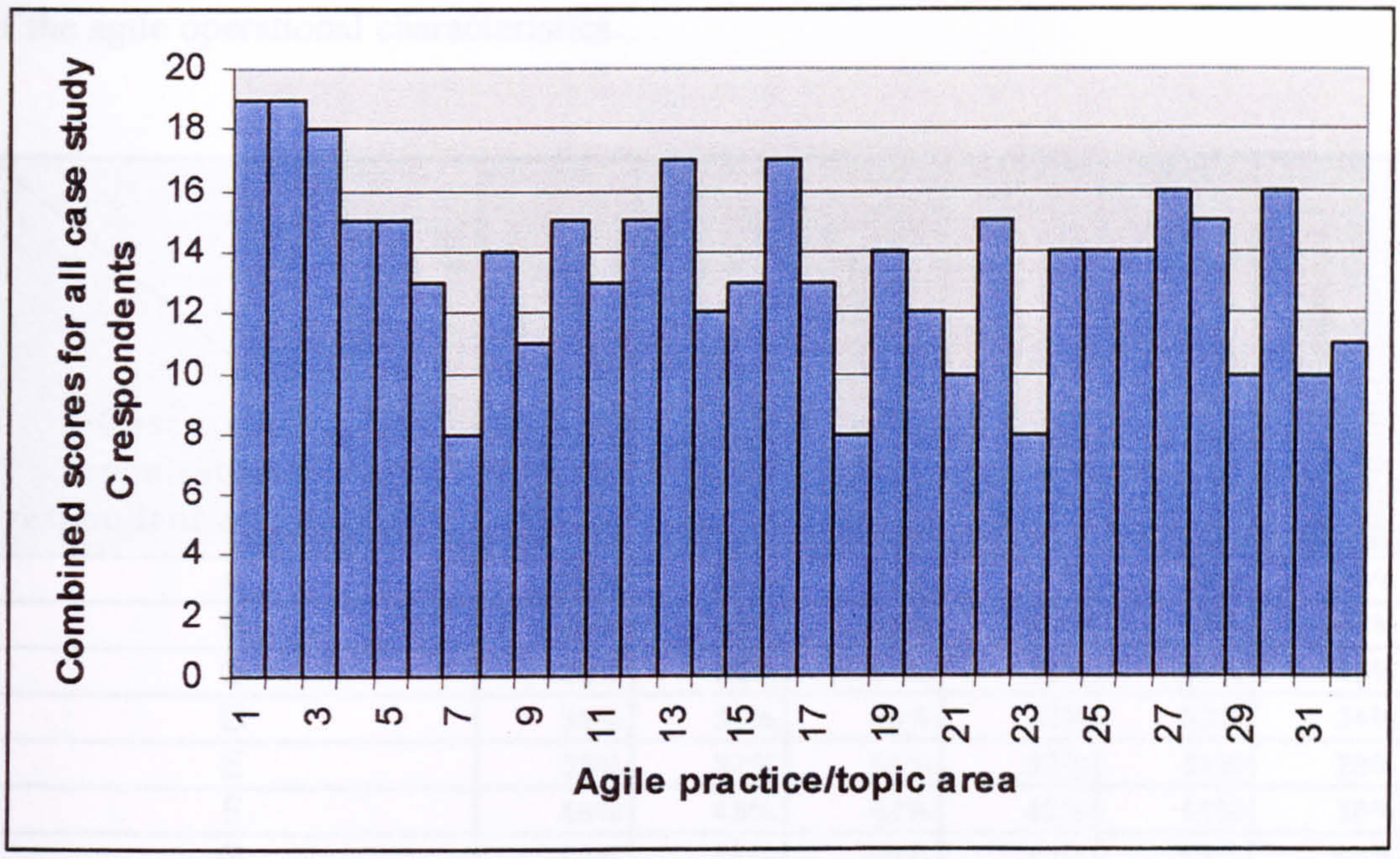

Figure 4:19: Combined scores of all case study C respondents per topic area

The next two highest scored topic numbers with combined score of 17 are topic numbers thirteen and sixteen which are the issues relating to strategic alliances and capability planning. However, strategic alliances (topic 13) across the seven respondents' scores is noticed as the greatest difference between highest and lowest score for this topic, with a maximum difference of 4. It is also noticed that the topic relating to use of metrics (topic 32) also has a difference of four between the highest and lowest scores for this topic. The lowest scored topics each with total score of 8 are topic numbers seven, eighteen and twenty-three relating to multidisciplinary teams, education and training and the topic of efficient and effective maintenance where the consensus of opinion (mode average score level) is these practices are adopted to a very low level.

4.4.1.3.1 Weighted Results for the Operational Characteristics

The weighted score per topic area is taken to provide calculated scores for each of the six operational characteristics (as described in section 3.3.1.4.1). Using this calculated weighted data a percentage score can be worked out for each respondent against each of the six agile operational characteristics. These averages are shown in table 4.10

below and consequently an average across the respondents can be calculated for each of the agile operational characteristics.

Case study organisation C respondent reference / Agile operational characteristic	Knowledge Management	Effective Information Systems	Change and Risk Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination
A	22%	26%	27%	25%	24%	28%
B	49%	46%	45%	49%	47%	44%
C	29%	30%	31%	33%	37%	45%
D	33%	31%	30%	33%	33%	34%
E	33%	32%	31%	33%	31%	28%
F	48%	45%	42%	45%	41%	36%
G	50%	48%	46%	49%	53%	57%
Highest	50%	48%	46%	49%	53%	57%
Lowest	22%	26%	27%	25%	24%	28%
Average	38%	37%	36%	38%	38%	39%

Table 4.10: Case study organisation C percentage weight score per respondent for each agile operational characteristic

Accordingly the data from table 4.10 can be plotted on charts to show the current position of the organisation in terms of their own respondents perceived agile operational characteristics and operational practices. Figures 4.20 and 4.21 therefore show the weighted results shown in table 4.10, which are calculated from the respondents' questionnaire answers.

Additionally these weighted scores can be compared to the minimum possible agile operational characteristic score (if all respondents scored a 1 against all the agile topic/agile practice) and the maximum potential agile operational characteristic score (if all respondents scored a 5 against all the agile topic/agile practice). This representation thus provides a measure of the opportunity for each organisation against each of the six agile operational characteristics as shown in table 4.11 and in figure 4.22. The "total actual score" represents the summation of all respondents calculated scores, the "max" is the maximum possible per operational characteristic and the min is the minimum possible.

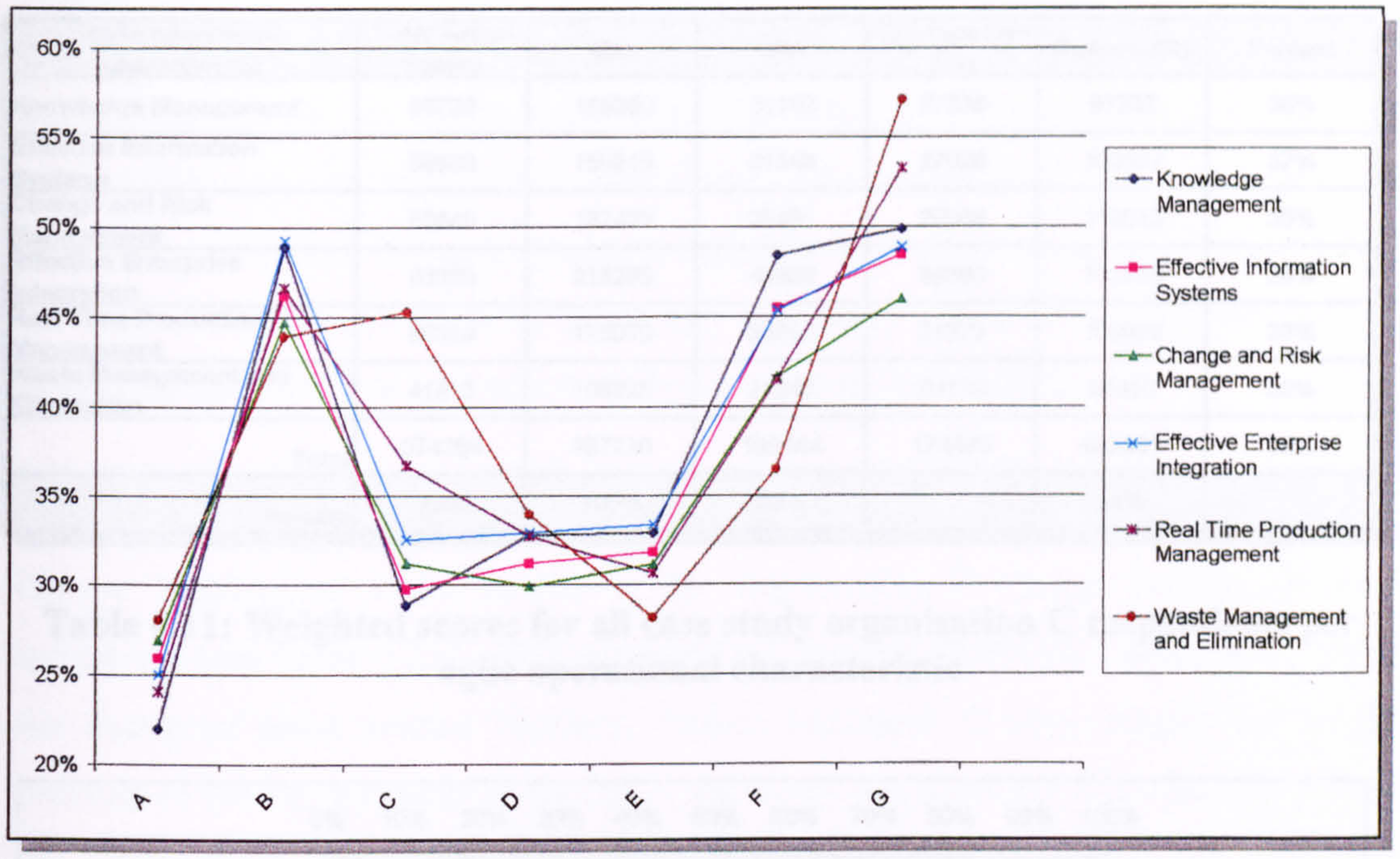

Figure 4.20: Case study organisation C percentage weighted scores per respondent for each agile operational characteristic

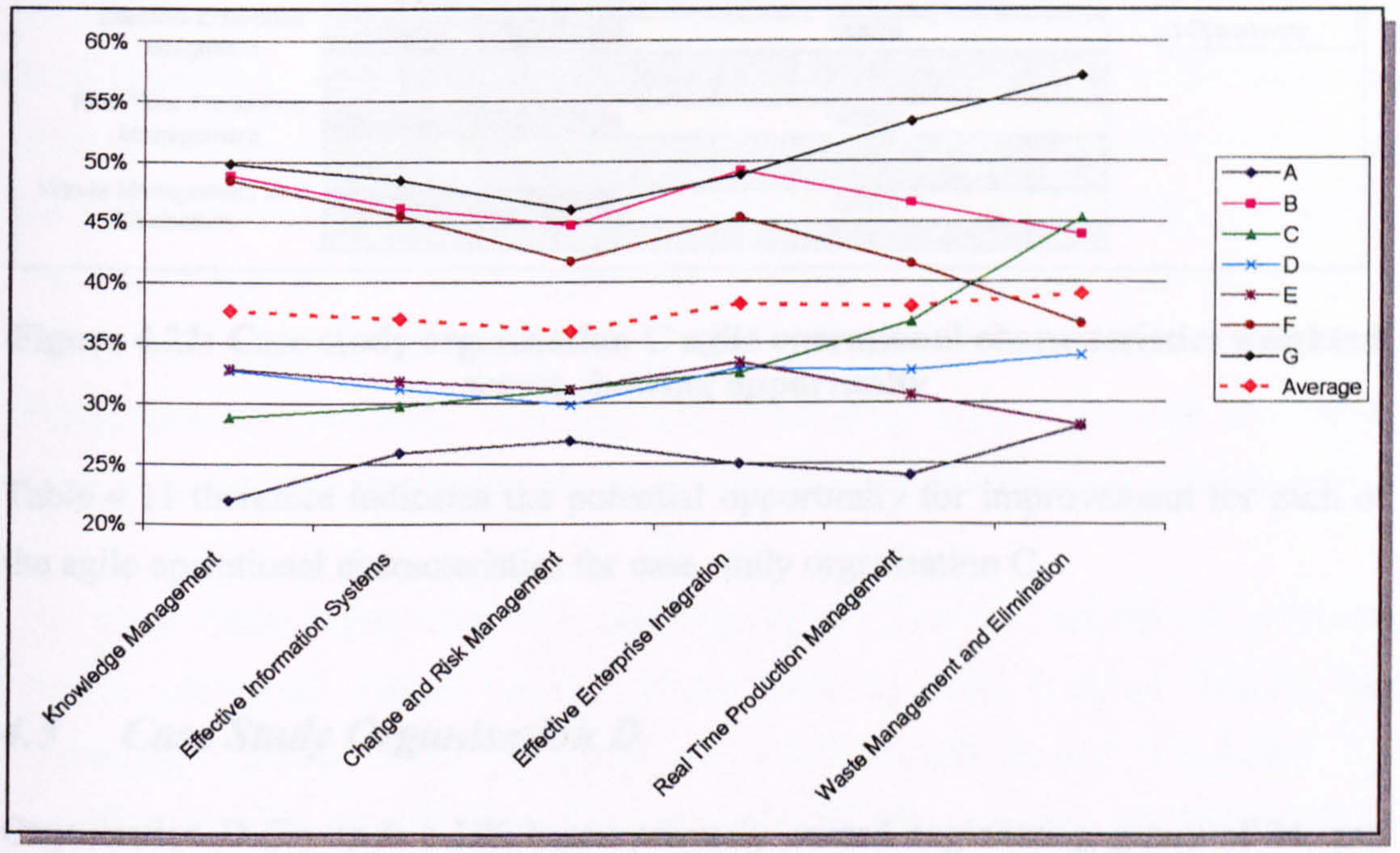

Figure 4.21: Case study organisation C percentage weighted scores per agile operational characteristic for each respondent

Agile operational characteristic	Total Actual Scores	Max	Min	Total scores - min	Opportunity	Percent
Knowledge Management	58728	155960	31192	27536	97232	38%
Effective Information Systems	58863	159215	31843	27020	100352	37%
Change and Risk Management	65540	182455	36491	29049	116915	36%
Effective Enterprise Integration	83339	218295	43659	39680	134956	38%
Real Time Production Management	66384	175070	35014	31370	108686	38%
Waste Management and Elimination	41415	106225	21245	20170	64810	39%
Total	374269	997220	199444	174825	622951	38%
Percent	38%	100%	20%		62%	

Table 4.11: Weighted scores for all case study organisation C respondents per agile operational characteristic

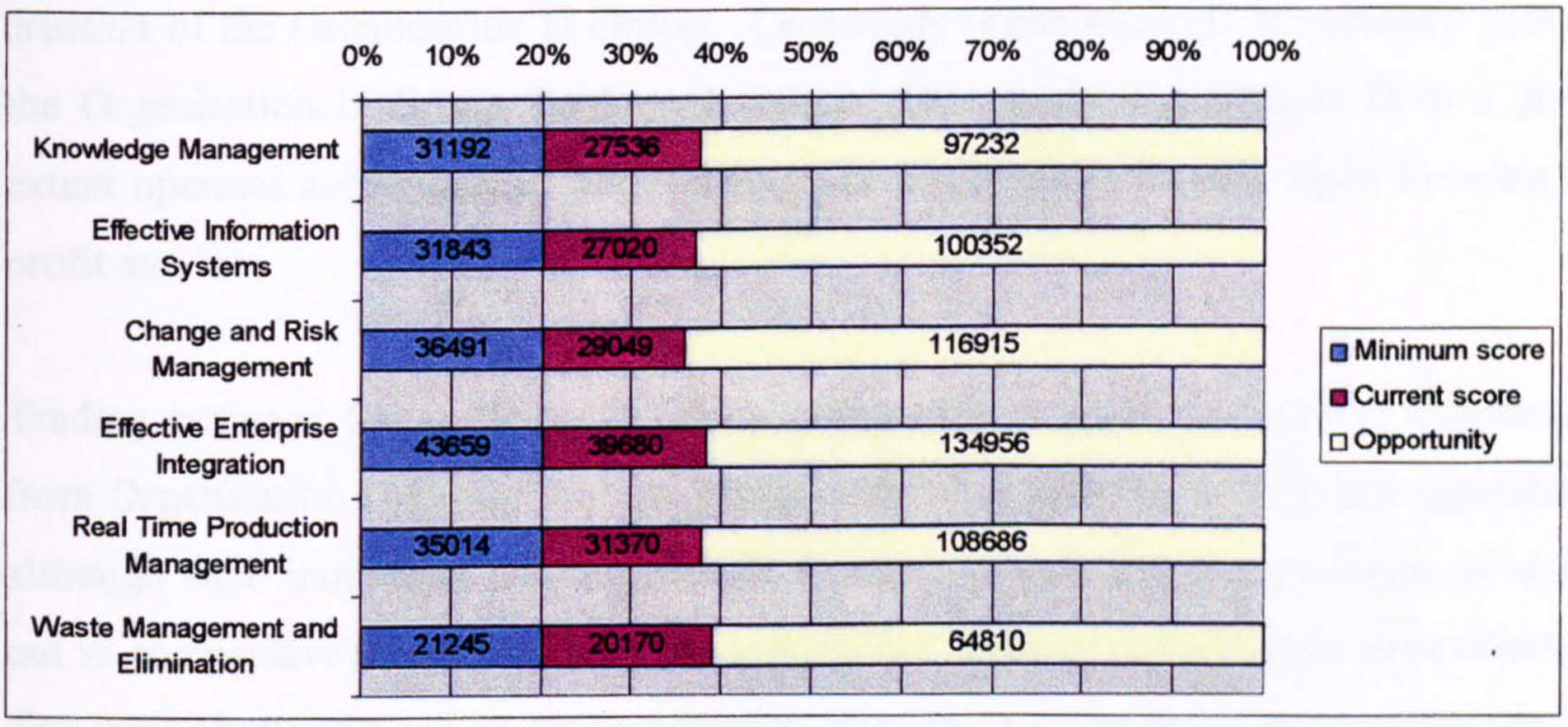

Figure 4.22: Case study organisation C agile operational characteristics weighted scores showing opportunity

Table 4.11 therefore indicates the potential opportunity for improvement for each of the agile operational characteristics for case study organisation C.

4.5 Case Study Organisation D

Organisation D Group is a UK based privately owned engineering group of 34, and expected to increase, semi-autonomous small companies specialising in all facets of airframe structure supply. It is a major first-tier engineering design, manufacturing and assembly company with over 1000 employees across the group of companies. Organisation D Groups' tooling organisation is reported by the company as the largest

single source subcontract aerospace tooling resource world-wide, supporting the provision of airframe components and structures in addition to its role in industry as an independent supplier of cradle to grave tooling solutions. Organisation D Group also has a wide range of component manufacture and treatment facilities available in-house. In addition to the main business suppliers to the aerospace industry the group has business ventures in mobile plant and machinery manufacture, special purpose measuring and technical instrumentation development and manufacture.

Case study organisation D, employing 60 personnel in total, in new premises in Greater Manchester, which is one of the Organisation D Group Tooling Division companies (see figure 4.23). This company was first established in 1968 and by 1984, the European trend toward Turnkey, Project Managed Tooling Supply led to the creation of the Organisation D Group. Case study organisation D is currently part of the Organisation D Group Tooling Division. Case study organisation D to a great extent operates autonomously and has to make a success in its own right, in terms of profit and loss.

Trading between Organisation D Group companies is usual, as work is distributed from Organisation D Group to those group companies with the appropriate capability, although each individual Organisation D Group company can put packages of work out to competitive tender ensuring the appropriate capacity requirements are achieved. The major bulk of Case study organisation D work is strategic in terms of aerospace supply and therefore they afford long lead-times enabling effective and relatively straightforward production planning and scheduling techniques with one works manager and projects engineer reporting directly to the two Directors of the company.

The Case study organisation D manufacturing facilities are capable of producing various aerospace related tooling: Pattern Making; Soft Tooling; Tooling and Composite Tooling; Final Assembly and Mating Fixtures and Alignment Jigs including all types of aircraft handling and parts handling equipment. The capability and capacity of the Case study organisation D manufacturing facility includes CNC machining centres, conventional grinders, milling stations, turning, jig boring , radial arm and several band-saws and pillar drills which is supported by a highly skilled and apprentice trained work force.

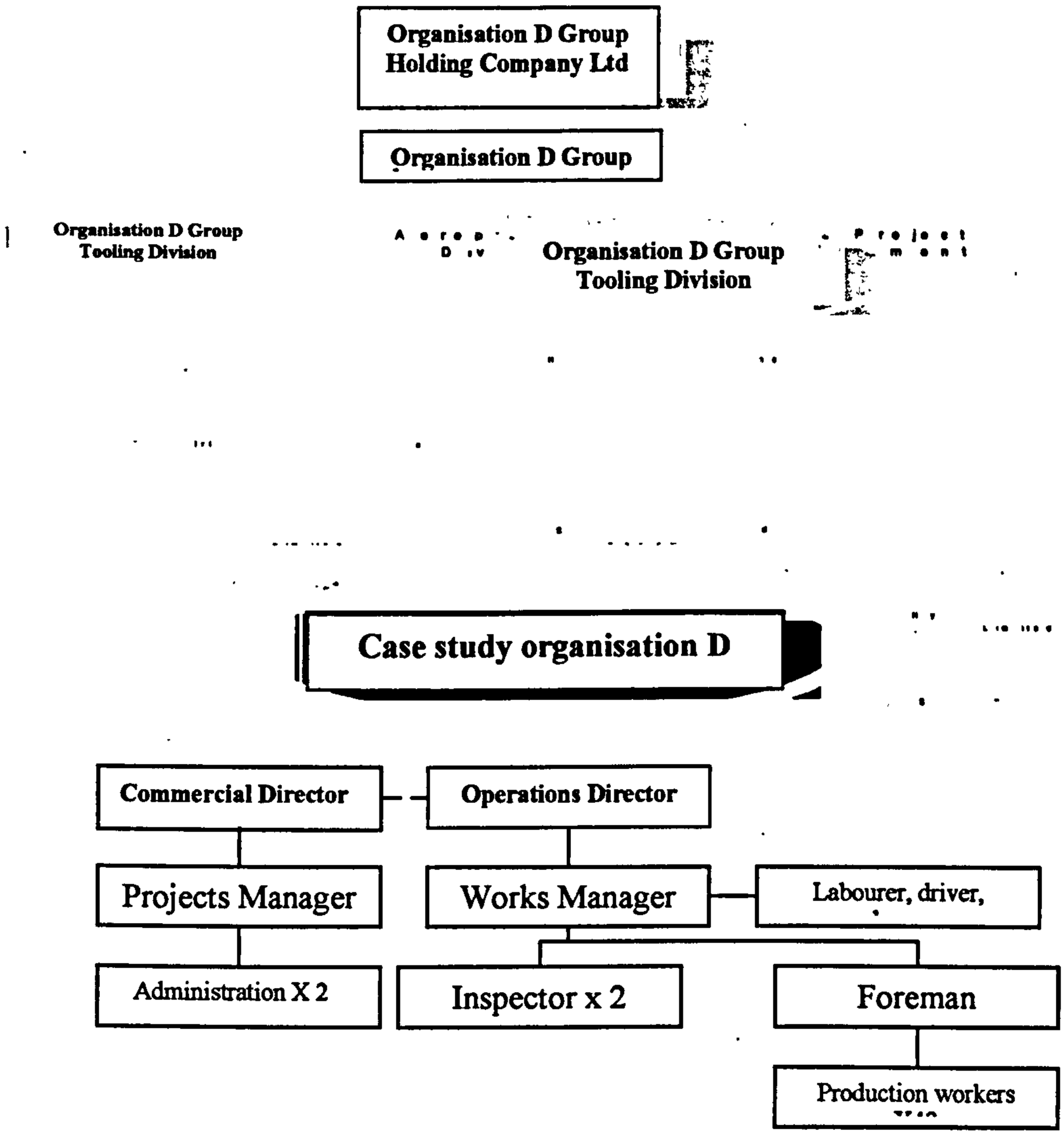

Figure 4.23: Case study organisation D organisational chart and Case study organisation D Tooling Group structure

The Case study organisation D has a UK customer base including: BAE Systems; Rolls Royce; Short Brothers; and Westland Aerostructures. It also has an international customer base and client approvals including amongst others: Lockheed Martin; McDonnell Douglas; SAAB and supplies tooling to the Boeing second tier fabrications offload supply network. The Case study organisation D current main customer is BAE Systems, which accounts for 75% of production throughput.

All of the organisation D group of companies, including The Case study organisation D, are subject to customer improvement initiatives from Rolls-Royce and British Aerospace Systems including SCRIA and Achieving Customer Excellence programmes. The case study organisation D is registered to the ISO 9002: 1994 quality management system standard and has, via the group, several aerospace accreditation approvals. In addition to these customers and quality driven initiatives the case study organisation D, alongside a group led initiative, is currently working toward improving the quality management system. The company is familiar with, and at a basic level introduced, advanced quality techniques such as Statistical Process Control (SPC), process flow charting, improvement project planning and also have an appreciation, and involvement in the organisation D group of companies interest, in applying the European Foundation for Quality Management model (or Business Excellence Model). In addition to this, an in-house survey has been carried out to identify opportunities to improve the operations and consequently the directors, for suitability of improvement projects, are investigating several shop floor generated suggestions.

4.5.1 The Ethnographic Study Report (Case Study Organisation D)

The fieldwork research with case study organisation D and group of companies continued over a period of eighteen months between July 2000 and August 2001 for an average of one and half days a week. During this period of time the research was involved in process mapping across the case study D group of companies with a focus on understanding the software and paper work interactions i.e. data and information management systems. This work included analysing specific project management methodologies and included some skills mapping and assessment of personnel.

The case study company D provided a desk and telephone access to all sites within the group and this gave a good opportunity to observe interactions between personnel across the group of companies. It was noted at this stage that case study company D, although had an inspection function did not have a clearly defined management structure. Moreover the function of quality management was seen as the direct responsibility of the group headquarters, whom incidentally employed a department of

quality management specialists which included the ownership of the quality management, environmental management and health and safety systems for the group of companies. The quality director of this department was responsible for the development of quality initiatives throughout the group and was aiming to deploy quality management to the responsibility of each company within the group. Incidentally the group quality director had created the quality systems documentation for company D to follow.

Although the aim was to develop a system of continued compliance to ISO 9001: 1994 there appeared to be very little understanding within the company of the requirements of the revised standard of ISO 9001: 2000 version. Furthermore, quality initiatives were not common place in case study company D, even though the group policy as mentioned above was to introduce continuous improvement and develop an interest in the EFQM model within each of the group companies.

Similarly the concept of lean manufacturing was not well understood although this was regularly talked about in the group. Consequently, activities such as 5S and kaizen improvement methods were not in operation at case study organisation D although the shop floor was very well organised and very tidy at all times. Although tools and machinery were very clean and tidy (well house kept) there was no planned or preventative maintenance activities being carried out other than service orders and work done under contract of new machine purchases.

The case study organisation D was very focused on delivery to customers on time and as such delivery performance is excellent, which is helped by the small numbers of product being worked on at any one time. Alongside this on time delivery ethos it was noticed that on delivery to the customer of costly and larger fabrications either a director or a project manager accompanied the deliveries. This approach was used to ensure the best chances of goods inward acceptance by the customer; that is to say if minor imperfections or non-conformances were found then wherever possible these would be immediately rectified, to provide the customer with a satisfactory product and without the costs of extra shipment and unnecessary logistical measures. Additionally on critical components, of high risk to the business if rejected determined at contract review stage, a senior project engineer would be appointed to spend time in

the customers' premises prior to delivery, building up a confidence and rapport while discussing the eminent delivery [the senior project engineer was provided a desk and other amenities].

Although the portfolio of customers was extensive the fact that very few orders were being processed at any one time meant that during the period of study the observation was made that only manufacture of goods to one customer. Likewise data and information management systems were to an absolute minimum and as such a project engineer said: "We are not swamped or overburdened with information ... we seem to have enough information to do the job we need to do, on time every time, according to the customer schedules." The product was slow moving through the factory with relatively long lead time [months as opposed to days] because of the complexity and size of products manufactured. Likewise a traditional functional layout on the shop floor was deemed appropriate.

The directors at case study organisation D were very visible management and were both heavily involved in the factory, ensuring that wherever possible every effort was made to hit deadlines and targets for production. In fact one of the directors said that: " ... without any doubt schedule adherence is our most important measure." The majority (99.5% quoted by the commercial director) of work was issued from the group of companies and very little work was for orders won by company D in their own right.

4.5.1.1 Process Mapping Exercises at Case Study Organisation D

The process maps presented in appendix VIII have been created and developed by the project personnel at case study organisation D group headquarters. The creation of the maps had been requested by a major customer to be included as part of a specific contracts' quality planning documentation. The process maps were created during project team meetings and established initially in free-hand format and then completed using software packages by the quality control function of the organisation. Further to this several iterations and amendments were made to the process maps to ensure that the accuracy was maintained before publishing accepted copies in their quality planning documentation.

This process of creation of the process maps indicates a certain level of maturity and understanding of both systems and process thinking from the case study organisation D group. Furthermore the maps, appendix VIII, show that information and data flow appear to be well understood and controlled, however interviews of personnel by the author, throughout the group indicate a frustration with the reporting and communication channels between companies and to and from group.

4.5.1.2 Other Activities and Findings

The management team at case study organisation D, during participant observation within the group of companies, had asked for suggestions for improvements to come from the shop floor personnel (see table 4.12).

Order full size lengths of material to avoid costs	All employees should be able to do every job
Jobs issued by store man should have completed documentation to avoid unnecessary work finding out information	Proper use of all personnel including labourers, apprentices.
Apprentices should do more value added work instead of labouring all the time	Cost reduction should come from savings not pay alterations
Use the internet more to improve communication with customer (use digital photography to aid discussion)	Employ our own maintenance engineers or employ a group maintenance engineer
Make a clear link between purchase orders and items received i.e same order numbers used throughout production	Better shop tidiness i.e. everything in its place
Have a manned stores	Don't pay for contract staff to work on jobs that we can do
When ordering materials check drawing, don't just take bill of materials for granted	Have a single pool car to reduce the number of company cars
More input from management rather than shop floor having to solve problems and trouble shoot	Reduce amount of product in storage

Table 4.12 Shop floor suggestions from case study organisation D

After several brainstorming sessions the senior management team were presented with a list of suggestions. The managers over the previous three months, although it included some very good ideas, had not assessed this list of suggestions.

The author, consequently, asked one of the skilled men on the shop floor if any thing had been done about these suggestions and he replied " ... that after two months we

are still waiting for some movement on the list but nothing has been acted on ...its like the skills matrix we have completed to identify the gaps in our production skills of each shop floor member ... nothing has been done with that other than it got pinned on the wall." From further discussion with other people on the shop floor it was obvious there was a lot of good intention to improve but very little activity to make progress.

4.5.1.3 Questionnaire Results for Case Study Organisation D

Case study organisation D decide that each individual that would take part in the question would complete the agile operational characteristics matrices (see appendix IV) in their own time, that is, neither at a given time and place nor together in one place as a group. In total seven respondents delivered the questionnaire with completed assessment scores. The names were provided for only two of the respondents, but all their names are removed from any of the data used in this thesis.

Table 4.13 is the tabulation of results from the respondents. The "Ave." column is the mean average of columns A to G rounded down to the nearest whole number. The "high" and "low" columns represent the highest score found against a particular topic and the "diff." column represents the difference between the highest score and the lowest score from any respondent against each of the topics. Figure 4.24 shows the combined scores per topic area.

The highest combined score of 34 is topic number twelve concerning customer focused production. The consensus of opinion among respondents (mode average of 4) is that this topic is at level 4 inferring a high maturity level of practice for customer-focused production. Following topic number twelve, as the highest combined score of 31 is topic number five, related to communication within groups and teams. The next highest scored topic number (combined score of 28) is topic number twenty-five issues relating to information and quality management with an average score of 3.5 indicated a slight difference of opinion for the adoption level of this topic at either level 3 or 4. Close behind with total scores of 27 are topic numbers twenty which is utilisation of resources (mode average of 3) and topic number eight which are issues concerning customer relations although a consensus of opinion for this topic was not reached (multi-modal response of 3, 4, and 5).

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twenty-three as the lowest combined (average) score are topic numbers thirty-two and twenty-one, which are concerning the use of metrics and process flow analysis.

4.5.1.3.1 Weighted Results for the Operational Characteristics

The weighted score per topic area is taken to provide calculated scores for each of the six operational characteristics (as described in section 3.3.1.4.1). Using this calculated weighted data a percentage score can be worked out for each respondent against each of the six agile operational characteristics. These averages are shown in table 4.14 below and consequently an average across the respondents can be calculated for each of the agile operational characteristics.

Case study organisation D respondent reference / Agile operational characteristic	Knowledge Management	Effective Information Systems	Change and Risk Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination
A	42%	43%	39%	42%	39%	41%
B	48%	49%	46%	48%	43%	42%
C	45%	45%	45%	45%	41%	44%
D	49%	49%	46%	47%	47%	46%
E	74%	69%	70%	71%	70%	62%
F	55%	54%	53%	56%	53%	49%
G	61%	56%	53%	60%	58%	57%
H	68%	63%	64%	63%	66%	63%
Highest	74%	69%	70%	71%	70%	63%
Lowest	42%	43%	39%	42%	39%	41%
Average	55%	53%	52%	54%	52%	50%

Table 4.14: Case study organisation D percentage weight score per respondent for each agile operational characteristic

Accordingly the data from table 4.14 can be plotted on charts to show the current position of the organisation in terms of their own respondents' perceived agile operational characteristics and operational practices. Figures 4. 25 and 4.26 therefore show the weighted results shown in table 4.14, which are calculated from the respondents' questionnaire answers.

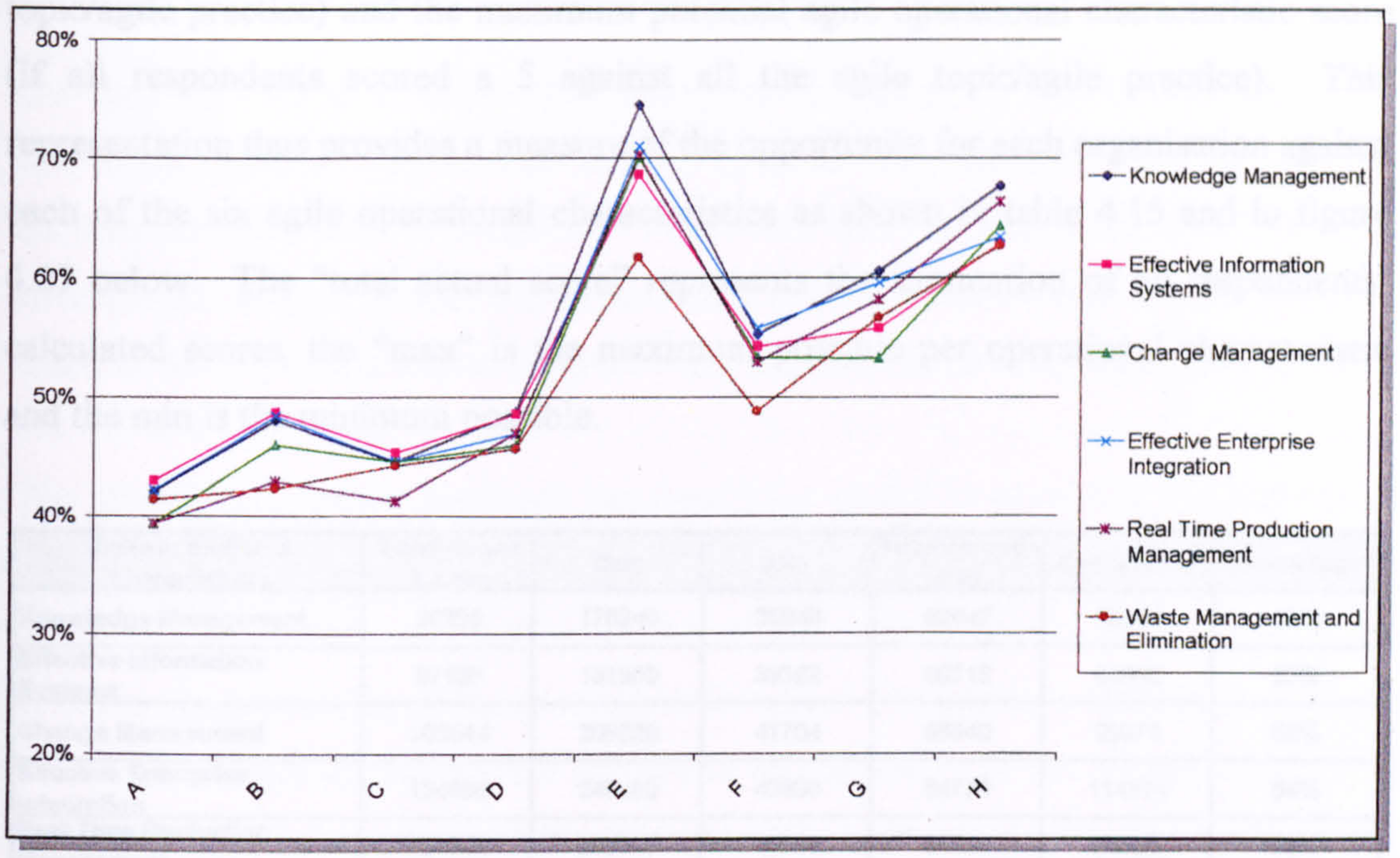

Figure 4.25: Case study organisation D percentage weighted scores per respondent for each agile operational characteristic

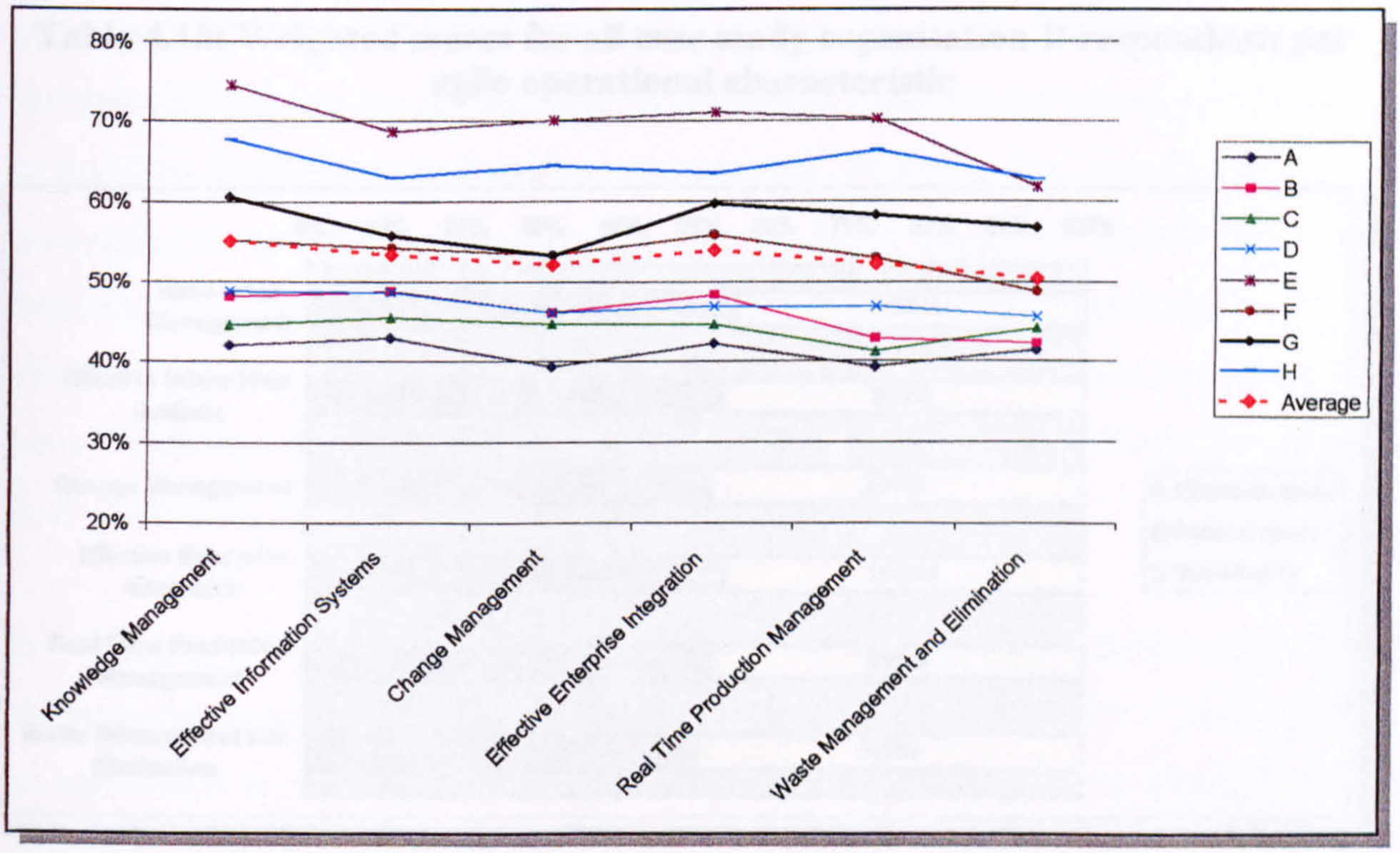

Figure 4.26: Case study organisation D percentage weighted scores per agile operational characteristic for each respondent

Furthermore these weighted scores can be compared to the minimum possible agile operational characteristic score (if all respondents scored a 1 against all the agile

topic/agile practice) and the maximum potential agile operational characteristic score (if all respondents scored a 5 against all the agile topic/agile practice). This representation thus provides a measure of the opportunity for each organisation against each of the six agile operational characteristics as shown in table 4.15 and in figure 4.27 below. The "total actual score" represents the summation of all respondents' calculated scores, the "max" is the maximum possible per operational characteristic and the min is the minimum possible.

Agile operational characteristic	Total Actual Scores	Max	Min	Total scores - min	Opportunity	Percentage
Knowledge Management	98295	178240	35648	62647	79945	55%
Effective Information Systems	97108	181960	36392	60716	84852	53%
Change Management	108644	208520	41704	66940	99876	52%
Effective Enterprise Integration	134666	249480	49896	84770	114814	54%
Real Time Production Management	104542	200080	40016	64526	95538	52%
Waste Management and Elimination	61212	121400	24280	36932	60188	50%
Total	604467	1139680	227936	376531	535213	53%
Percent	53%	100%	20%		47%	

Table 4.15: Weighted scores for all case study organisation D respondents per agile operational characteristic

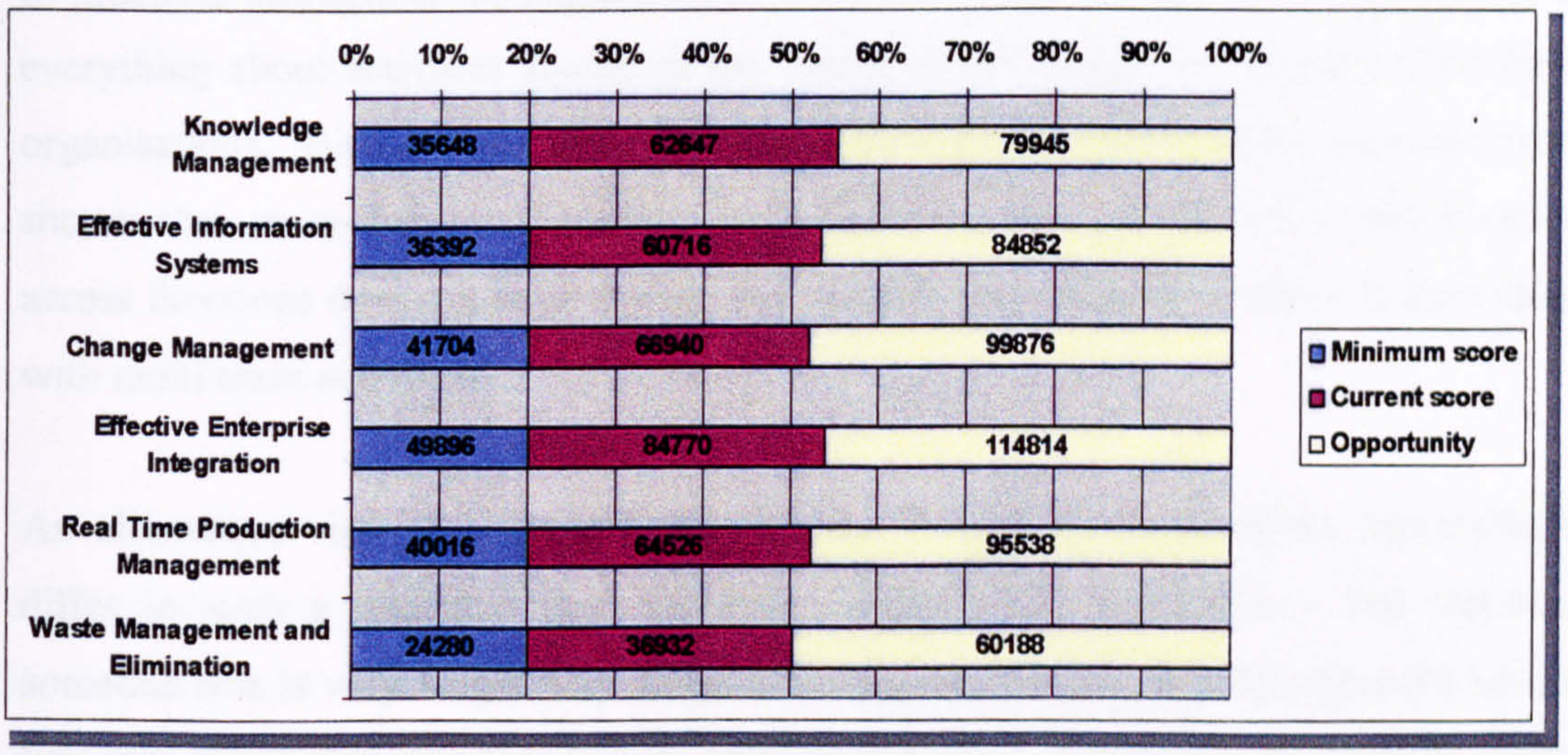

Figure 4.27: Case study organisation D agile operational characteristics weighted scores showing opportunity

Table 4.15 therefore indicates the potential opportunity for improvement for each of the agile operational characteristics for case study organisation D.

4.6 A Critique of the Case Study Findings

The findings offered in this chapter have been presented case study organisation by case study organisation yet some interesting issues have emerged from the methods adopted to elicit the information. The two methods adopted have been the ethnographic study approach and a respondent questionnaire, both of which have been found to be very useful in providing different but sometimes-complimentary findings.

The ethnographic study approach has been very useful in providing the participant observer with the context of agility for the case study organisations and consequently has provided context and understanding of the respondents' attitudes and hence attitudes toward scoring of the questionnaire topics. For instance, although there have been many responses that have a consensus of opinion as to the adoption level of a particular topic in an organisation, there has also been many differing opinions per topic.

The ethnographic approach can shed some light on this, but will not be able to provide all the reasons for these differences. Accordingly, it could be viewed that one reason for these differences in score per topic is the lack of communication and understanding of practices throughout the organisations assessed. That is to say, not everyone knows everything about activities across all the functions and disciplines found within these organisations. Furthermore, the observations through the ethnographic approach have shown that cross-functional team-work is not prevalent and hence communication across functions does not have the less formal (but very effective) channels associated with multi team activities.

An alternative view that could be considered, is that the respondents personality's differ in such a way that their responses accordingly may differ. For instance, someone that is very frugal may adopt a scoring regime that is predominantly on the low side while someone that is not, may score higher. Therefore the responses may say more about the respondent than the actual topic in question. There is however, no evidence that hierarchical level of the respondent, has played a role in the differences noticed per topic.

Chapter 5 Analyses and Discussions

5.1 Introducing the Analyses and Discussions

A theoretical framework was provided in chapter 3 that has enabled the assessment of aerospace manufacturing small to medium size enterprise (SME) case study organisations operating in the North West of England. Accordingly, the aim of this research has been to assess agile manufacturing within UK aerospace manufacturing SMEs and consequently section 1.3.3 gives five objectives that directed the research toward achieving this aim. In order to fulfil the aim and objectives, the findings within four case study organisations have therefore been presented separately in chapter 4 and now this chapter aims to provide both analyses and discussions, or interpretation, of these findings.

This analyses and discussions chapter hence, aims to be thorough, clear, logical, relevant and cautious as recommended by Brause (2000) concerning the presentation of doctoral research findings. As such the analyses and discussions, presented in this chapter, firstly relate to the synthesised theory of aerospace agile manufacturing in SMEs and provides comparative analyses of each and every case study organisation to the four agility enabling macro sub-systems, as provided in section 3, of:

- Agile manufacturing strategy
- External motivators
- Organisational psychology
- Operational characteristics

Secondly, the discussions integrate the analyses of the four agility enabling macro sub-systems to provide a holistic review of the findings in terms of the entire conceptual model of aerospace agile manufacturing SMEs as presented in this thesis. The final part of this chapter includes a review of the research methodology and therefore discusses the implications of the findings to both agile manufacturing theory development and the practice of agility in aerospace and other sectors.

5.1.1 Analysing Agile Manufacturing Strategy

The synthesis of current theory on agile manufacturing, presented in section 3.3.1.1, suggested that, for an organisation to be agile, a clear agile strategy is expected to be developed, deployed, assessed and then a commitment to act upon the assessment be made. Hence, agile manufacturing strategy in these terms and as shown in figure 5.1 is dynamic and a continuous process. The arrows in figure 5.1 show the agile manufacturing strategic process direction.

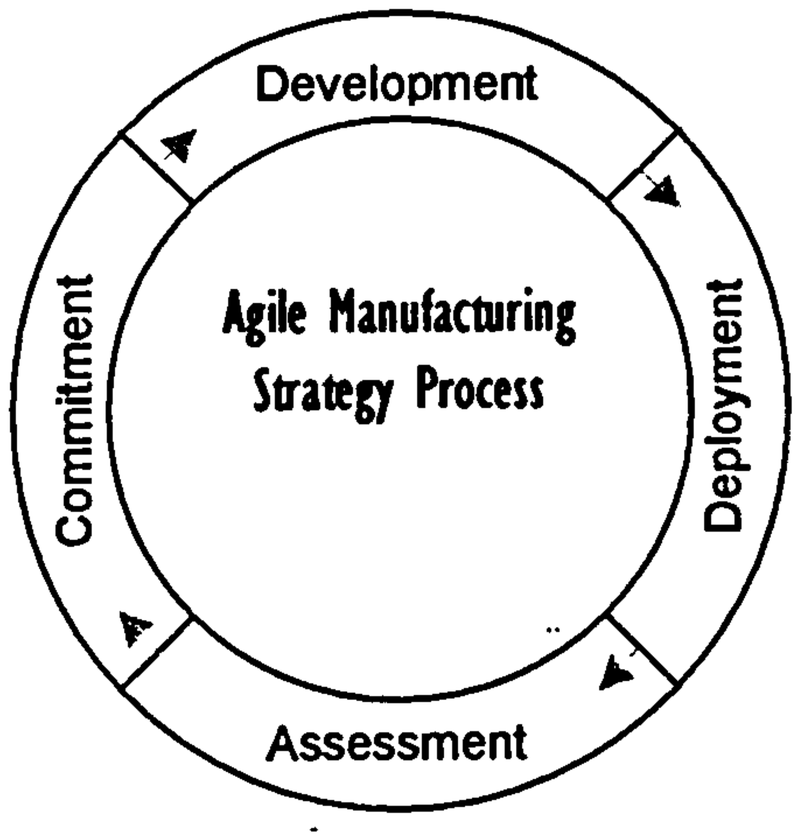

Figure 5.1: Agile manufacturing strategy process

Acknowledging, the inference as discussed in section 3.3.1.2, that an agile strategy should be developed from a review of the external motivators of agility and enhanced from a contribution from the operational aspects of an organisation as discussed in 3.3.1.3 and 3.3.1.4, analyses and discussions of the four case study organisations' agile manufacturing strategies are presented below.

5.1.1.1 Case Study Analyses of Agile Manufacturing Strategy

The method of assessment of each case study organisations' agile manufacturing strategy was primarily the ethnographic studies, complemented by the use of the questionnaire (i.e. agile operational characteristics assessment matrices). From that assessment approach, case study organisation A has been shown to be active on developing their strategy (see table 4.1 in section 4.1.1.2) but not as active or effective in deploying the strategy, and furthermore, during the period of the 14 month ethnographic study no evidence of assessment of the strategy was observed other than the use of measures of performance for delivery, quality and cost. Likewise, the

questionnaire results indicate that the 30 key topic areas (not including topics 31 and 32, which are associated with integration and measurement of the 30 key topic areas) that relate to the agile operational characteristics have not been integrated with the business strategy (topic 31) and hence the use of agile operational characteristic related metrics (topic 32, the sixth lowest combined score from respondents out of the 32 topics scored) was considered by case study organisation A respondents as not widely practiced.

The analysis of case study organisation A's agile manufacturing strategy process is shown in figure 5.2. The shaded areas provide visual representation of the levels of adoption of each agile manufacturing strategy process stage.

Figure 5.2: Case study organisation A's agile manufacturing strategy adoption level

In a similar way to case study organisation A it was observed that case study organisation B had also developed a strategic intent (see vision in table 4.6, section 4.3.1.2) but had not assessed the deployment and consequently was not committed to action to further improve the agile status of the organisation[1]. Assessment of operations was against basic measures of performance including cost, quality, delivery and productivity. Accordingly, the questionnaire results show a consensus of opinion that the 30 key topic areas are perceived by respondents as not being integrated with the business strategy (topic 31) and the use of metrics to assess agile operational characteristics (topic 32) is also perceived as not being adopted by the organisation.

The analysis of case study organisation B's agile manufacturing strategy process is shown in figure 5.3. The shaded areas provide visual representation of the levels of adoption of each agile manufacturing strategy process stage.

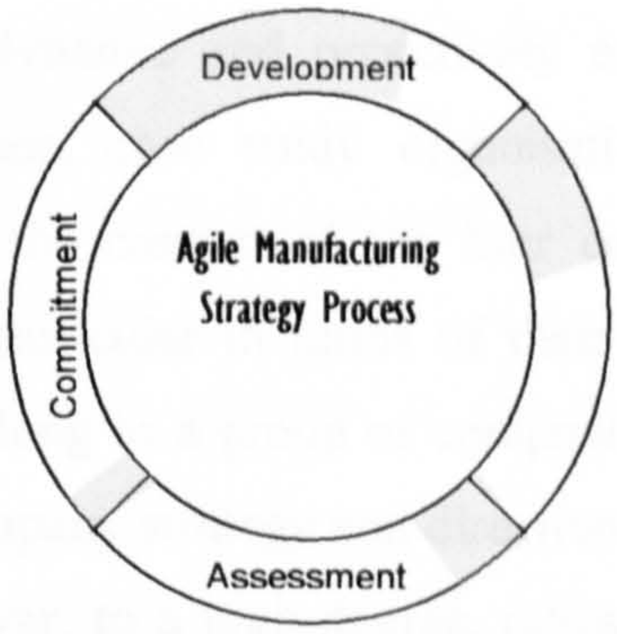

Figure 5.3: Case study organisation B's agile manufacturing strategy adoption level

[1] *Discussion of the case study organisation B strategy can be seen in Economou (1999).*

In contrast to the two examples of case studies A and B, it was observed that case study organisation C had no published or documented strategic intent or vision of the future. This is not to say that strategy development was not considered an issue at case study organisation C, on the contrary, it appeared that the managing director, had committed to developing the business through acquisition of production capability and capacity from a key aerospace and defence customer. Further to this the managing director continued to expand the portfolio of products (e.g. into motor racing parts and assemblies; special purpose machinery; and an e-procurement venture). This attempt, by the managing director, to re-align his business concerns, is analogous to both the concept of incremental change in strategy, in terms of increasing sales through acquisition and hence acquiring more orders, and also a radical strategic change, in terms of the e-procurement venture. To support the strategy of the increasing sales portfolio, new business processes were being considered and improvements in the computer communication and information systems being partially implemented, but the effects of these changes had not been assessed.

The analysis of case study organisation C's agile manufacturing strategy process is shown in figure 5.4. The shaded areas provide visual representation of the levels of adoption of each agile manufacturing strategy process stage.

Figure 5.4: Case study organisation C's agile manufacturing strategy adoption level

Case study organisation D belongs to a very dynamic and proactively expanding aerospace focused group of companies. Hence, case study organisation D is considered distinctive, in the author's view, in the context of the four case study organisations assessed for this research and in particular in terms of their strategic process. Similarly, case study organisation B belong to a group of companies but in contrast have committed to develop their own company strategy and direction with the group in mind. Case study organisation D however, to a high degree, relies on their group for direction. Consequently, the group headquarters for case study organisation D takes responsibility for the strategic thinking of the organisation and hence the

destiny of case study organisation D, in many respects, is a group matter and not a local concern. Nevertheless, the case study organisation D directors had shown initiative toward understanding some of the local issues of the organisation (see discussion in section 4.5.2) and considered to amending operating practices, but unfortunately its consideration was not being acted upon. Further to this, no evidence was found that case study organisation D had published a strategy or were consciously progressing through an agile manufacturing strategy process. It is not surprising therefore that respondents to the questionnaire have scored the use of metrics for agility low (second to lowest combined respondents score) compared to other agility operational characteristics scored. This is in accordance with the ethnographic study that showed little formal measurement of agile practice taking place.

The analysis of case study organisation D's agile manufacturing strategy process is shown in figure 5.5. The shaded areas provide visual representation of the levels of adoption of each agile manufacturing strategy process stage.

Figure 5.5: Case study organisation D's agile manufacturing strategy adoption level

5.1.1.2 Key Discussions of Agile Manufacturing Strategy

The conceptual model of agile manufacturing in UK aerospace small to medium size enterprises (SMEs), chapter 3 and figure 3.3, shows that an agile strategy follows the principles of plan-do-check-act and therefore recognises that an agile strategy is not static but must follow a continuous learning cycle and consequently be a dynamic process. The findings aimed at assessing the agile manufacturing strategy of the four case study organisations infers that a strategy process in line with the conceptual model, presented in this thesis, is not being entirely adopted by the case study organisations as represented in figures 5.2 to 5.4.

To summarise the previous sections' analyses and discussions, the four case study organisations' strategic processes, to a certain degree, have developed an agile strategy

aimed at improving aspects of their company's agility, although each organisation has addressed strategy differently and to differing degrees. These observations are represented graphically as figure 5.6 to illustrate levels of adoption of the agile strategy enabling factors of development, deployment, assessment and commitment across the four case study organisations. Figure 5.6 is not meant to be an accurate or precise mathematical model and serves only as an illustration to help conceptualise the current situation as observed across four case study organisations.

For example case study organisations A and B had developed their initial strategic intents to a relatively high degree, supported by documented and communicable statements, while case study organisation C had not documented their strategy but the managing director had formulated a way forward, hence strategy development had taken place to a lesser degree. Additionally, case study organisation D had not formulated their own strategy and to a large extent had strategic issues imposed on them from their group headquarters. Consequently, the agile manufacturing strategy development zone of activity across the four case study organisations is shown by "area α" on figure 5.6. For instance no case study organisation can be considered as 100% effective in developing strategy, but all case study organisations have developed to varying degrees an agile manufacturing strategy.

However, with the exception of case study organisation A since their strategy process involved first line managers and supervisors, strategy intent was not well communicated and therefore not well understood by the majority of the case study organisation's people. Hence, it could be considered that deployment of strategy as less effective than development of strategy in all cases. Additionally, it could be stated that strategy deployment was not carried out effectively in all cases, as no evidence existed in any of the case study organisations of a structured or actively controlled strategy deployment process. Consequently, the agile manufacturing strategy deployment zone of activity across the four case study organisations is shown by "area β" on figure 5.6. For instance, no case study organisation can be considered as having deployed strategy as effectively as they developed strategy, but all case study organisations have deployed to varying degrees an agile strategy. The respondents of the questionnaires mirror this statement in scoring of topic 27, "change deployment", where the average scores for all four case study organisations is a level 2. This score

of level 2 for "change deployment" indicates a maturity level, according to level 2, were *"managers initiatives appear but findings tend to be ignored and the majority of initiatives fail"* as stated on the assessment matrix appendix IV.

Furthermore, agile manufacturing strategy assessment is not adopted to any serious degree at the four case study organisations, for instance the four case study organisations respondents' average score as shown in table 4.2, 4.6, 4.9 and 4.13 against "the use of metrics topic 32" out of a possible score of level 5, was a score of level 1 for case study organisations B, C and D and only an average score of level 2 for case study organisation A. Consequently, the agile manufacturing strategy assessment zone of activity across the four case study organisations is shown by "area γ" on figure 5.6. For instance, no case study organisation can be considered as entirely effectively assessing their strategy, but all case study organisations have assessed to minimum degrees parts of their agile strategy intent and deployment.

The agile manufacturing strategy commitment stage is the stage where the organisation commits to acting upon an assessment of the strategy development and of the effects of implementing, or not, the developed strategy. Consequently, agile strategy commitment is virtually non-existent in the four case study organisations assessed. In fact, because all organisations had not effectively and completely assessed their organisational agile manufacturing strategy, there could be little or no acting upon the results of any assessment. Moreover, case study organisation C appeared not to act upon any assessments made to their operations, but continued to develop the business, never mind to act upon an assessment of their agile manufacturing capabilities. Consequently, the agile manufacturing strategy commitment zone of activity across the four case study organisations is shown by "area δ" on figure 5.6. For instance, no case study organisation can be considered as entirely effectively committing to a change in their developed strategy, and hence, commitment is less effective than their assessment of strategy and on occasion non-existent.

The cross-hatched section of the graph in figure 5.6 represents the zone of adoption of agile manufacturing strategy across the four stages of the strategy process, thus inferring from the findings that little assessment of existing strategies is being carried out while very little or no commitment to changing strategy is seen.

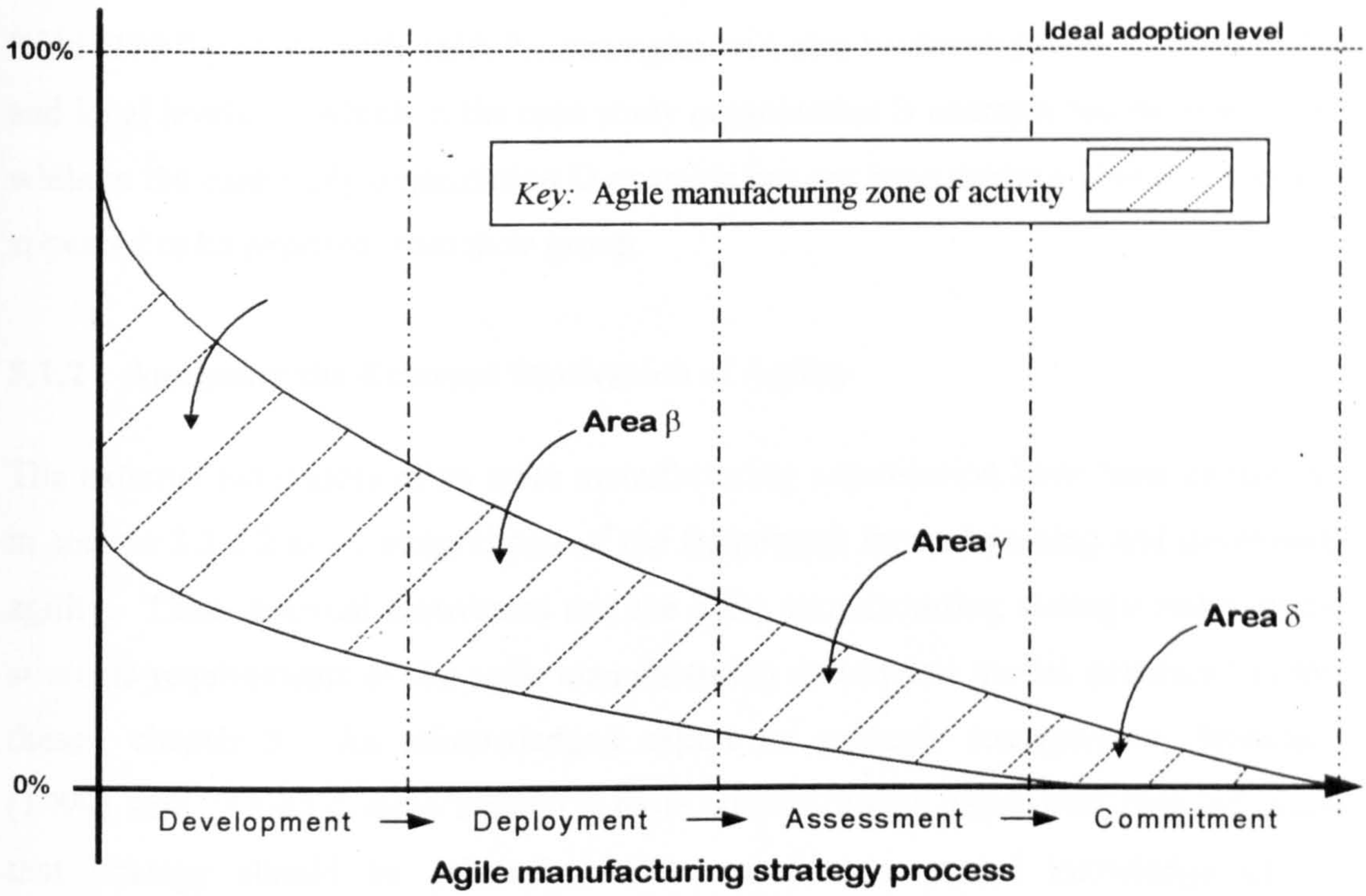

Figure 5.6: Graphical representation of case study organisations' adoption levels of the agile manufacturing strategy process

The ideal adoption level of an agile manufacturing strategy is when the four stages of the agile manufacturing process are being carried out 100% effectively. Thus when development, deployment, assessment and commitment ensure as Dove (1994) said, that the organisation can do whatever it wants to do whenever it wants to.

The figure 5.6 infers that the agile manufacturing strategy process, adopted at the four case study organisations is not as effective as possible for many reasons. For example each strategy development process involved a small number of participants, usually senior management with little or no involvement from the shop floor and the strategies were never developed further during implementation. This is in total contrast to Kidd's (1997b) discussion on agile manufacturing strategy:

> *"With regard to the strategy development process, everyone potentially has a role to play, so the process is both top-down and bottom-up. Strategies are*

> *also likely to be developed in advance of implementation and during implementation....*" Kidd (1997b).

Kidd (1997b) additionally said; "...strategies will also be developed at both the global and local levels..." which in the case study organisation B example has been achieved while in the case study organisation D example has not been achieved because strategy appeared to be imposed from their group.

5.1.2 Analysing the External Motivators of Agility

The external motivators of an agile manufacturing organisation have been considered in section 3.3.1.2 as an integral part of the framework for maintaining and developing agility. These external motivators and the agile manufacturing strategy make up the strategic requirements of the agile manufacturing conceptual model, presented in this theses, chapter 3. An acknowledged expert on strategic management, Strickland (1999), said: "Good strategy making is more outside-in than inside-out" thus indicating that strategy should be primarily influenced from a sound knowledge of the organisations' operating environment. It is therefore essential that an organisation be aware and consequently manages the external factors that can influence the operations and the operating environment of that organisation to enable them to be agile.

The assessment of the case study organisations' awareness and management of their external motivators has been through the ethnographic studies and also through certain topics in the questionnaire (agile operational characteristics assessment matrices), although this has not been easy, because, as Strickland (1999) described: "Company strategies are partly visible and partly hidden to outside view". Nevertheless, the awareness and management of external motivators of agility have been assessed and the findings presented in chapter 4. These findings are now analysed and discussed in the following sections considering the elements of the framework of enabling and resisting forces of agility as shown in figure 5.7.

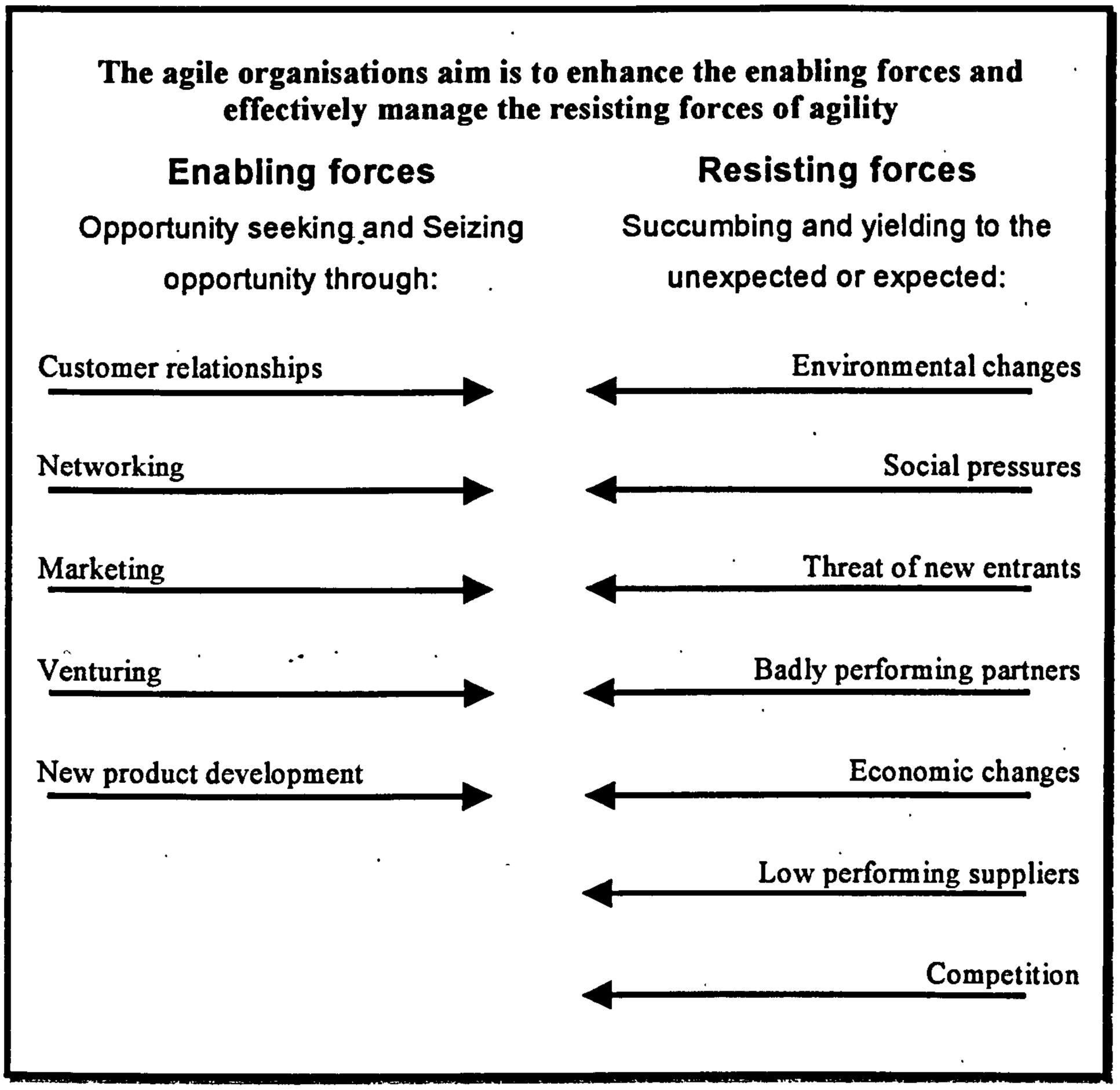

Figure 5.7: The external motivators of agile manufacturing represented as enabling and resisting forces

5.1.2.1 Case Study Analyses of the Awareness and Management of the External Motivators of Agility

In terms of opportunity seeking case study organisation A had a good tradition of working closely with existing customers in order to solve problems of a mutual benefit. An example of this was the creation of a manufacturing cell, at case study A premises, funded by one of their customers, solely for the production of a range of products for that customer. While case study organisation A is a member of trade organisations, such as the North West Aerospace Alliance, networking to seek opportunities and seize opportunities beyond the scope of existing customers is a limited activity. Likewise, the sales and marketing functions (one director) did not appear to be proactive in this role. However, within the framework of the existing

customer base, case study organisation A have demonstrated to be very active at new product introduction and hence, developed a large portfolio of manufacturing competence to such an extent the customers send "the most challenging of jobs" to them. In fact, strategic orders have been won from their two key customers as described in section 4.2.

Case study organisation A currently does not work in partnership with any other organisation, other than suppliers and customers. However, supplier relations are adversarial in nature, although, some work is being carried out to improve this. In general terms, in the author's view, case study organisation A do not have sufficient mechanisms in place to provide the "wide deep scanning", as described by Meredith and Francis (1999), necessary to be aware of the resisting forces of agile manufacturing as shown in figure 5.7, however with existing customers they do actively collaborate. The questionnaire results for case study organisation A support this view, for instance, topics 8 – 14 relate to the external motivators of agile manufacturing (see table 5.1).

Topic		Respondent reference and assessment score							Total score	Average (rounded down integer)
		A	B	C	D	E	F	G		
8	Customer relations	2	2	4	3	4	3	3	21	3
9	Supplier relations	2	2	3	2	1	1	2	13	1
10	Customer knowledge	2	2	3	3	2	2	2	16	2
11	Supplier knowledge	2	1	3	3	1	1	1	12	1
12	Customer focused production	2	3	4	3	2	2	3	19	2
13	Strategic alliances	3	2	4	3	3	3	3	21	3
14	Rapid collaborations	1	1	4	3	1	2	1	13	1

Table 5.1: Questionnaire responses relating to the external motivators for case study organisation A

Table 5.1 indicates that the respondents perceive, that case study organisation A are at a higher level of maturity in their customer relations, customer knowledge, and customer focus than their level of maturity for supplier relations and supplier knowledge. Interestingly, the respondents have scored relatively high for their

strategic alliance competence even though the ethnographic study showed that case study organisation A was not active in partnering with other organisations to deliver packages of work. This higher score for strategic alliances could be because case study A have, over a long period of time developed strategic relations with existing customers, although working with other companies strategically is not occurring. Additionally, the respondents have scored low for rapid collaborations indicating that case study organisation A do not possess a competence for this agile operational characteristic.

Case study organisation B, on the other hand is very actively pursuing collaborative partnering ventures with both local companies and global companies. In fact, during the period of ethnographic studies, in terms of the case study organisation B operations, three such partnerships of a strategic nature where continuing. One of these partnerships, albeit in the early stages, was with a Malaysian company to supply machined components as a joint venture for the Eurofighter program. Alongside this activity the organisations' group is continually acquiring new companies and with this bringing a potentially wider scope for marketing and sales activities. Consequently, new product introduction is a core competence of case study organisation B that enables them to provide this needed attributed to any partnership arrangement. However, working closely with suppliers to solve problems and make improvements are not activities the company is used to, as on occasion an adversarial approach to supplier relations was observed.

Additionally, a great deal of emphasis is placed on customer related improvement projects, in particular aimed at improving delivery schedule adherence. Accordingly, topic 12 "customer focused production" is scored relatively highly (see table 5.2) in comparison to other topics indicated that case study organisation B respondents believe their *"production to be in the main meeting the requirements of quality, cost and delivery requirements of the customer"*. However, case study organisation B respondents scored topic 8 "customer relations" low (an average of level maturity 1) indicating from the matrix a level of maturity in this characteristic, stating: "Communication is poor, there is mistrust and conflict. Customer needs have not been identified. Satisfaction is not monitored. Deliverables are not clear."

Topic		Respondent reference and assessment score						Total score	Average (rounded down integer)
		A	B	C	D	E	F		
8	Customer relations	1	1	2	2	1	2	9	1
9	Supplier relations	2	3	2	1	1	2	11	1
10	Customer knowledge	3	1	3	2	2	2	13	2
11	Supplier knowledge	2	1	3	1	1	2	10	1
12	Customer focused production	4	2	4	3	4	3	20	3
13	Strategic alliances	3	3	4	4	2	4	20	3
14	Rapid collaborations	2	2	3	3	1	4	15	2

Table 5.2: Questionnaire responses relating to the external motivators for case study organisation B

Table 5.2 infers that the case study organisation B respondents believe there is considerable room for improvement in the competencies of customer relations, supplier relations and supplier knowledge. While, it may be considered expectedly from the participant observations, the respondents consider their organisations' competence for strategic alliances is better.

As previously discussed in section 5.1.1.1 case study organisation C are, through the managing director's efforts, aiming to develop a key strategic relationship with their largest customer. The developing of this partnership, toward sharing capacity and capability, is very time consuming for the managing director and consequently little time or commitment is afforded to developing other partnerships either with customers, competitors or suppliers. Marketing activities are virtually non-existent at case study organisation C, although a new appointment of a commercial manager was made, this appointment lasted only for the duration of the ethnographic study and the manager left for a; "job with better prospects and pay". Additionally, case study organisation C are the only company, within the four case study organisations assessed, that were not moving toward the requirements of ISO 9001: 2000 and all interviewed, at case study organisation C, were ignorant of this new revision to the quality standard.

The ethnographic study showed that case study organisation C operates an adversarial relationship policy with their suppliers. While, their relationship with customers also appears to be less than collaborative, primarily because customer delivery dates are not being met effectively and this consequently places a large strain on the relationships. Table 5.3 shows that the case study C respondents consider "supplier relations" and "supplier knowledge" a weak competence. However, the respondents do perceive that their organisational competence, and hence maturity levels, for the customer related topics of the questionnaire (topic 8,10 and 12) are higher than their supplier related competence (topic 9 and 11).

Topic		Respondent reference and assessment score							Total score	Average (rounded down integer)
		A	B	C	D	E	F	G		
8	Customer relations	1	4	2	1	1	3	2	14	2
9	Supplier relations	1	3	1	1	1	3	1	11	1
10	Customer knowledge	1	4	1	1	2	3	3	15	2
11	Supplier knowledge	1	2	1	1	2	3	3	13	1
12	Customer focused production	1	3	2	2	2	2	3	15	2
13	Strategic alliances	1	2	1	3	3	5	2	17	2
14	Rapid collaborations	1	1	1	2	2	3	2	12	1

Table 5.3: Questionnaire responses relating to the external motivators for case study organisation C

The respondent scores shown in table 5.3 indicate that their general perception is that supply chain relations are at a relative low level of maturity and therefore there is considerable room for improvement. Interestingly, for topic 13 related to strategic alliances, a score of 5 was given from one of the respondents, although no evidence during the ethnographic study that indicated; *"Effective strategic alliances exist with customers, suppliers and potential market competitors"*. Nevertheless, the average as shown in table 5:3 is more in line with the ethnographic study report shown in section 4.4.1 indicating their level of maturity for this topic is described as; *"There is recognition that strategic alliances hold potential benefits. However there are no immediate intentions to initiate any strategic alliance initiatives"*. It is possible, in the author's view, a score level of 3 should be given to topic 13 (i.e. *"...Strategic alliances*

with customers are being pursued.") because as repeatedly mentioned (section 4.4.1, section 5.1.1 and 5.1.2 and earlier in this section) the managing director was negotiating with a major customer, but the truth is, no other member of case study organisation C new about this possible venture.

Case study organisation D relies very much on their group headquarters scanning of the environment in which they operate. This has been mentioned in earlier text, section 5.1.1.2, with regards strategy development and is no different with regard management of the external motivators of agility for case study organisation D. Hence, in terms of opportunity seeking and opportunity seizing this organisation uses, or more so expects, the group to take care of these issues. In other words, the focus of case study organisation D is always on current production and short term planning activities as opposed to strategic issues.

In response to the agile manufacturing operational characteristics questionnaire case study organisation D scores for topics 8 to 14 are shown in table 5.4 below.

Topic		Respondent reference and assessment score								Total score	Average (rounded down integer)
		A	B	C	D	E	F	G	H		
8	Customer relations	1	2	3	3	4	4	5	5	27	3
9	Supplier relations	3	2	1	1	4	3	3	3	20	2
10	Customer knowledge	1	2	1	2	3	3	3	3	18	2
11	Supplier knowledge	1	2	1	2	2	2	3	2	15	1
12	Customer focused production	4	4	4	4	5	3	5	5	34	4
13	Strategic alliances	3	4	3	3	2	3	3	4	25	3
14	Rapid collaborations	2	2	2	2	2	2	2	3	17	2

Table 5.4: Questionnaire responses relating to the external motivators for case study organisation D

Table 5.4 infers that the perception of the respondents is that "supplier knowledge" can be improved considerably while, their "customer focused production" is perceived as very mature and therefore here, there is less room for improvement. This perception

concurs with the author's view that case study organisation D is very inward looking although customer related metrics are used effectively.

5.1.2.2 Key Discussions of the External Motivators of Agility

The conceptual model of agile manufacturing in UK aerospace small to medium size enterprises (SMEs), chapter 3 and figure 3.3, shows that to increase agility, the external motivators of agile manufacturing must be considered in an organisations' strategy. The findings aimed at assessing the awareness and management of these external motivators, within the four case study organisations, infers that each organisation places different emphasis and importance of this issue. For instance, case study organisation C, following the participant observations, is considered as being unaware of many of the external environment issues associated with the successful operation of an organisation and furthermore, marketing activities and networking activities are not fully supported or committed to. While, on the other hand, case study organisation B are experienced at partnering with customers or other organisations and therefore have forged several strategic alliances which consequently increases their awareness of the operating environment and associated issues. Furthermore, case study organisation B are actively marketing their capabilities through their group and independently. Likewise, case study organisation D use their group to market their activities but they do very little to promote themselves independently.

Overall, it could be considered that from these assessments and analyses only one of the case study organisations, that is case study organisation B, is effectively seeking and seizing opportunity through developing customer relationships, effective networking, marketing activity, joint venturing and new product development. The other case study organisations all are involved with new product development, usually from existing customers, but do not network or market effectively in their own right with the aim of seeking and hence seizing opportunity. Additionally, each and every organisation has seen customer relationships as a major issue in the success of their organisation but has demonstrated different levels of maturity in this respect. Figure 5.8 attempts to show the level of maturity of the assessed resisting and enabling forces of agility, as perceived by the author. As such, those enablers or resistors to which

little knowledge has been gained across each and every case study organisation is omitted (i.e. environmental, social and economic).

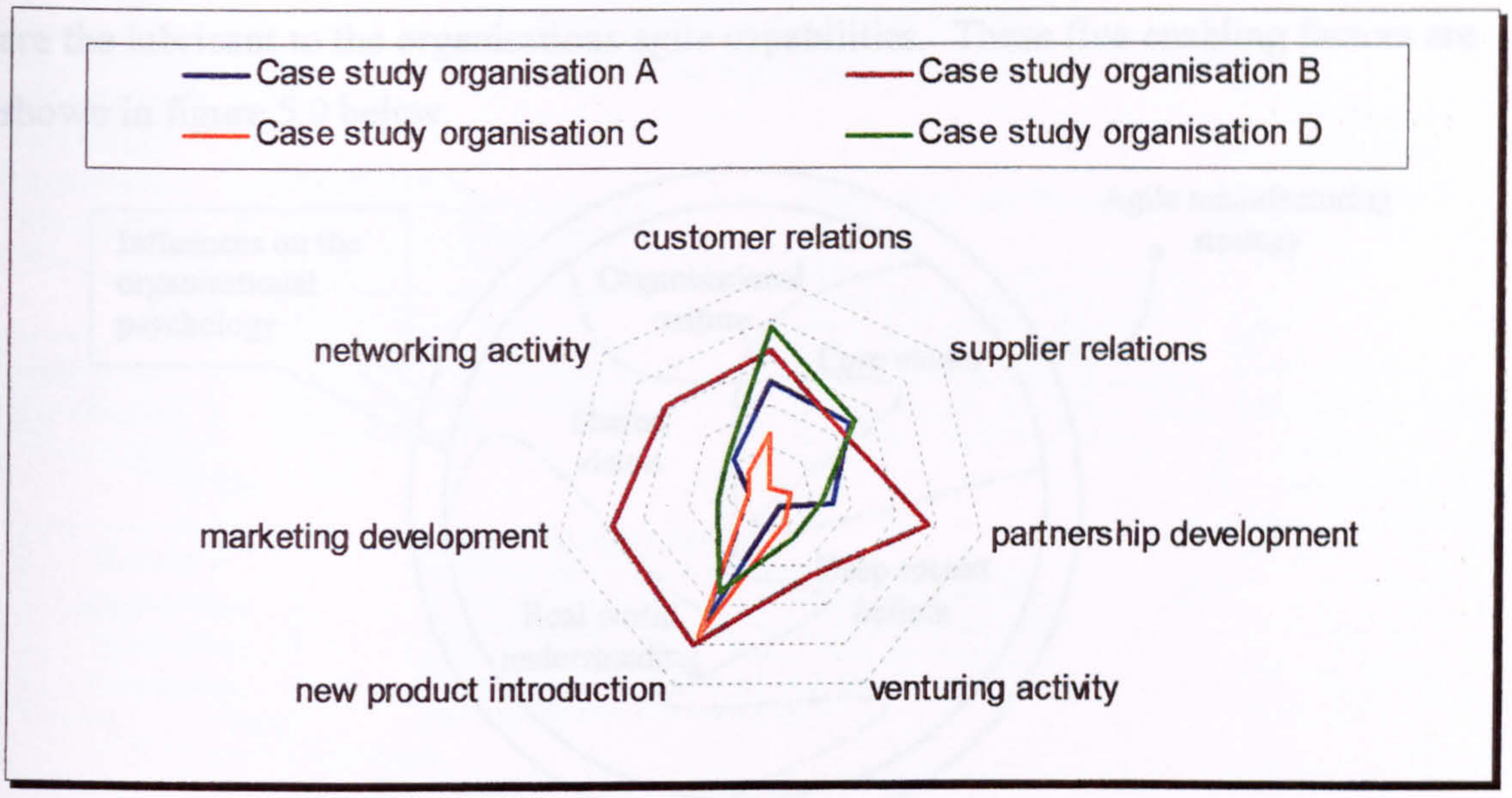

Figure 5.8: Relative maturity levels for external motivators of agile manufacturing per case study organisation

Figure 5.8 infers that across the four case study organisations "new product introduction" is a better-developed practice than the other external motivators of agile manufacturing shown. This figure also infers, that case study organisation B is more advanced in the practice of the external motivators shown, with the exception of customer relations, than the other case study organisations. The really important issue to be drawn from this is that from the assessment, figure 5.8 shows a level of immaturity, across all of the case study organisations, in the practice of managing the external motivators of agility, which indicate a great deal of improvement is needed in this area for theses companies to remain in operation. This is to say, that the knowledge, understanding and therefore practice in the management of these external motivators of agility is in its infancy across the organisations assessed. Additionally, figure 5.8 indicates that all of the case study organisations, in the respondents' opinion, have a high level of maturity for new product introduction.

5.1.3 Analysing the Agile Manufacturing Organisational Psychology

The synthesis of current theory on agile manufacturing, presented in section 3.3.1.3, suggested that, for an organisation to be agile, the agile manufacturing strategy is supported by the vision, beliefs, understanding and culture of the organisations'

people, which is assisted by their core values. The conceptual model of agile manufacturing, figure 3.3, has suggested within this thesis, the five agile manufacturing enabling factors of the macro sub-system of organisational psychology, are the lubricant to the organisations agile capabilities. These five enabling factors are shown in figure 5.9 below.

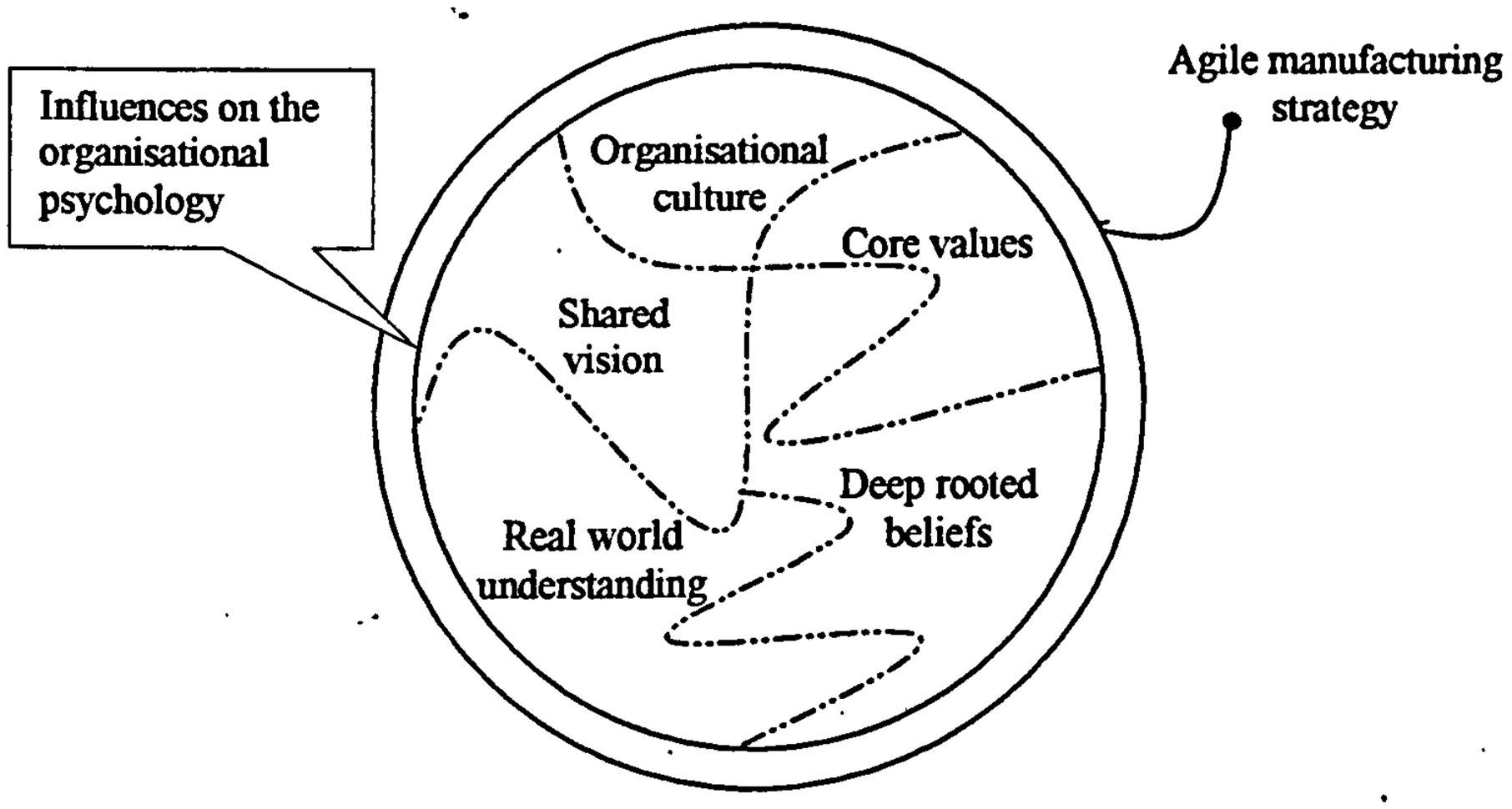

Figure 5.9: Agile manufacturing organisational psychology

Acknowledging, the inference that an agile manufacturing strategy should influence the organisational psychology and *visa-versa*, as discussed in sections 3.3.1.2 and 3.3.1.2, and that everything is interrelated, complex and dynamic within the conceptual model of agility, analyses and discussions of the four case study organisations' agile manufacturing organisational psychology is presented below. The ethnographic study work as presented in chapter 4, has been the predominant form of knowledge elicitation, toward each case study organisation assessment of the organisational psychology aspects.

5.1.3.1 Case Study Analyses of the Organisational Psychology

The prevailing organisational psychology paradigm for each case study organisation is drawn from the ethnographic study report, section 4.2.1, and presented in figures 5.10 to 5.13. These organisational paradigm profiles show statements inferring the author's view of each case study organisational psychology paradigm and the key influences on this prevailing paradigm are shown in the call-out boxes. The key discussions of organisational psychology derived from these analyses are provided in the next section.

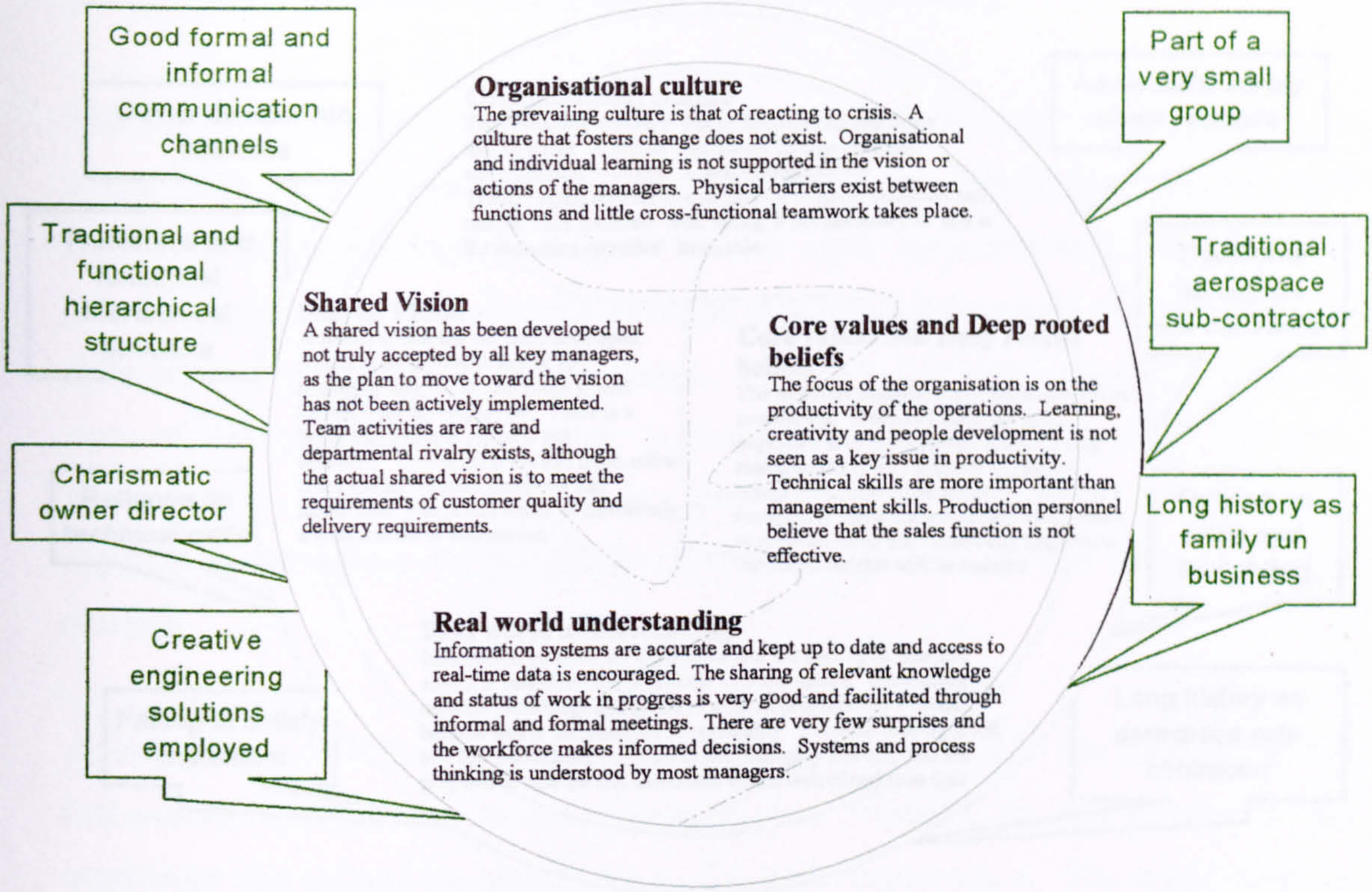

Figure 5.10: Organisational psychology paradigm profile for case study organisation A

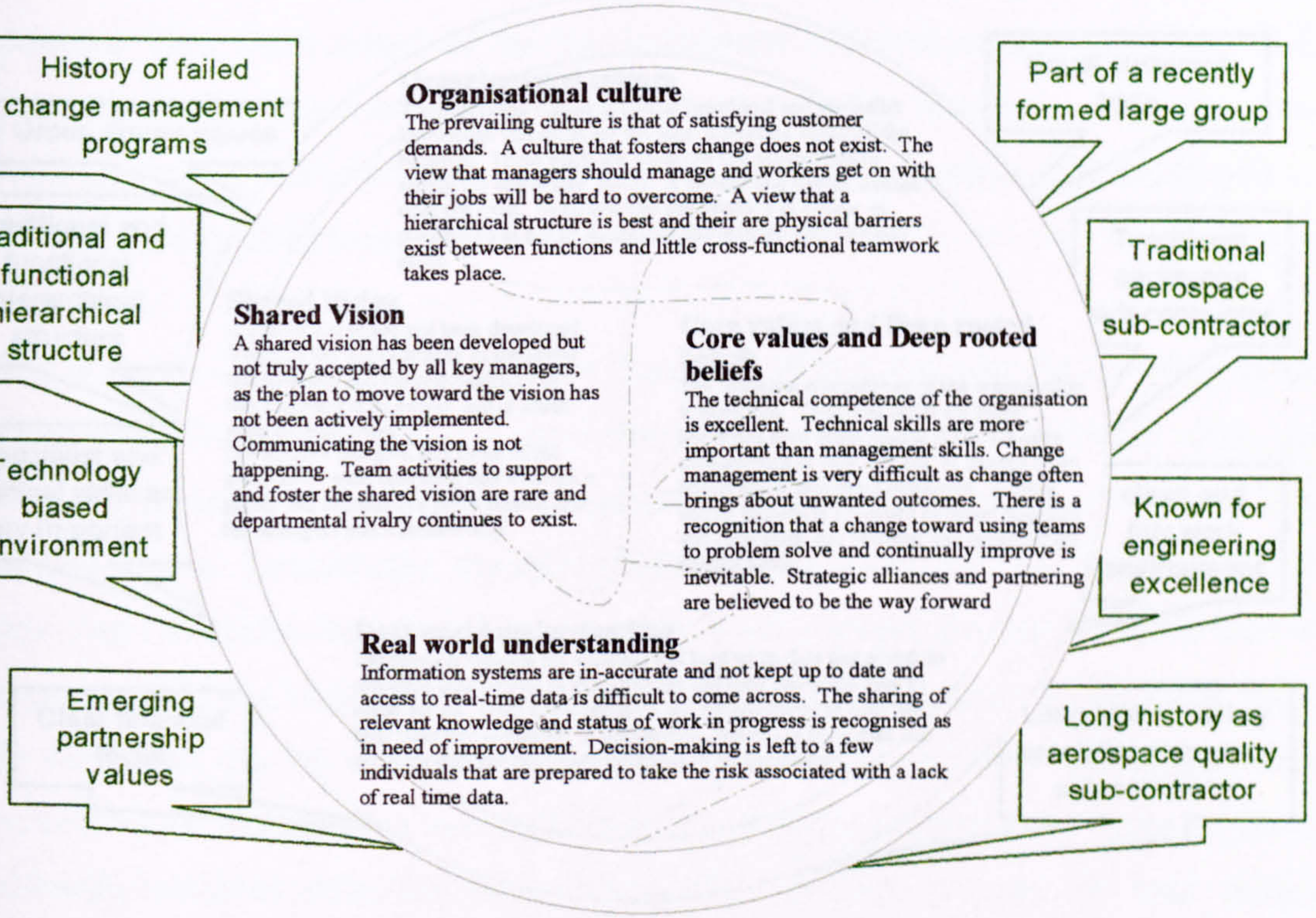

Figure 5.11: Organisational psychology paradigm profile for case study organisation B

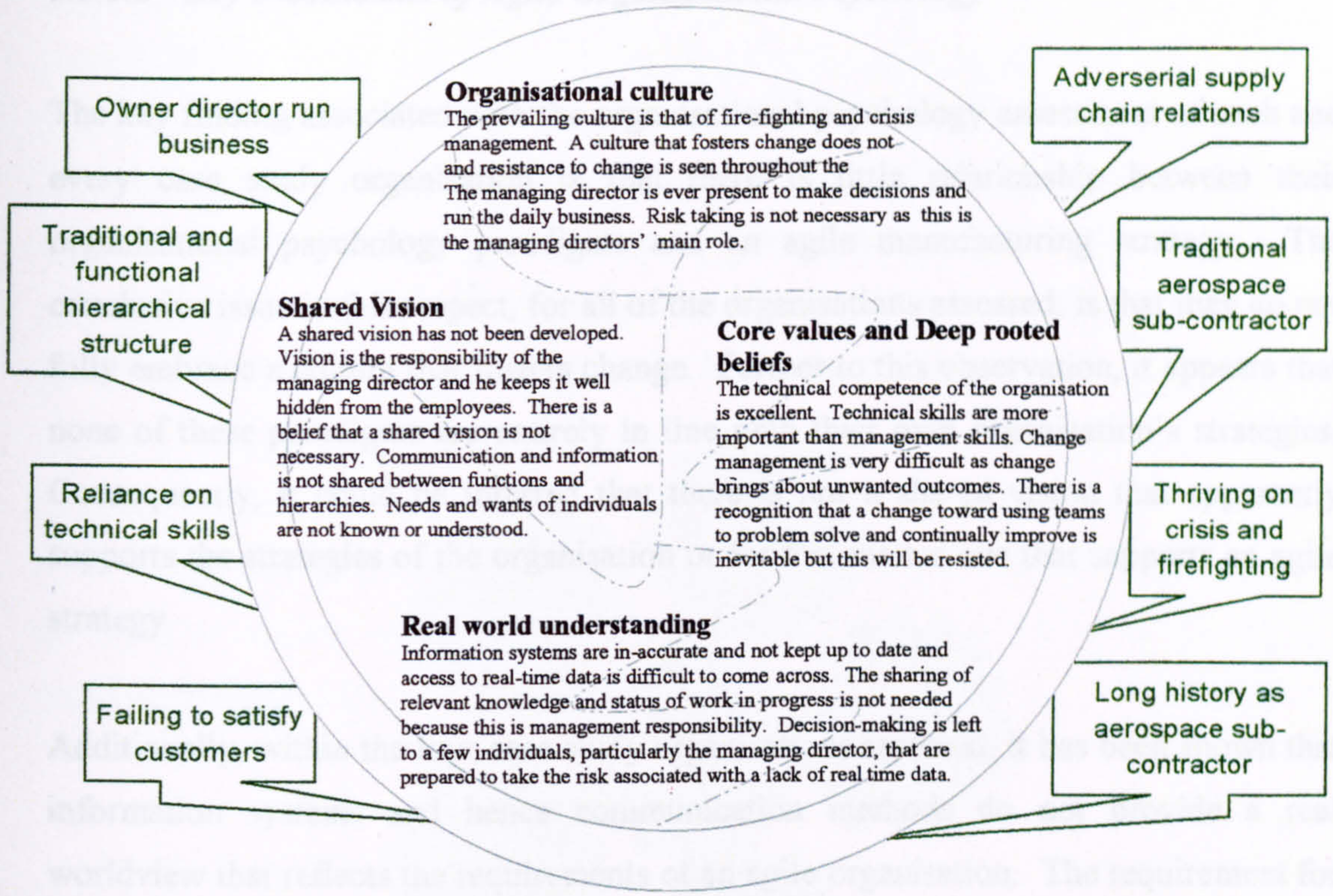

Figure 5.12: Organisational psychology paradigm profile for case study organisation C

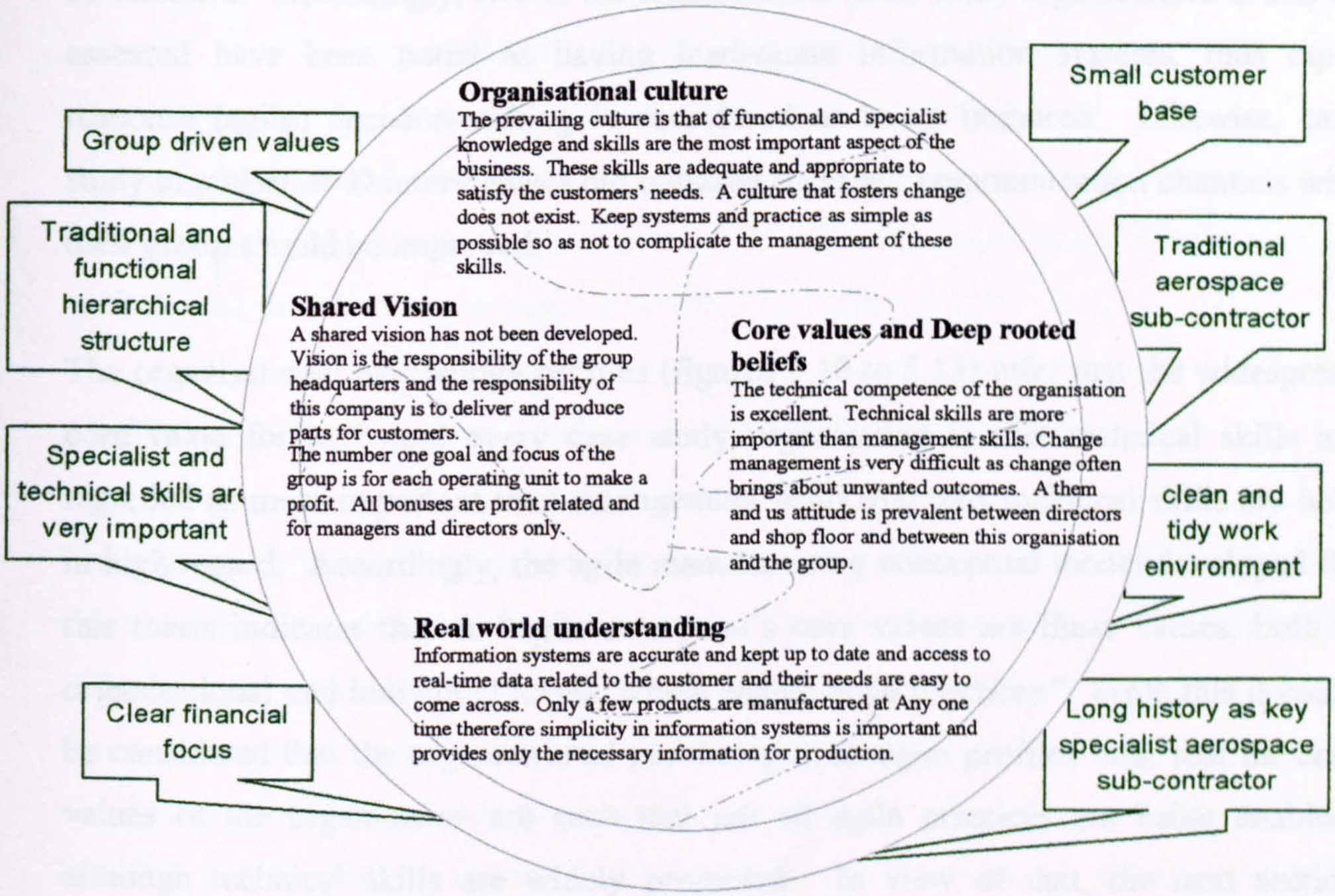

Figure 5.13: Organisational psychology paradigm profile for case study organisation D

5.1.3.2 Key Discussions of Agile Organisational Psychology

The key finding associated with the organisational psychology assessment of each and every case study organisation is that there is little relationship between their organisational psychology paradigms and an agile manufacturing strategy. The conclusive issue in this respect, for all of the organisations assessed, is that they do not fully embrace a culture that fosters change. Further to this observation, it appears that none of these paradigms are entirely in line with their own organisation's strategies. Consequently, it could be inferred that there is not a shared vision that apparently supports the strategies of the organisation or for that matter one that supports an agile strategy.

Additionally, within the four case study organisations assessed, it has been shown that information systems and hence communication methods do not provide a real worldview that reflects the requirements of an agile organisation. The requirement for accurate real time data is paramount in an organisation that wishes to respond rapidly to the changing demands of customers, because without this, decision-making cannot be effective. Accordingly, two of the organisations (case study organisations B and C) assessed have been noted as having inadequate information systems, thus rapid response (agile) decision-making is considered as being impaired. Likewise, case study organisation D interviewees did consider that their communication channels with their group should be improved.

The organisational psychology profiles (figures 5.10 to 5.13) infer that the widespread core value for each and every case study organisation is that technical skills are regarded as more important than management skills and thus technical skills are held in high regard. Accordingly, the agile manufacturing conceptual model developed for this thesis indicates that an "agile enterprise's core values are those values, both at organisational and individual levels, which enable agile practices." From this it could be considered that the organisational psychology paradigm profiles infer that the core values of the organisation are such that not all agile practices are being enabled, although technical skills are widely promoted. In view of that, the next section considers the findings related to the agile operational characteristics and the 32 agile practices identified as enablers of agility assessed by this research.

5.1.4 Analysing the Agile Operational Characteristics

The six operational characteristics, shown in figure 5.14, identified as; knowledge management, effective information systems, change and risk management, effective enterprise integration, real-time production management and waste management and elimination have been shown to be assessed by measuring attitudinal responses to 32 topics within a questionnaire (see appendix IV for the questionnaire).

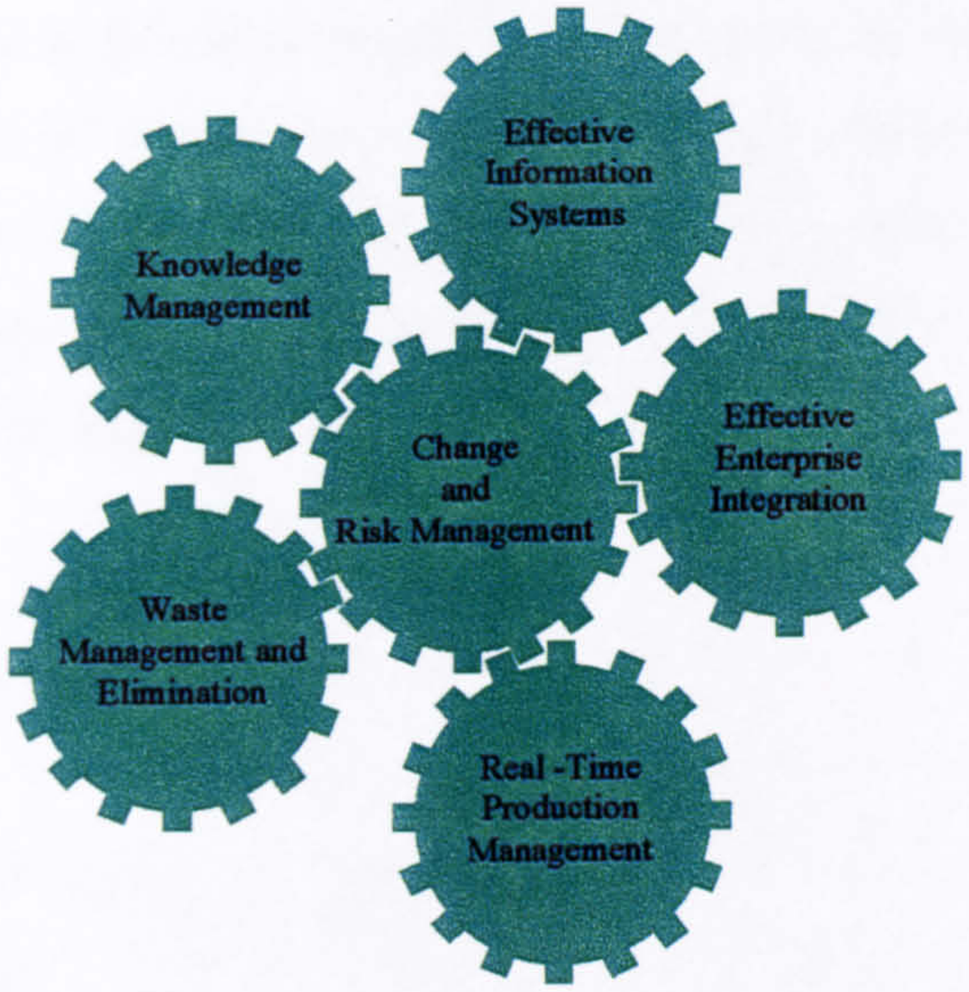

Figure 5.14: Agile operational characteristics

The results from administering the questionnaire have been shown in chapter 4 and each case study results set discussed separately, while the analyses and discussions are presented in the following sections, (section 5.14.1 and 5.4.1.2).

5.1.4.1 Case Study Analyses of the Agile Operational Characteristics

The average calculated scores, for these six agile operational characteristics, from the respondents of each case study organisations, is offered in figure 5.15 to represent the difference in attitudes presented from organisation to organisation (calculation methods have been presented in chapter 3). Figure 5.15 indicates that no organisation assessed consider themselves to have a fully developed capability for any of the six enablers, and in fact no company has scored more than an average of 60% for any of the six characteristics assessed.

Case study organisations A and D have provided very similar scores for their; knowledge management (both 55%), effective information systems (52% and 53% respectively), change and risk management (53% and 52% respectively) and their effective enterprise integration (both at 54%). However, the calculations show that their real time production scores (A=56% and D=52%) and their waste management and elimination scores (A=57% and D=50%) show larger differences in their perceived maturity of these two agile operational characteristics. This demonstrates a degree of effectiveness in the agile operational characteristics assessment tool and the methods of calculation of scores for each of the six operational characteristics. In other words, if any two of the organisations assessed had provided very similar results for each of the six operational characteristics then the tool could be considered inadequate and therefore inappropriate.

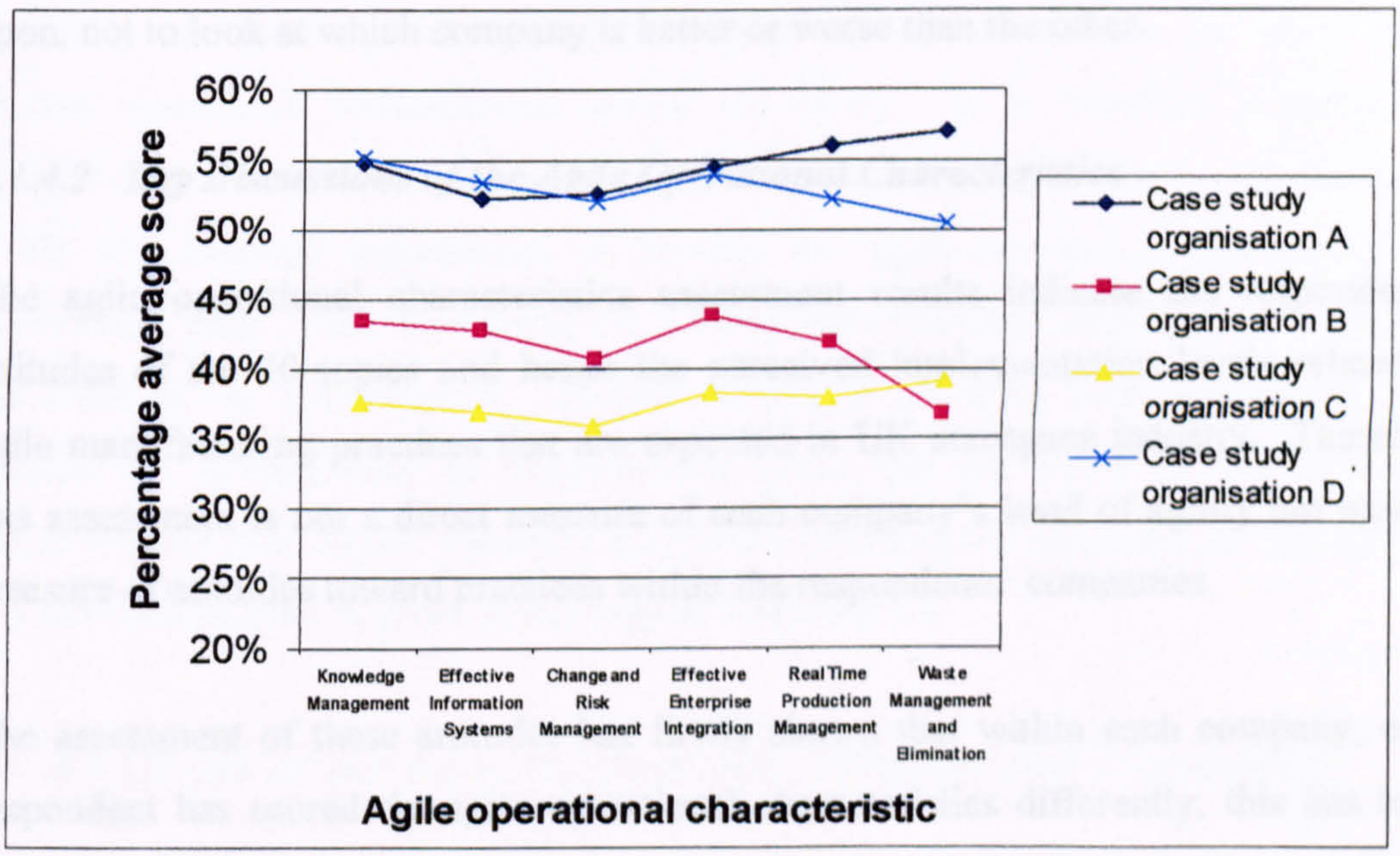

Figure 5.15: Percentage average score for each agile operational characteristic for each case study organisation

The line graphs shown in figure 5.15 indicate that change and risk management is perceived as one of the less mature agile operational characteristics as no assessed organisation rank this more than second lowest. This result correlates with the organisational psychology paradigm profiles presented in the previous section, thus

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individuals' scores have been shown within the case study chapter, chapter 3. Notably, the author considers two main reasons for these differences in each individuals' perception of the level of maturity of a given operational characteristic; (i) knowledge of the practice relating to the topic assessed is low, therefore communication of the topic has not been universal throughout the organisation and (ii) the topic is not fully understood and assessment has been from a local perspective and not company wide. However, the differences in the combined agile operational characteristics percent is a calculation based on the average of scores against each topic and therefore represents a group perception of the organisation and not an individuals' perception. Therefore, it is argued by the author, that the difference in individuals' topic scores is a matter of either communication or knowledge and understanding of the individual respondents in each organisation. While, the difference presented in figure 5.16 is not as significant, because these combined agile operational characteristic percents are only useful to the individual companies assessed as a positioning point for them to improve upon, not to look at which company is better or worse than the other.

5.1.4.2 Key Discussions of the Agile Operational Characteristics

The agile operational characteristics assessment results indicate the respondents' attitudes of the 30 topics and hence the perceived implementation levels related to agile manufacturing practices that are expected in UK aerospace industry. Therefore this assessment is not a direct measure of each company's level of agility but more a measure of attitudes toward practices within the respondents' companies.

The assessment of these attitudes has firstly shown that within each company, each respondent has scored the agile operational characteristics differently; this has been documented in section 4 and interpreted in section 4.6. Accordingly, agile operational characteristics related topic areas with least spread of scores per organisation demonstrate a convergence of views across those people questioned. It is anticipated by the author that if group and team improvement initiatives progress, communication will improve and there will be a convergence in the consensus of views for operating characteristics in each of these organisations. The assessment has revealed that even though organisation scores are different, there is agreement across the case study organisations that change and risk management is less developed than other

characteristics (i.e. more improvement potential and need). This observation is supported with the findings from the ethnographic studies presented in all four of the organisational psychology paradigm profiles, figures 5. 10 to 5.13. All four organisations therefore recognise that there is a need for good change and risk management and also recognise that they are not well developed in this discipline and hence recognise they need improvement.

Additionally, it has been shown that, although each organisation has self-scored the questionnaire topics/agile practices at different levels, none feel that they have developed fully the practices associated with the six agile operational characteristics. Furthermore, the assessment of the agile operational characteristics is carried out in such a manner that for any given characteristic there are virtually infinite ways in which a company could obtain a particular score. Consequently, as each organisation perceives they have different strengths and different weaknesses in terms of their agile capabilities and their agile practices (or topics assessed), this does not mean that different operational characteristic scores are likely. It is therefore possible to highlight these strengths and weaknesses and work backwards through the calculations to help any assessed organisation to develop an "agile operational characteristics improvement path", with the starting point being agile practices identified from the 30 topic areas of the questionnaire. Further discussion on using these assessments to facilitate the development of improvement plans can be found in the EPSRC (IMI/A/05/004) final report, therefore discussion of this is not presented in this thesis but a recommendation is given in this regard in section 5.3.

5.2 A Critique of the Research Methods, Findings and Discussions

The conceptual model as discussed in section 3.1 has provided a holistic system of agile manufacturing in UK aerospace small to medium size enterprises (SMEs) that describes a conceptual agile manufacturing system model. This system has been used as the assessment framework for research activities in four case study organisations. The assessment of these four organisations has clearly shown that their organisational processes are interrelated, as described by the model in section 3.3.1, however the investigations for this research have clearly shown that the agile enabling macro sub-systems are dysfunctional.

This research therefore suggests that there is a lack of understanding and application of the concepts of systems thinking throughout the four case study organisations. In particular, the organisations assessed have not shown a great deal of connectedness of their strategic intent with their operational aspects and *vice-versa.* Additionally, the organisations have not considered a link between agile operational characteristics (practices) and the organisational psychology (attitudes) although there is obviously many causal links from one to the other. It is beyond the scope of this thesis however, to attempt to define these causal links, but it is considered enough to point out that these exist.

Furthermore, the author considers, that change and risk management has been considered a low development level because there is a lack of agile systems development and understanding. This is not to say that the organisations assessed are not agile, on the contrary, the organisations are surviving in a rapidly changing market sector, which indicates that they are adaptable which is, to a certain degree agile. The organisation's ability to rapidly change production processes and thus respond to existing customer demands is not in question either, as the findings have shown that within production activities creativity and inventiveness in problem solving is seen many times. It is the organisation's ability to respond to changes in the market place and to transfer strategic intent into operations that appear to be a major problem for these aerospace SMEs. In this respect, for each organisation, there is a key role for improving communications and developing a shared vision and real world understanding through three of the agile operational characteristics; knowledge management, effective information systems and effective enterprise integration.

Consequently, it is noticed in both the organisational psychology assessments and the agile operational characteristics assessments that teamwork and team related activities are considered, by the author and the organisations' respondents, in its infancy in these case study organisations. The use of teams at all levels within the concept of agile enterprises is very well documented and furthermore the value of teams (particularly cross-functional and cross-organisational teams) in developing organisational communication channels and hence developing culture has been discussed by Castka *et al* (2001). Therefore a critical issue related to the findings of this research is that

teamwork is well known as playing a major role in an agile enterprise and also playing a major role in change and risk management but this is not exploited within the case study organisations assessed.

5.2.1 A Review of the Theoretical Framework

The ethnographic studies have played a vital role in the assessment of three parts of the conceptual model of agility; agile manufacturing strategy, external motivators and the organisational psychology. This assessment (research) technique has provided the author with the knowledge and understanding of the context in which the respondents have scored their agile operational characteristics. This has therefore led to a deeper understanding of the state of agile manufacturing in each of the four case study organisations assessed. In practical terms, this agile manufacturing research has shown that ethnographic studies can be enhanced by questionnaire techniques and *vice-versa.* The argument brought forward here is that to assess in any organisation, any part of the conceptual model of agile manufacturing, in isolation of any other part of the model would not provide a balanced, and would not be unbiased, assessment.

Therefore, although it has proven to be robust and for this research, provided interesting results the assessment tool (the conceptual model of agile manufacturing in UK aerospace SMEs), is considered extensive and comprehensive hence, time consuming and resource intensive to apply. Acknowledging agile manufacturing is an overarching theory and that ethnography coupled with a questionnaire approach is resource intense, it is argued that this knowledge elicitation approach is valid and rigorous when employed in the manner described in this thesis. That is, the model has been developed from a rigorous yet unique synthesis of the literature relating to the subject and furthermore the research methods that have been uniquely brought together for this research are in their own rights proven techniques.

Consequently, from the evaluation of the four case study organisations and comparison of the findings to the (chapter 3) conceptual model of agile manufacturing in UK aerospace SMEs it is considered that the model is valid and applicable to a range of aerospace small to medium size enterprises. However, this is not to say, that further development of the model is not needed, but rather to say that further use of the model

is certainly necessary to find the limitations in its scope, as it has been clearly adequate for assessing the four case study organisations used in this research. Moreover, it is argued that the successful use of this model in assessing agile manufacturing as a system, in these four very different aerospace case study organisations, demonstrates its usefulness and potential adoption (and adaptation) in other manufacturing domains possibly outside the aerospace sector.

5.2.2 The Contribution to Existing Knowledge

The discussions so far have included many contributions that this research has made to existing knowledge, although these contributions have not yet been specifically spelled out, this is the main purpose of this section. Accordingly this thesis considers the following achievements of this research as essentially fulfilling the requirements of an original contribution to existing knowledge:

1. The development of a unique conceptual model of agility relevant to aerospace manufacturing through a synthesis of different sources of literature.
2. The combined use of ethnography and questionnaire techniques to enhance interpretations of the research findings.
3. The analyses and discussions of the findings associated with the assessment of agile manufacturing in the four UK aerospace case study organisations.

These three achievements are considered unique primarily because the conceptual model and associated assessment techniques developed within this thesis have never been published prior to submission of the thesis. This acknowledges the fact that the agile operational assessment tool (agile matrices) has been published, but this has been in isolation of the whole systems view of agile manufacturing in UK aerospace SMEs as presented in this thesis. These three claims also acknowledge the fact that other researchers have used ethnography and also considers the use of questionnaire techniques as very common in quantitative research, but hitherto, these techniques have predominately been used separately and never brought together in a manner used in this research. Finally, the analyses and discussions related to the four case study organisations are certainly unique, as no other research been carried out or publication

documented relating to the findings associated with these organisations within the theoretical framework presented in this thesis.

5.2.2.1 Advancement of Knowledge of Agile Manufacturing in UK Aerospace Small to Medium Size Enterprises (SMEs)

The analyses and discussions of the findings associated with the assessment of the four UK aerospace manufacturing SME case study organisations as presented in sections 5.1.1.1 to 5.1.4.2 represent an original contribution to knowledge. Given that, in chapter 1 a knowledge gap was identified as presented in figure 5.17 and it was acknowledged that if this gap could be bridged, then the contribution to knowledge would be significant. However, the generalisability of the findings is in question by the author, because each and every case study has contributed very different findings, as discussed throughout section 5.1, to this research, suggesting more case study organisations would help. Although three interrelated key findings can be considered as significant, for the four case study organisations, it is not to say that these are generally prevailing in all UK aerospace SMEs:

1. An agile manufacturing strategy is not effectively developed, deployed or assessed and neither is there an effective commitment to change the strategy following any assessment.
    a. Input to an agile manufacturing strategy should come from the operational aspects as well as the external motivators of agility.
2. The practice of change and risk management is not fully understood and consequently not developed. Therefore, the improvement of the agile manufacturing operational characteristics, competencies or practice is considerably hindered.
    a. A competence in change management is first needed, then companies can begin to effectively improve their agile operational characteristics
3. Teamwork is not exploited to its potential and therefore is not effectively employed in either change management or strategic management activities.
    a. As cross-functional and inter-company teams foster better communication these companies do not reach their agile potential.

Further to this, innovation and creativity in production environments has been seen as a key practice in these case study organisations. This practice has enabled the successful introduction of new product and new production processes (mainly machining and machining practices) into all four organisations assessed. Accordingly, the technical and engineering competencies that are obviously present in these organisations are used effectively in their production domains and supported entirely by their organisational psychology paradigm profiles presented in this thesis. There is no doubt that these technical and engineering competencies have been sufficient to help maintain competitiveness of these companies in the UK aerospace sector. However, it has been noted through the ethnographic studies that one organisation that has diversified into other markets is struggling to make profits, and furthermore it is argued that the lack of experience in team working for change management, if not addressed would severely affect the capabilities of these organisations to remain competitive in the global aerospace manufacturing sector of the future.

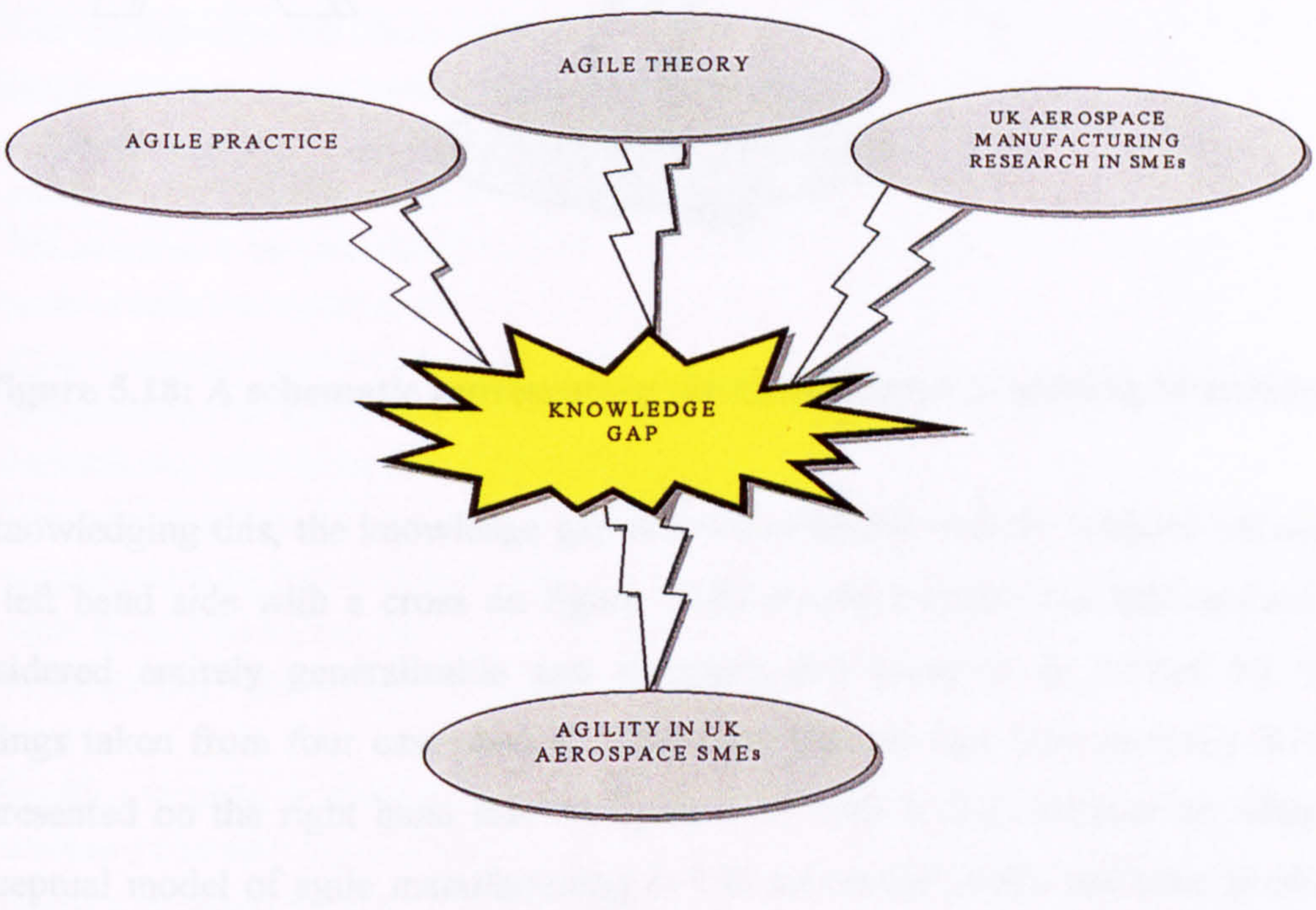


Figure 5.17: A schematic representing the knowledge gap

It is therefore, prudent to say that the knowledge gap identified in figure 5.17 has not been fully plugged, hence the significance of the findings is limiting, but nevertheless to a certain degree as shown in figure 5.18 the gap has been abridged. Moreover, agile manufacturing practice in the four case study organisations has been assessed using a

hitherto not previously developed, conceptual model of agile manufacturing in UK aerospace SMEs. Therefore an important contribution to existing knowledge of agile manufacturing in UK aerospace manufacturing SMEs has been made. Figure 5.18 therefore, considers the contribution made by this research aimed at plugging the knowledge gap shown in figure 5.17 and acknowledges that the gap is not entirely plugged and further work is necessary to plug this gap.

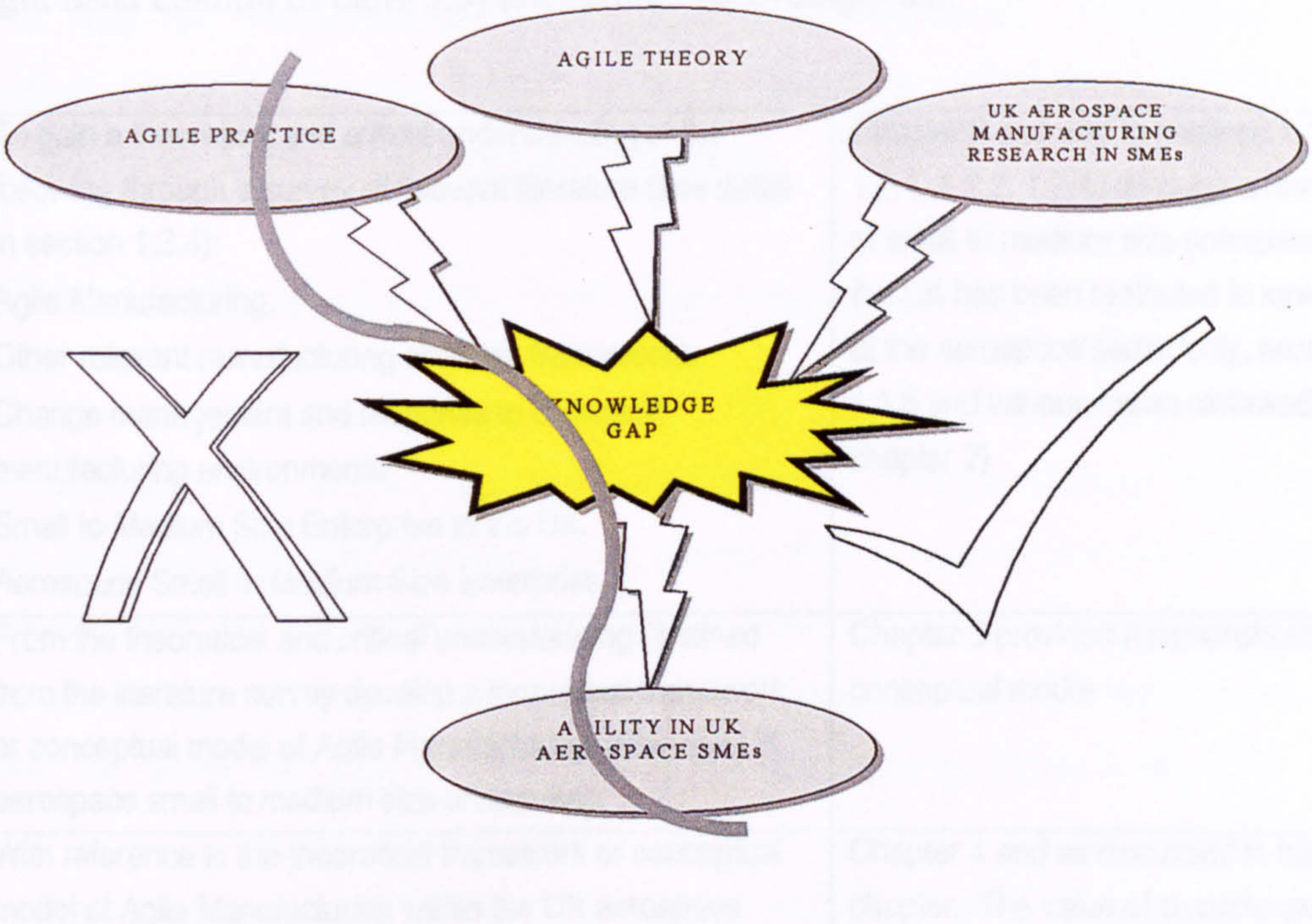


Figure 5.18: A schematic representing the contribution to existing knowledge

Acknowledging this, the knowledge gap is not considered entirely bridged (shown on the left hand side with a cross on figure 5.18) mainly because the findings are not considered entirely generalisable and therefore this research is limited by these findings taken from four case studies. However, the gap has been partially bridged (represented on the right hand side of figure 5.18 with a tick) because an adequate conceptual model of agile manufacturing in UK aerospace SMEs has been produced and that model then used to asses the four case study organisations in terms of that model. It is therefore considered in this thesis that the model (chapter 3) is appropriate for all aerospace manufacturing enterprises as an assessment tool, and for individuals as a learning package to increase their knowledge and understanding of agile theory applicable to the aerospace sector.

5.2.2.2 Meeting the Aim and Objectives of the Research

The specific aim of this research was "*To assess agile manufacturing within UK aerospace manufacturing small to medium size enterprises (SMEs).*" Essentially, this aim has been achieved successfully through the research objectives being fulfilled. The specific objectives of this research [cross-reference to achievement of objectives is in right hand column of table 5.5] are defined accordingly as:

1. To gain a theoretical and critical understanding of the following through a survey of relevant literature (see detail in section 1.3.4): • Agile Manufacturing. • Other relevant manufacturing strategic frameworks. • Change management and response to change in manufacturing environments. • Small to Medium Size Enterprise in the UK. • Aerospace Small to Medium Size Enterprise.	Chapter 2 and also in sections 1.1.5, 1.2.1, 1.2.2, 1.2.4 (although a review of small to medium size enterprise in the UK has been restricted to looking at the aerospace sector only, section 1.1.5 and various cases reviewed in chapter 2)
2. From the theoretical and critical understanding obtained from the literature survey develop a theoretical framework or conceptual model of Agile Manufacturing within the UK aerospace small to medium size enterprises.	Chapter 3 provides a comprehensive conceptual model
3. With reference to the theoretical framework or conceptual model of Agile Manufacturing within the UK aerospace small to medium size enterprises assess agile manufacturing in an appropriate number of UK aerospace manufacturing SMEs (case study organisations).	Chapter 4 and as discussed in this chapter. The value of a combined ethnographic and questionnaire approach has been discussed in sections 4.5.2 and section 5.2.2
4. From an evaluation of the case study organisations and comparisons to the theoretical framework or conceptual model develop the findings into a theoretical generic aerospace SME Agile Manufacturing model (the theoretical model).	Chapter 5 although as discussed in this section and specifically in 5.2.2 the conceptual model remains the same as in chapter 3
5. Provide a complete and detailed discussion of the developed theoretical model which shall: • Include a framework for agility in the aerospace manufacturing sector with the focus and main relevance to UK aerospace SMEs. • Enhance the understanding of Agile Manufacturing theory, concepts and practice. • Have the ability to be an assessment tool for agile manufacturing in UK aerospace SMEs.	Chapters 3, 4 and 5 although as discussed in this section and specifically in 5.2.2 the conceptual model remains predominantly the same as in chapter 3

Table 5.5: Meeting the objectives of the research

5.3 Recommendations Resulting from the Research

The recommendations represented in this section are divided into three areas that are considered as needing addressing for a number of reasons, which are mentioned accordingly. These recommendations have been drawn from the interpretations of the findings and are therefore informed by the rigour of this research. The three areas are obviously interrelated, as mentioned throughout this research nothing sits in isolation, and as such the connectedness of the issues is also discussed. These three areas, separated for clarity, are considered as; (i) the case study organisations, (ii) The UK aerospace sector and (iii) The research community.

5.3.1 Future Directions for The Case Study Organisations

The four case study organisations assessed within this thesis although shown to be very different in size, culture and capabilities have been chosen through a normalised set of characteristics and therefore to a certain degree any of the common issues discussed could be considered appropriate for other UK aerospace small to medium sized enterprises (SMEs). Hence, when considering the recommendations in this section, the reader may bear in mind other aerospace SMEs operating in the UK.

This thesis proposes that there are three main issues that should be addressed in order to improve the agility of the case study organisations and hence improve their chances of survival in a changing operating environment. These interdependent issues are considered important because as clarified throughout sections 1.1.5 and 1.2 many factors are affecting the UK aerospace sector, which is rapidly changing, and there is a need for these organisations not just to recognise this but also to do something about it if they want to survive. These three issues are concerned with the three key findings shown in section 5.2.2.1 related to strategy, change management and teams.

Accordingly, these issues must be addressed systematically as they are considered by the author to be intrinsically connected. Likewise, these organisations should consider their strategy for survival by taking positive action in gaining understanding of their external motivators, for it is these that will help guide them to the future [strategic development]. Further to this the operational aspects [organisational psychology and operational characteristics] of an organisation should be considered when developing

an agile strategy for the future, because with the knowledge and input from the operational aspects a roadmap [deployment strategy] to the future can be achieved. A fundamental part of any agile strategy must include the management of change, that is change issues concerning all levels and parts of the enterprise as a competence provides the ability to rapidly respond to the needs of the organisation [change and risk management]. Accordingly, these organisations should improve their understanding and focus on teamwork and team activities for a number of reasons; teams help improve communication [knowledge management] and [real-world understanding], teams are fundamental for cross-functional and inter-organisational change programmes [change and risk management], teams facilitate enterprise integration both at intra- and inter-organisational [effective enterprise integration] levels. In effect, what is trying to be said here is, that teams should drive the organisations' agile strategy and also teams should drive organisational change, but also there is a need for teams to work on change issues to develop their team competencies, this view is represented in figure 5.19, where if one cog is removed this system fails.

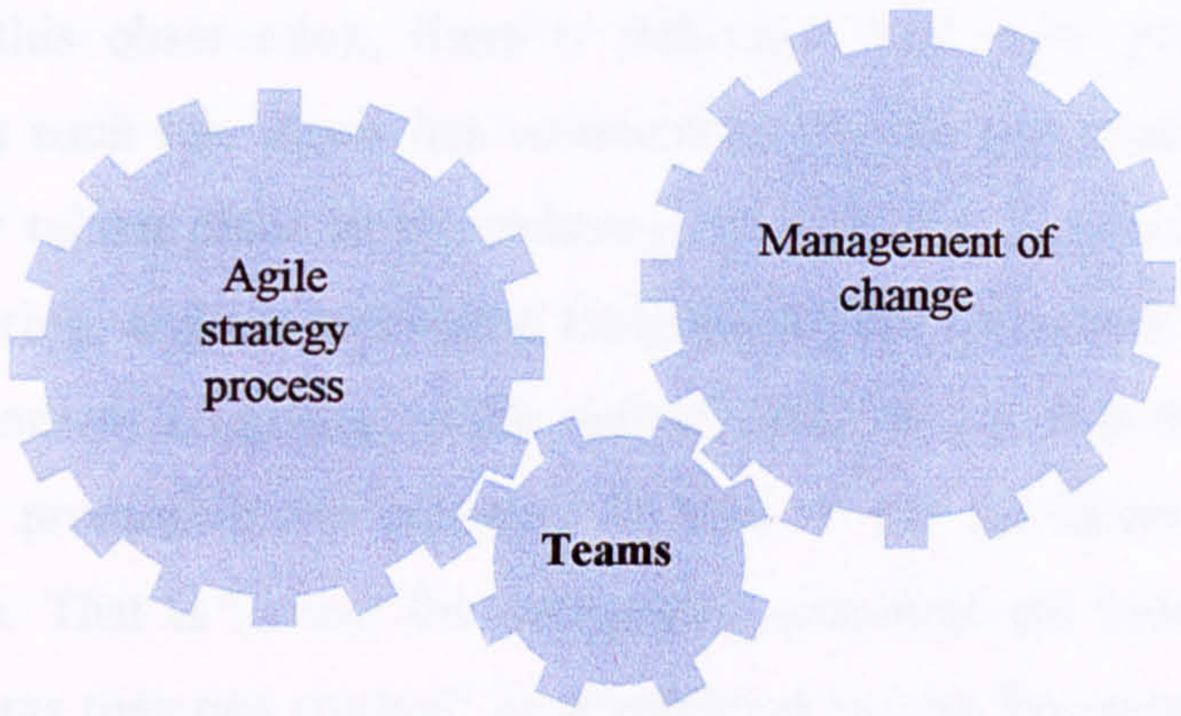


Figure 5.19: Interdependent issues of agile strategy, change and teams

A discussion of the exact form of the agile strategy that these organisations should adopt is beyond the scope of this thesis, however, as discussed above, the management of change and team development should feature clearly in the strategy of these organisations. Other issues that have been highlighted throughout this thesis include; building a competence to network, building partnerships and alliances across the supply chain and wide deep scanning of the environment, as these competencies will help the organisations to develop the ability to seek opportunities and seize opportunities. These competencies are necessary for the case study organisations

assessed to enable them to explore and move toward alternative futures to the current paradigms they find themselves in.

5.3.2 Recommendations for the UK Aerospace Sector

A notable finding from this research impacting upon all the aerospace organisations taking a part in, or those organisations related to aerospace that have been reviewed through literature searches in, this research, is the lack of understanding that the concept of lean and the concept of agile are markedly different. Consequently, this difference has been discussed by Bamber *et al* (1999) and Bamber *et al* (1999a), although other writers such as Phillips (1999) have confused the issue by blurring the boundaries between these two concepts. Consequently, as observed throughout this study, the UK aerospace industry has primarily spearheaded improvements by promoting the concepts of lean manufacturing as discussed in section 2.1.1 and not primarily through an understanding of agile manufacturing.

Acknowledging this observation, there is indication that agile practices are being developed and as such this thesis has commented on; the partnerships and alliances that are currently taking place in the industry; an increase in global networking and global manufacturing; and the increasing integration with customers' operations. The main area for concern, according to the author, must be the fact that the aerospace industry itself is promoting the concepts of lean to the detriment of the essential practices of agile. That is to say, the aerospace companies are being encouraged to "focus on the things they can control" as proclaimed in lean literature as discussed by Bamber (1999a), when they should be building a "change competence or change proficiency" to cope with the unanticipated and unexpected. Further to this the aerospace organisations assessed within this research are underdeveloped in their ability to seek opportunity and seize opportunity, therefore they are not directing their own agile competencies and consequently limiting their survival capability in a changing sector.

The recommendation to the aerospace industry, and for that matter to the government of the UK (see sections 1.1.5 and 1.2.4), is to stop promoting the concepts of lean because this is well known to the industry and focus is needed elsewhere. In stead the

concepts of agility that help organisations seek and seize new opportunities and be aware of their external motivators should be promoted. Furthermore, the primes (e.g. Rolls-Royce and BAE Systems) have a roll to play in the education and development of their supply chains (past, present and future) and not just the future suppliers. This education and development should include publication of their manufacturing supply chain strategic intent and future directions, thus enabling the supply chain organisations to make informed decisions about their own future, which as a result may or may not be in aerospace.

5.3.3 Recommendations for the Research Community

A number of suggestions can be made in terms of future research directions. It would certainly be beneficial to conduct a longitudinal study of agile practice permitting both causality assessment and results generalisability to diverse manufacturing industries as well as to the aerospace manufacturing sector as a whole. In particular, the causal relationships of the elements within the agile manufacturing model presented within this thesis are to a great extent undetermined and therefore still unknown. Although some studies such as Ho (2000) have attempted to clarify causality within parts of the model e.g. between culture and strategy, this too is inconclusive and not grounded in thorough research. It is a recommendation that the use of qualitative data reduction techniques such as factor analysis could be used aimed at reducing the number of topics presented in the agile operational characteristics assessment matrix. However, this would require a wider study with a higher number of respondents to make this and associated techniques valuable.

Given the complex, multiplicative nature of agility, future research could also focus on defining the key causal factors of an agile organisation, where a framework for assessment could be the thirty key or thirty-two topics or agile operational practices presented in this thesis. On the other hand, further case study research into the cultural aspects of agility is needed, as this current research suggested little empirical research has been published in this area within manufacturing domains. Although, this research has to a certain degree added to the knowledge of organisational psychology within the concept of agility much further work is needed to additionally clarify the situation.

The development of ethnographic research techniques continues by many researchers and accordingly, the use of ethnography coupled with questionnaire techniques could be part of that development. Furthermore, findings of the current study would also advocate the future use of the model to assess whether other organisations exhibited the same phenomena as expressed in section 5.2.2.1 relating to the three underdeveloped issues of strategy, change management and teams within organisations.

Finally, it is considered inevitable from a number of sources cited in this thesis, that some aerospace small to medium size enterprises (SMEs) have to change the way they operate to stay in business. It is inevitable also, that some of these SMEs will not play a role in the UK aerospace manufacturing supply chain of the future. Hence, the UK government, prime aerospace companies and the research community [Universities] could play a role in efforts to explore a future that adopts or adapts the competencies held by these companies into new markets. The aerospace organisations assessed during this research have shown an ability to and aptitude toward introducing new products into production. Accordingly, for the benefit of the current UK aerospace SMEs and the people that they employ, the research community including government and aerospace primes could provide research and associated funding aimed at exploring the re-deployment of aerospace manufacturing competencies to other existing and future industries and markets.

Chapter 6 Conclusions

6.1 The Aim and Objectives of the Research

The aim of this research has been to assess agile manufacturing within UK aerospace manufacturing SMEs, which has been achieved by fulfilling the five objectives that directed the research toward achieving this aim. In order to fulfil the aim and objectives, ethnography and questionnaire findings from four case study organisations have been analysed and discussed in comparison with the conceptual model of agile manufacturing incorporating the four agility enabling macro sub-systems of:

- Agile manufacturing strategy
- External motivators
- Organisational psychology
- Operational characteristics

Accordingly, the ideal adoption level of an agile manufacturing strategy is when the four stages of the agile manufacturing process are being carried out 100% effectively. Thus when strategy development, deployment, assessment and commitment ensure that an organisation can do whatever it wants to do whenever it wants to. This research has shown that the four organisations assessed have not effectively adopted the four stages of agile manufacturing strategy and a graphical representation of their adoption levels per stage has been developed, as in figure 6.1, to illustrate this point.

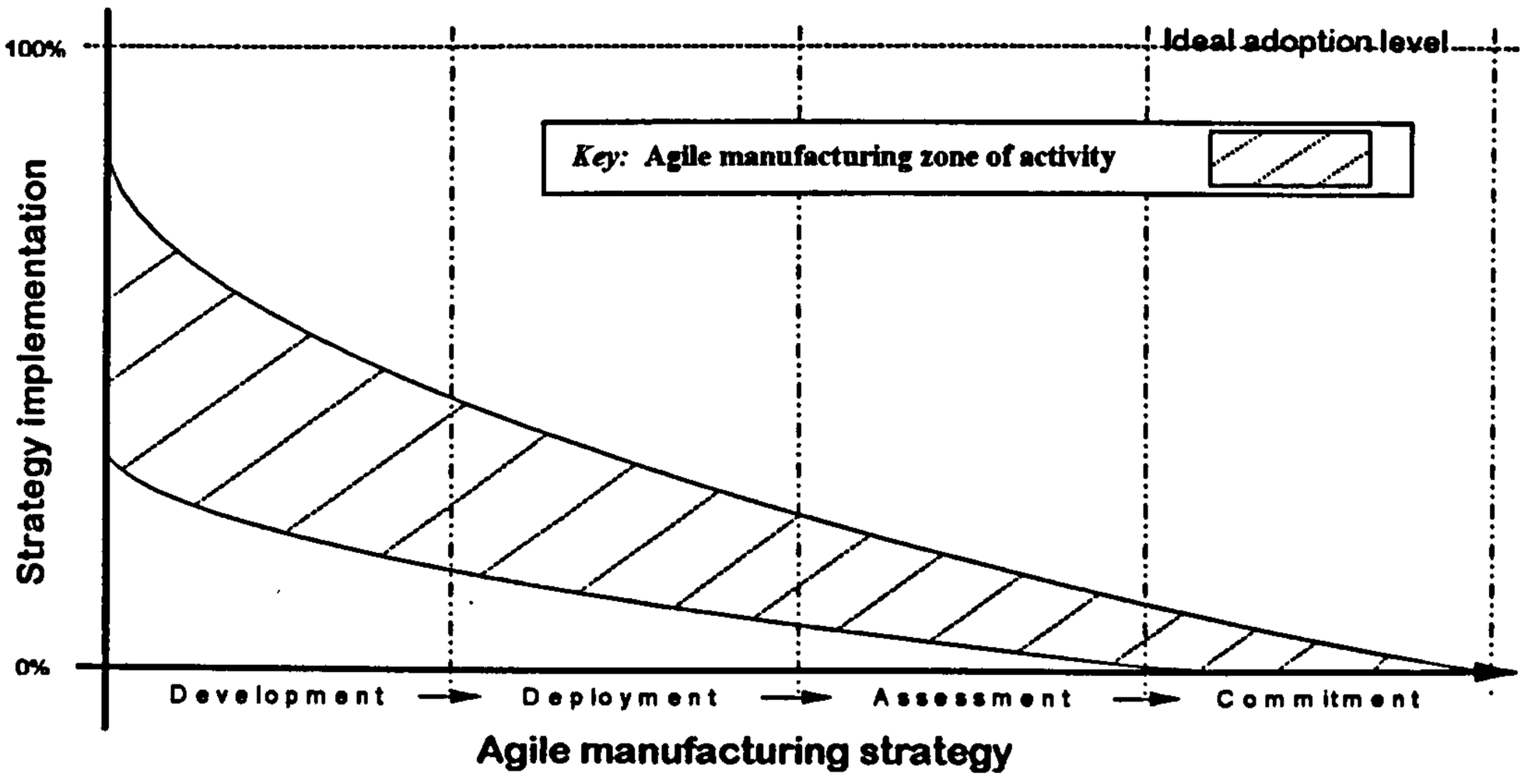


Figure 6.1: Graphical representation of case study organisations' adoption levels of the agile manufacturing strategy process

The external motivators of an agile manufacturing organisation have been considered as an integral part of the framework for maintaining and developing agility. These external motivators and the agile manufacturing strategy make up the strategic requirements of the agile manufacturing conceptual model, presented in this thesis. The conceptual model of agile manufacturing indicates that to increase agility, the external motivators of agile manufacturing must be considered in an organisations' strategy. The findings aimed at assessing the awareness and management of these external motivators, within the four case study organisations, infers that each organisation places different emphasis and importance on this issue. The discussion has shown that from these assessments and analyses only one of the four case study organisations, that is case study organisation B, is effectively seeking and seizing opportunity through developing customer relationships, effective networking, marketing activity, joint venturing and new product development. The three other case study organisations are all involved with new product development, usually from existing customers, but do not network or market effectively in their own right with the aim of seeking and hence seizing opportunity. Additionally, each and every organisation has seen customer relationships as a major issue in the success of their organisation but has demonstrated different levels of maturity in this respect. This is to say, that the knowledge, understanding and therefore practice in the management of these external motivators of agility is in its infancy across the organisations assessed.

The conceptual model of agile manufacturing has shown within this thesis, the five agile manufacturing enabling factors of the macro sub-system of organisational psychology, are the lubricant to the organisations agile capabilities. These five enabling factors are shown in figure 6.2 below.

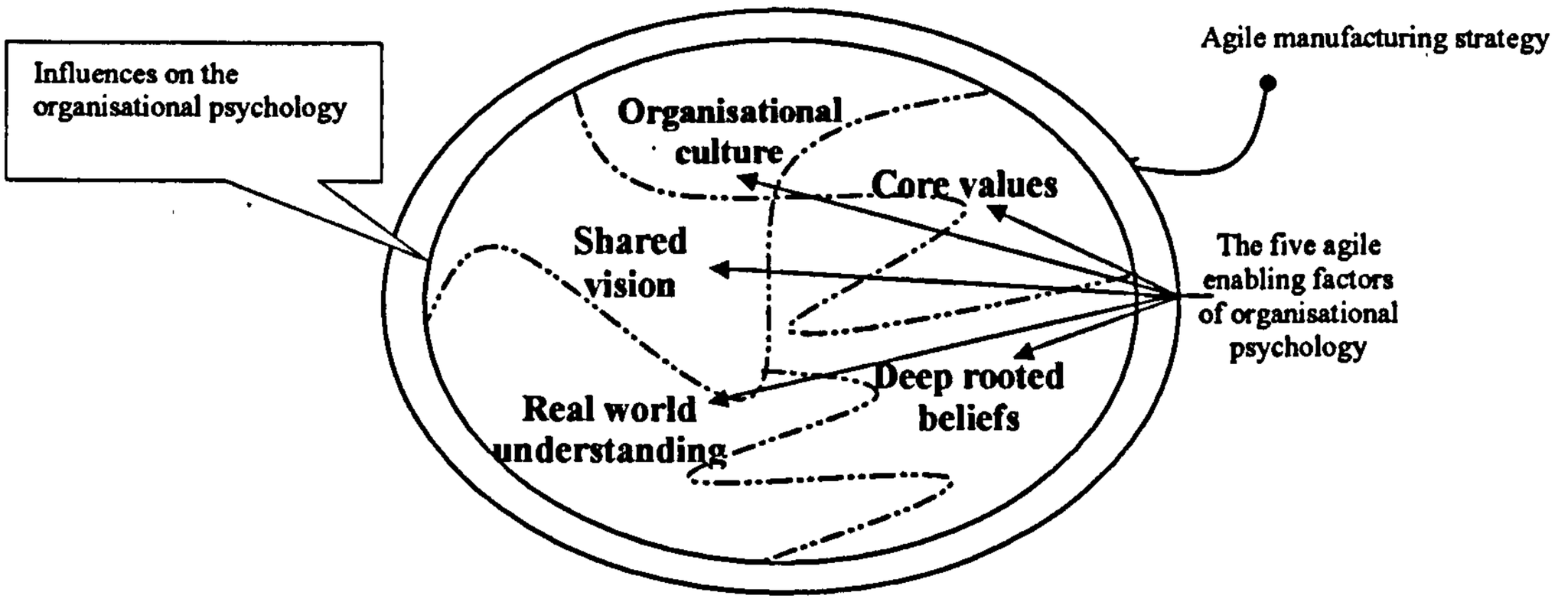


Figure 6.2: Agile manufacturing organisational psychology

Accordingly, the key finding associated with the organisational psychology assessment of each and every case study organisation, is that in the author's view, there is little or no relationship between their organisational psychology paradigms and an agile manufacturing strategy. The conclusive issue consequently, for all of the organisations assessed, is that they do not fully embrace a culture that fosters change. Furthermore, it appears that none of the assessed organisational paradigms are entirely in line with their own organisation's strategies. Consequently, it could be inferred that there is not a shared vision that apparently supports the strategies of the organisation or for that matter one that supports an agile strategy.

Additionally, within the four case study organisations assessed, it has been shown that information systems and hence communication methods do not provide a real worldview that reflects the requirements of an agile organisation. The requirement for accurate real time data is paramount in an organisation that wishes to respond rapidly to the changing demands of customers, because without this, decision-making cannot be effective.

The organisational psychology profiles infer that the widespread core value for each and every case study organisation is that technical skills are regarded as more important than management skills and thus technical skills are held in high regard. Accordingly, the agile manufacturing conceptual model developed for this thesis indicates that an "agile enterprise's core values are those values, both at organisational and individual levels, which enable agile practices." From this it is the author's view that the organisational psychology paradigm profiles indicate that the core values of the organisation are such that not all agile practices are being enabled, although technical skills are widely promoted.

The six operational characteristics, shown in figure 6.3, have been identified as; knowledge management, effective information systems, change and risk management, effective enterprise integration, real-time production management and waste management and elimination have been shown to be assessed by measuring attitudinal responses to 32 topics within a questionnaire.

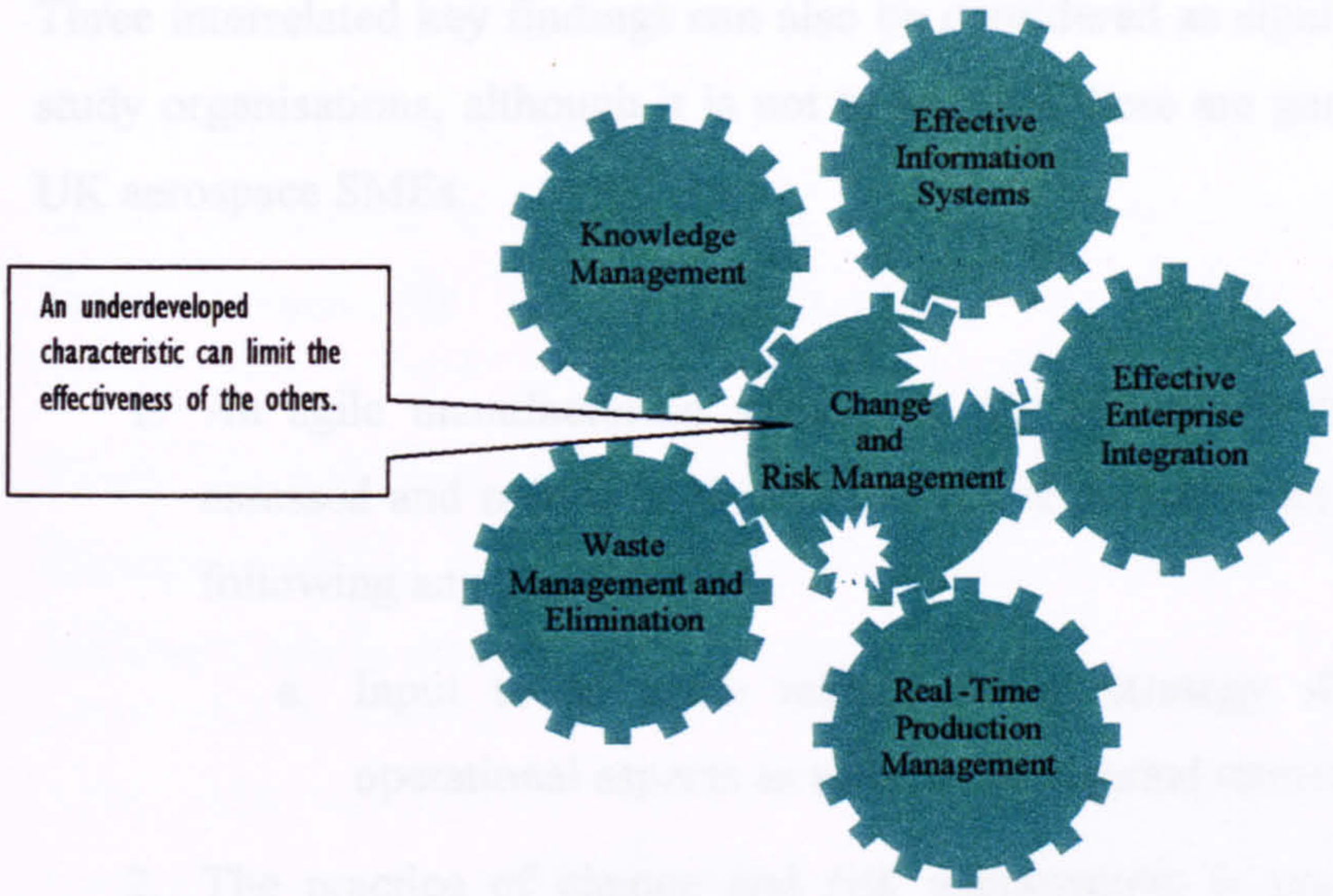


Figure 6.3: Agile operational characteristics

The assessment of these six agile operational characteristics has revealed that even though organisation scores are different, there is agreement across the case study organisations that change and risk management is less developed than other characteristics (i.e. more improvement potential and need). This observation is supported by the findings of the ethnographic studies presented in all four of the organisational psychology paradigm profiles. All four organisations therefore recognise that there is a need for good change and risk management and also recognise that they are not well developed in this discipline and hence recognise they need improvement.

6.1.1 The Contribution to Existing Knowledge

Three aspects of this research have provided an original contributed to existing knowledge:

1. The development of a unique conceptual model of agility relevant to aerospace manufacturing through a synthesis of different sources of literature.
2. The combined use of ethnography and questionnaire techniques to enhance interpretations of the research findings.
3. The analyses and discussions of the findings associated with the assessment of agile manufacturing in the four UK aerospace case study organisations.

Three interrelated key findings can also be considered as significant for the four case study organisations, although it is not to say that these are generally prevailing in all UK aerospace SMEs:

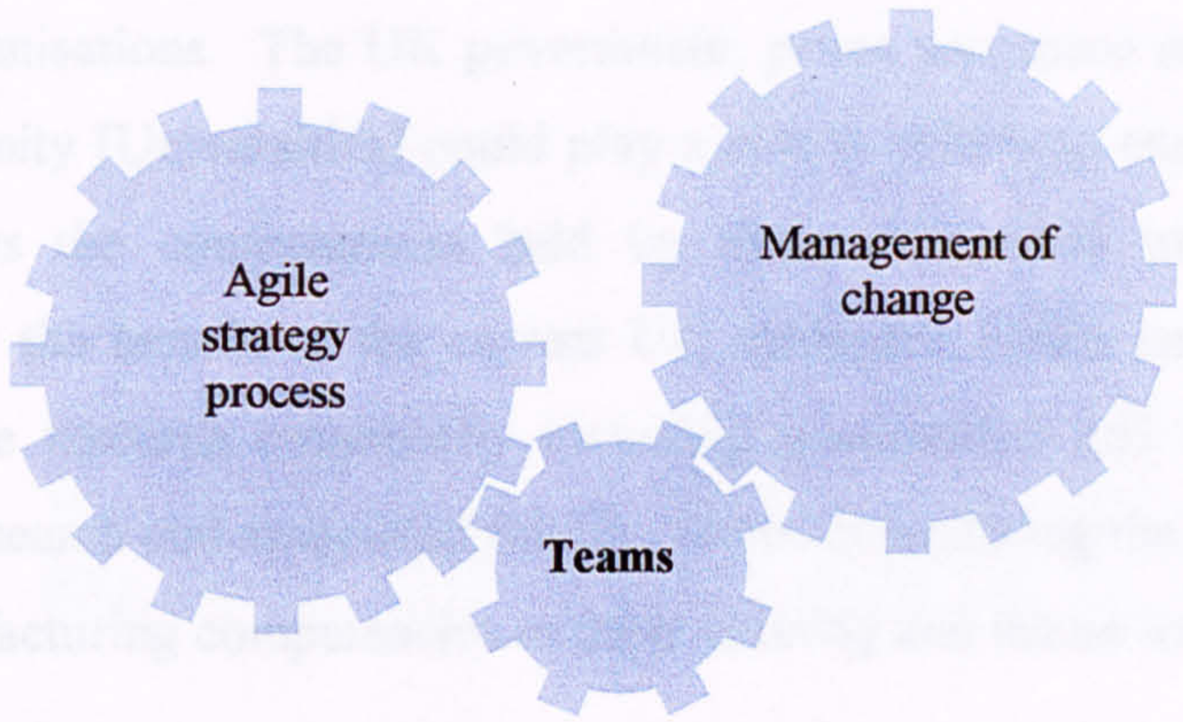
1. An agile manufacturing strategy is not effectively developed, deployed or assessed and neither is there an effective commitment to change the strategy following any assessment.
    a. Input to an agile manufacturing strategy should come from the operational aspects as well as the external motivators of agility.
2. The practice of change and risk management is not fully understood and consequently not developed. Therefore, the improvement of the agile manufacturing operational characteristics, competencies or practice is considerably hindered.
    a. A competence in change management is first needed, then companies can begin to effectively improve their agile operational characteristics
3. Teamwork is not exploited to its potential and therefore is not effectively employed in either change management or strategic management activities.
    a. As cross-functional and inter-company teams foster better communication these companies do not reach their agile potential.

Further to this, innovation and creativity in production environments has been seen as a key practice in these case study organisations. This practice has enabled the successful introduction of new product and new production processes (mainly machining and machining practices) into all four organisations assessed. Accordingly, the technical and engineering competencies that are obviously present in these organisations are used effectively in their production domains and supported entirely by their own organisational psychology paradigm profiles presented in this thesis.

6.2 Recommendations Resulting from the Research

The recommendations resulting form this research are in three areas, separated for clarity, considered as the case study organisations; the UK aerospace sector and the research community.

Firstly, the case study organisations should consider the relationship of the three key findings related to strategy, change management and teams. Recognising that teams can play a role in driving the other two.



6.4: Teams can drive the strategy and the management of change

Secondly, the UK aerospace sector and the government of the UK should stop promoting the concepts of lean because this is well known to the industry and focus is needed elsewhere. Instead, the concepts of agility that help organisations seek and seize new opportunities and to be aware of their external motivators should be promoted. Furthermore the primes (e.g. Rolls-Royce and BAE Systems) could contribute to the education and development of the SMEs by publication of their manufacturing supply chain strategic intent and future directions, thus enabling the supply chain organisations to make informed decisions about their own future, which as a result may or may not be in aerospace.

Finally, the research community could conduct a longitudinal study of agile practice in aerospace manufacturing permitting both causality assessment and results generalisability to diverse manufacturing industries as well as to the aerospace manufacturing sector as a whole. Additionally, future research could also focus on defining the key causal factors of an agile organisation, where a framework for

assessment could be the thirty or thirty-two topics or agile operational practices presented in this thesis. While further case study research into the cultural aspects of agility is needed, as this current research suggested little empirical research has been carried out in this area within manufacturing domains. The development of ethnographic research techniques continues by many researchers and accordingly the use of ethnography coupled with questionnaire techniques could be a further part of that development. Furthermore, findings of the current study would also advocate the future use of the model to assess whether other organisations exhibited the same phenomena as relating to the three issues of strategy, change management and teams within agile organisations. The UK government, prime aerospace companies and the research community [Universities] could play a role in efforts to explore a future that adopts or adapts the competencies held by these companies into new markets. Accordingly, for the benefit of the current UK aerospace SMEs and the people that they employ, the research community including government and aerospace primes could provide research and associated funding aimed at exploring the re-deployment of aerospace manufacturing competencies to other existing and future industries.

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APPENDICES

A Review of the US Lean Aircraft Initiative and the Lean Enterprise Model

Lean Aerospace Initiative (LAI)

Description

The Lean Aerospace Initiative (LAI) is a research partnership between US government industry, labor and MIT LAI performs research on supplier relation, product development, policy and external environment, factory operations and space systems. The Lean Enterprise Model (LEM) is a systematic framework for organizing and disseminating research results. The LEM encompasses lean enterprise principles and practices and is populated by research-based benchmarking data derived from surveys, case studies, and other research activities. Available only to LAI consortium members, the LEM serves as a reference to help LAI consortium members better understand the leanness of their own organizations and processes. It is intended to provide insights as to where they might direct lean efforts in the future.

Lean Aircraft Initiative: http://web.mit.edu/lean/
Contacts: Debbie Nightingale, Lean Enterprise Model Team Lead Dnight@mit.edu
Fit to ABB research needs: LAI members are working many of the same practices that are required for a transition to agility. This research is a way to share best practices and learn from other industries experience.

The LAI organization is a model collaborative effort between the Air Force and its partners within government (Joint Aeronautical Commanders Group), industry (19 aerospace corporations), labor and MIT. LAI is funded through a cooperative agreement between the government and MIT. In Phase I, the government's share was funded by the Air Force. Through individual consortium participation agreements with MIT, industry provided two-thirds of the initiative's funding through a share arrangement for the same period. During Phase II (September 1996-September 1999), the same agreements exist between the consortia members and MIT with additional funding provided by eight new government members including participation from Army, Navy, Defense Logistics Agency, Coast Guard, and NASA organizations. This makes the government/industry share ratio approximately 50/50.

The Lean Enterprise Model (LEM) (from LAI site: http://lean.mit.edu/public/)
Developed by LAI, the LEM is a comprehensive framework of lean principles backed by years of research, case studies, and related data. It is also a tool for organizing and sharing lean research results among consortium partners. It contains valuable industry data derived from surveys, case studies, and other research activities. The LEM is a dynamic resource that gives members practical insights about the use of lean principles.

The LEM is:

- A framework for disseminating LAI research results to its consortium members.
- A reference tool to assist in the self-assessment of leanness.
- A guide for identifying leverage points for organizational change.
- A tool to encourage the development of new lean paradigms relating to the design, development, and production of military aerospace products.
- The LEM is organized in a hierarchical framework that ranges in scope from high-level principles to specific practices.
- The framework provides a structured environment to help guide the user to research results addressing specific lean practices.

A Review of the US Lean Aircraft Initiative and the Lean Enterprise Model

Lean Enterprise Model (LEM) Principles

Meta-Principles:
Responsiveness to Change
Waste Minimization

Enterprise Principles:
Right Thing at Right Place, Right Time, and in the Right Quantity
Effective Relationships within the Value Stream
Continuous Improvement
Optimal First Delivered Unit Quality

Enterprise Level Metrics
Flow Time - Order To Delivery Time In Months, Product Development Cycle Time (Industry Comparative, % Reduction)
Stakeholder Satisfaction - On Time Deliveries, Continuous Cost / Price Improvement
Resource Utilization - Output / Employee, Inventory Turns
Quality Yield - Scrap and Rework Rate, Design Changes / Initial Release / Project Phase

Overarching Practices
1. Identify and Optimize Enterprise Flow
2. Assure Seamless Information Flow
3. Optimize Capability and Utilization of People
4. Make Decisions at Lowest Possible Level
5. Implement Integrated Product Process Development
6. Relationships Based on Mutual Trust and Commitment
7. Continuous Focus on the Customer
8. Promote Lean Leadership at All Levels
9. Maintain Challenges of Existing Processes
10. Nurture a Learning Environment
11. Ensure Process Capability and Maturation
12. Maximize Stability in Changing Environment

Industry Participants

AIL Systems, Inc.
AlliedSignal Aerospace, Inc.
Boeing Defense & Space Group
General Electric Aircraft Engines
Hughes Aircraft Company
Lockheed Martin Aeronautical Systems Company
Lockheed Martin Electronics & Missiles Group
Rockwell International Corp.
Sundstrand Corp.
Texas Instruments Defense Systems & Electronics Group
Textron Systems Division, (Textron, Inc.)
TRW Avionics Systems Division
McDonnell Douglas Aerospace
Northrop Grumman Corp.
Pratt & Whitney (United Technologies Corp.)
Raytheon Aircraft, (Raytheon Corp.)

LAI has heavy participation from US Air Force, Army, and Navy organizations, and involves other Universities beside MIT, as well as Labor and Industry associations.

EPSRC Research: IMI/A/05/004 Project Abstract

EPSRC Research: IMI/A/05/004 Project Information (taken from draft final report)

1 The Research Programme *(grant number GR/M 23168)*

The research programme was developed to pilot the business process interaction between a group of SME suppliers, in order to develop a methodology for aerospace suppliers at various supply chain tiers to engineer their enterprises towards becoming agile manufacturers. The emphasis was placed specifically on SME suppliers such that the key deliverable is a methodology for developing strategies the achieve Agile Manufacturing which are consistent with the aspirations of their larger aerospace customers, resulting in successful business integration. The results of this project are intended to be transferable to other aerospace SME suppliers. In addition, the results will contribute directly to the Lean Aerospace Initiative in order to ensure that the Lean Enterprise Model relates to companies at all levels in the aerospace industry.

1.1 Aims and Objectives

In meeting IMI key success factors of: reducing delays and interruptions in the supply chain, increasing flexibility of aerospace SME suppliers and reducing the cost of supply chain partnering in order to improve the competitiveness of UK Aerospace industry, the following specific objectives were identified:

a) To contribute to the UK LAI lean enterprise model (LEM) through:
   - Elicitation of best practices in supply chain SMEs.
   - Identification of appropriate performance metrics in SMEs thereby verifying relevance of LEM metrics.

b) To facilitate effective customer-supplier integration

c) To disseminate elements of best practice throughout the aerospace supply sector

d) To aid aerospace SMEs to adopt generic best practice from the lean and agile manufacturing philosophies

e) To contribute to the theoretical understanding of supply chain business processes in SMEs

f) To develop a methodology to assist SMEs in a migration to lean and agile

Consequently, a research programme was developed to complement the UK Lean Aerospace Initiative by capturing the best practice and the development of lean and agile methodologies for UK Aerospace SMEs and made a major contribution to improving the competitiveness of the whole industry by reducing lead time and production costs, whilst improving the quality and effectiveness of the supply chain in meeting the customer requirements emanating from their prime contractors throughout the world. The relationships between the research programme activities are illustrated in figure 1.

EPSRC Research: IMI/A/05/004 Project Abstract

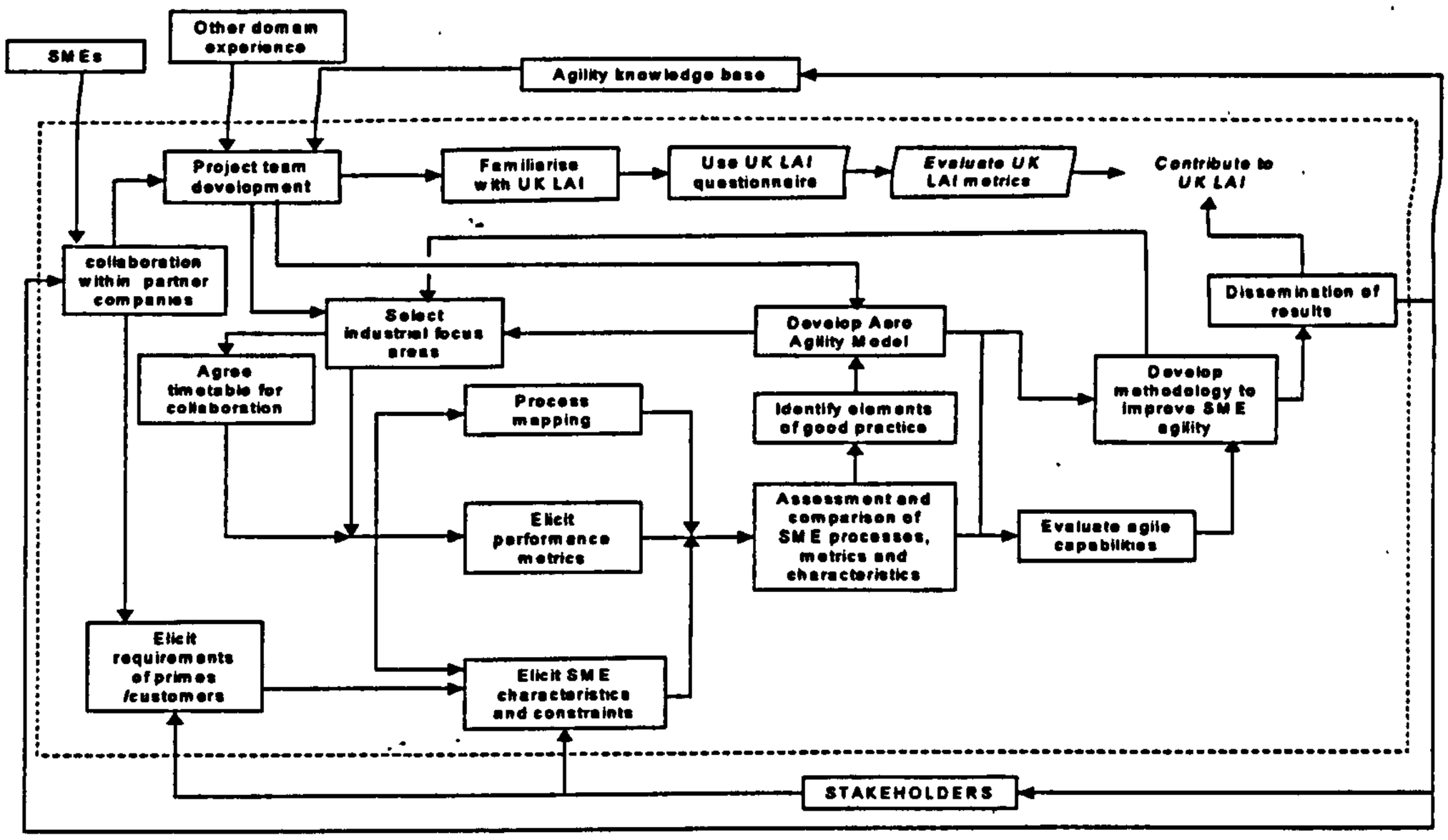


Figure 1 Relationships of research programme activities

1.2 Industrial - Academic Collaboration

An important aspect of the agile manufacturing research programme was the effective collaboration between industry and academia. The nature of this collaboration can be seen in figure 1 and figure 2 where figure 2 illustrates, from a different perspective, the intended collaboration between the UK LAI research programme, the agile manufacturing research programme and industry.

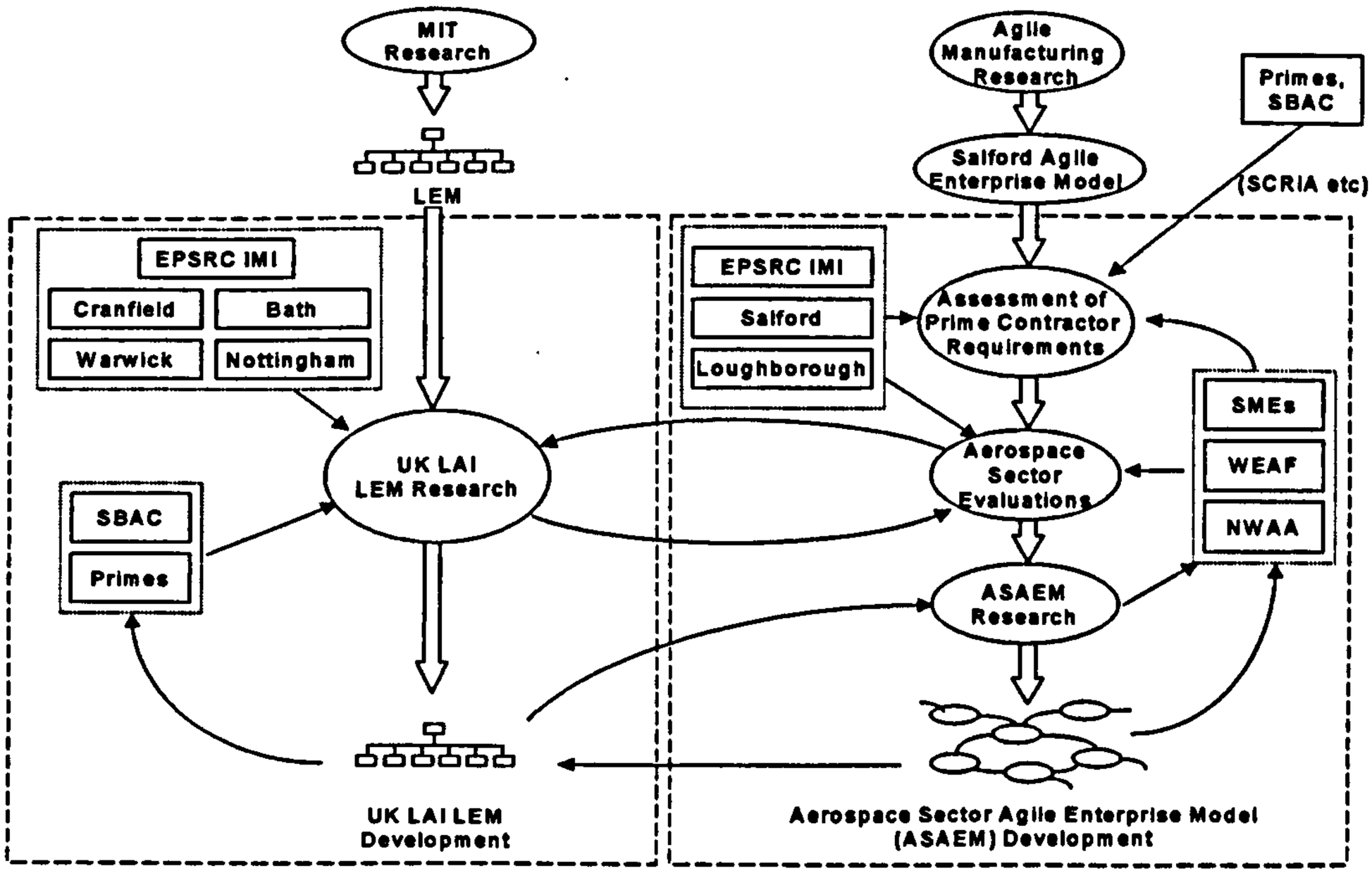


Figure 2 Industrial - academic collaboration

EPSRC Research: IMI/A/05/004 Project Abstract

1.3 Collaboration with UK Lean Aerospace Initiative (LAI)

The UK's Lean Aerospace Initiative (LAI), a collaborative programme involving the universities of Warwick, Bath, Cranfield and Nottingham is seeking to address issues relating to complex design processes, long lead times for new product and delivery of existing product, low flexibility in manufacturing processes, and high capital investment requirements. The funds for the UK LAI come from the Society of British Aerospace Companies and the EPSRC. The focus of the UK LAI collaboration is to transfer the techniques of lean manufacturing from the motor industry, for example, to the aerospace sector, with its shorter production runs and higher value products. The UK LAI is looking at the processes involved in going lean. The initiative has developed a 'lean' model and established UK best practice. Currently the key elements necessary to provide Lean Aerospace are being defined, leading to a robust framework and a deployment route map.

Through collaboration with the UK Lean Aerospace Initiative (UK LAI) research team ideas, views and findings, could be exchanged, thereby enriching both research programmes and maximising the benefit to UK aerospace industry. Figures 1 and 2 illustrate, respectively, the intended contributory research activities and the parallel development of both research programmes as envisaged shortly after the launch of the research programmes.

Although some time was spent gaining familiarity with the UK LAI, predominantly through literature reviews of background information pertaining to UK LAI and MIT lean manufacturing programme, information exchange and knowledge share between the two research programmes was inhibited by collaboration issues. Consequently it was not possible to complete activities that depended on the close collaboration with the UKLAI research programme such as 'Use of UK LAI questionnaire' and 'Evaluation of UK LAI metrics' (see Appendix A 'Project Plan'). This resulted in the decision to proceed with the agile manufacturing research programme making use of information that was being released into the public domain from both the UKLAI and MIT thereby still maintaining the capability to provide a valuable contribution to the UKLAI research programme.

Details of the collaboration issues are referred to in the minutes of steering group meetings.

1.4 Collaboration with the North West Aerospace Alliance (NWAA)

The North West Aerospace Alliance (NWAA) is an industry grouping in the North West of England which represents a broad cross-section of companies involved in aerospace activities. The Alliance represents an area that is totally unique in the United Kingdom and one of the most outstanding aerospace manufacturing areas anywhere in the world. The Alliance is an industry-led initiative, dedicated to promoting the region's world class aerospace and high technology engineering base. Formed in 1992, the Alliance was initially a lobbying organisation for the UK/NW Aerospace Industry. The NWAA is supporting Original Equipment Manufacturers (OEMs) and Small to Medium Size Enterprises (SMEs) and is particularly aimed at smaller subcontractors averaging around fifty employees, who had no track record of working together to maximise their resources.

The North West Aerospace Alliance represents more than 140 companies in the North West of England actively involved in the aerospace industry. These companies have total annual sales in excess of £5 billion. Over 75% of their products are exported and over 60,000 people are employed because of the industry's standing in the region. The Alliance has backing from prime aerospace companies such as British Aerospace and Rolls-Royce. The region's unique 'know-how' and skills base has played a major part in developing and producing some of the industry's most advanced and innovative products.

EPSRC Research: IMI/A/05/004 Project Abstract

NWAA played a key role in the agile research programme by:

- Providing expert knowledge from individuals such as the chief executive John Whalley, with extensive experience in the aerospace industry and expertise through his previous responsibilities within BAE SYSTEMS for Quality Management and Supply Chain Management.
- Facilitating the interaction and dissemination of information between collaborating members and the wider aerospace community. An example of this dissemination is the newsletter article published for distribution among alliance members and the wider aerospace community.
- Hosting and chairing all steering group meetings.

1.5 Collaboration with SMEs

The collaborating SMEs, are all suppliers to prime aerospace contractors, or major first-tier suppliers, looking for methodologies enabling them to apply lean and agile manufacturing: thereby more closely aligning, indeed integrating, their business processes with those of prime contractors such as BAe, Boeing, Lockheed-Martin, Rolls Royce, Lucas, Shorts, etc. The impact of this project has been significant in that the collaborating SME partners have been given access to the methodology that enables them all to better understand the migration paths available for moving towards agile manufacturing.

Key topic areas of agile practice

6 agile operational characteristics

Waste management and elimination
Real time production management
Effective information systems
Knowledge management
Change and risk management
Effective enterprise integration

30 key topic areas of agile practice

1	Working environment
2	Waste Time
3	Waste Space
4	Waste Materials
5	Communication within Groups/Teams
6	Communication between Groups/Teams
7	Multidisciplinary Teams
8	Customer Relations
9	Supplier Relations
10	Customer Knowledge
11	Supplier Knowledge
12	Customer Focused Production
13	Strategic Alliances
14	Rapid Collaboration
15	Process and project visibility
16	Capability planning
17	Skills and Competencies
18	Education and Training
19	Dynamic project scheduling
20	Utilisation of Resources
21	Process flow analysis
22	Capacity planning
23	Efficient and effective maintenance
24	Efficient and effective administration
25	Information Quality & Management
26	System Compatibility (standards, protocols and metrics)
27	Change deployment
28	Product Innovation
29	Risk
30	Responsibility

2 assessment frameworks

31 Integration within the business strategy

32 Use of metrics

Agile operational characteristics assessment matrix/questionnaire

	Agile Operational Characteristic Assessment Matrix					
	Topic \ Level	1	2	3	4	5
1	Working environment	The working environment is disorganised and untidy	It is recognised that a tidy, organised working environment can be beneficial to morale, productivity and the marketing of the business.	Initiatives are being pursued to improve the working environment. An organised tidy environment soon becomes disorganised and untidy.	There is evidence that a tidy, well organised working environment is beneficial to morale, productivity and marketing	The working environment is kept clean, well organised and tidy by a committed workforce.
2	Waste Time	No efforts to reduce set-up times. No efforts to reduce machine down time.	20%-40% of activities are the focus of set-up reduction. Some efforts are being made to reduce machine down time.	40%-60% of activities are the focus of set-up reduction. Machines identified as being process critical are the focus of activities to reduce down time.	60%-80% of activities are the focus of set-up reduction. Significant reductions have been made to unscheduled down time through focused activities	80%-100% of activities are the focus of set-up reduction. Unscheduled down time is negligible Stock levels are controlled to reduce waiting time
3	Waste Space	No efforts are made to reduce waste space	The need to consider the effect of inventory levels and floor space has been recognised.	Efforts are being initiated to improve inventory levels and floor space utilisation.	There is evidence to show that the initiatives undertaken to improve inventory levels and floor space utilisation are beneficial to the business	Inventory levels and floor space utilisation are maintained at optimal levels.
4	Waste Materials	No efforts are made to reduce the quantity of scrap and waste material produced.	Efforts are being made to reduce production defects/ errors and scrap.	Efforts are being made to reduce production defects/ errors and scrap. Some waste material and scrap is collected for recycling/disposal	Continuing initiatives have been successful in reducing production defects/ errors and scrap. Most waste material and scrap is collected and segregated prior to recycling/ disposal	There are no production errors or resulting scrap. All waste material is segregated for recycling (no production scrap).
5	Communication within Groups/Teams	Group performance is poor There is confrontation between individuals Individual roles are not understood Individual objectives are not understood.	Group performance is below average There is some confrontation between individuals Individual roles are not understood. Individual goals are vague.	Team performance is acceptable Individuals are comfortable with each other Individual roles are clear Individual goals are clear	Team performance is good Individuals work well together. Individual roles are understood Individual goals are understood. Team objectives are clear	Team performance is excellent Individuals are work well together Individual roles are understood. Individual objectives are understood. Team objectives are understood The team is open to outside influences and contributions
6	Communication between Groups/Teams	Inter-group performance is poor There is confrontation between groups Inter-group roles and objectives are not understood There is no awareness of business objectives	Inter-group performance is below average There is confrontation between some groups Some synergy between teams. There is a vague awareness of the business objectives	Inter-team performance is acceptable Groups comfortable with each other There is synergy between many teams Business objectives are communicated clearly down through the company.	Inter-team performance is good The majority of teams work well together and have a good understanding of their common objectives. Company business objectives are seen to effect team objectives.	Inter-team performance is excellent All teams within the company work together effectively to achieve their collective purpose.
7	Multidisciplinary Teams	Multi-disciplinary teams are not used.	It is recognised that multi-disciplinary teams may benefit the organisation.	Some multi-disciplinary teams are operating ie concurrent engineering work.	Many multi-disciplinary teams are working.	Many multi-disciplinary teams are working effectively and can show evidence of success
8	Customer Relations	Communication is poor, there is mistrust and conflict. Customer needs have not been identified. Satisfaction is not monitored. Deliverables are not clear.	Customers are implementing communication initiatives. Customer needs have not been identified. Customer satisfaction is not monitored. Deliverables are not clear.	Communication is good. Customer needs are monitored. Customer satisfaction is not monitored. Deliverables are agreed.	Communication is very good. Customer needs are monitored. There is interaction with regards to changes in production and products. Customer satisfaction is monitored. Deliverables are agreed and defined.	Communication is excellent, there is a high degree of trust Customer needs are continually monitored, there is a high level of interaction with regards to changes to production or products. Customer satisfaction is continually monitored. All deliverables are clearly defined and agreed with the customer at regular review meetings.
9	Supplier Relations	Communication is poor there is mistrust and conflict. Quality, cost and delivery requirements are rarely met.	Supplier communication initiatives are being implemented. Improvements are apparent in the ability to meet quality, cost and delivery requirements.	Communication with suppliers is good. In most cases quality, cost and delivery requirements are satisfied. Supplier needs are monitored.	Communication is very good. Quality, cost and delivery requirements are discussed and agreed upon. Supplier needs are monitored. There is interaction with regards to changes in production and products. Supplier satisfaction is monitored.	Communication is excellent, there is a high degree of trust. Supplier needs are continually monitored, there is a high level of interaction with changes to production, new and modified products. Supplier satisfaction is continually monitored. Quality, cost and delivery requirements are always met.
10	Customer Knowledge	There is no knowledge of customer business plans / strategy. Reaction times to changes in customer requirements are slow.	There is informal knowledge of customer business plans and strategies. Reaction times to changes in customer requirements are slow.	Mechanisms are being implemented that improve knowledge of customer business plans and strategies. Reaction times to changes in customer requirements are improving.	There is a good knowledge of customer business plans and strategies. Mechanisms are in place to facilitate customer knowledge transfer. Reaction times to changes in customer requirements are short.	There is a excellent knowledge of customer business plans and strategies. Mechanisms used to facilitate customer knowledge transfer. Reaction times to changes in customer requirements are minimal.
11	Supplier Knowledge	There is no knowledge of supplier business plans / strategy. Reaction times to changes in supplier requirements are slow.	There is informal knowledge of supplier business plans and strategies. Reaction times to changes in supplier requirements are slow.	Mechanisms are being implemented that improve knowledge of supplier business plans and strategies. Reaction times to changes in supplier requirements are improving.	There is a good knowledge of supplier business plans and strategies. Mechanisms are in place to facilitate supplier knowledge transfer. Reaction times to changes in supplier requirements are short.	There is a excellent knowledge of supplier business plans and strategies. Mechanisms used to facilitate supplier knowledge transfer. Reaction times to changes in supplier requirements are minimal.
12	Customer Focused Production	No production meets the quality, cost and delivery requirements of the customer	20%-40% of production meets the quality, cost and delivery requirements of the customer.	40%-60% of production meets the quality, cost and delivery requirements of the customer.	60%-80% of production meets the quality, cost and delivery requirements of the customer	80%-100% of production meets the quality, cost and delivery requirements of the customer.

Agile operational characteristics assessment matrix/questionnaire

13	Strategic Alliances	There are no strategic alliances with customers, suppliers or potential market competitors.	There is recognition that strategic alliances hold potential benefits. However there are no immediate intentions to initiate any strategic alliance initiatives.	There is recognition that strategic alliances hold potential benefits to the business. Strategic alliances with customers are being pursued.	Strategic alliances are being pursued with both customers and suppliers. There is evidence that alliances are working Efforts are being made to align and collaborate with potential market competitors	Effective strategic alliances exist with customers, suppliers and potential market competitors.
14	Rapid Collaboration	The potential benefits of rapid collaborations are not understood. No short term collaborations with other companies have occurred.	There is recognition that the company needs to be good at quickly entering collaborative agreements with other companies.	Initiatives are being undertaken to facilitate rapid collaborations with companies identified as being potential collaborators on future projects.	The company has developed its collaborative ability with selected companies. The company advertises its developing collaborative capability.	The company has successfully collaborated with other companies in order to satisfy customer requirements. The company advertises its availability and capability to enter into rapid collaborations. Collaboration friendly organisations are continuously monitored.
15	Process and project visibility	There is no project or process visibility. Actual activities do not equal scheduled activities. There is no visibility of customer/supplier processes.	Project and process plans are communicated along the external supply chain. Plans are unrealistic.	Project and process plans are communicated throughout the supply chain (internal and external). Scheduled and actual activities become detached.	Process and project visibility is good. Plans are communicated throughout the supply chain. Scheduled activities match actual activities.	Process and project visibility are excellent Plans are communicated throughout the supply chain. Scheduled activities match actual activities
16	Capability planning	The impact of new and changing capabilities throughout the organisation and supply chain is not addressed. There is no intention to increase / improve capabilities.	There are various, dissimilar, perceptions of capability within the organisation There is a high level of unused capability. Acquisition of new capability is slow and ineffective	Perceptions of capability are communicated at management levels. Unused capability is recognised as being a problem. Acquisition of new capability is slow.	Perceptions of capability are communicated at all levels within the organisation. Capability is effectively used. Acquisition of new capability is effected where appropriate.	Perceptions of capability are communicated at all levels and reviewed on a regular basis. Capability is communicated with customers, suppliers and partners. Capability is used effectively. Acquisition of new capability is effected where appropriate.
17	Skills and Competencies	There are no efforts directed towards enhancing skills and competencies.	Although the company recognises the need to enhance skills and competencies there is no direction or focus.	The company has identified its core skills and competencies and has implemented initiatives to ensure they are maintained.	The company is maintaining its core skills and competencies and is implementing new initiatives to develop skills and competence to enhance overall company capability	The company is effectively extending its range of core skills and competencies in line with the business strategy.
18	Education and Training	There is no company policy to support career development. There are no training schemes. There are no definite career development routes. There are no self development facilities.	There is no company policy to support career development. Training is dictated. Career development routes only exist for certain jobs. There are no self development facilities.	The company is generally supportive of career development. Training schemes are available. Career development routes only exist for certain jobs. There are some self development facilities	The company is supportive of career development. Training schemes are available and publicised. Career development routes only exist for certain jobs. Facilities for self development are available to everyone.	The company encourages career development Training schemes are available and publicised. Career development routes exist for all jobs. Facilities for self development are available to everyone.
19	Dynamic project scheduling	Schedules are not adhered to. Schedules are not communicated. Changes to the project schedule are avoided. Programme recovery cannot be achieved.	Schedule adherence is poor. Schedules are not communicated. Changes in project schedules are slow to take effect. Programme recovery times are high (months)	There are some difficulties with schedule adherence. Changes in project schedules are effected and communicated through the supply chain. Programme recovery times are short (weeks)	The organisation is able to adjust/reconfigure its schedules. Changes to schedules are communicated through the supply chain. The impact on other projects is minimal Recovery programme times are short (days)	The organisation is able to effectively and efficiently adjust/reconfigure its schedules and communicate the change to all relevant parties with no adverse effects.
20	Utilisation of Resources	Inadequate resources available. Resource is poorly managed Additional resources not available.	Sufficient resource available but not effectively distributed or managed. No additional resource available. Resources are shared on some projects.	Sufficient resources are available Some additional resource available if urgently required. Resources are commonly shared on a project basis.	Sufficient resources are available Some additional resource available if urgently required. Resource is effectively managed and distributed. Sharing of common resources is commonplace.	Sufficient resources are all integrated where relevant within and between business units. Resource is effectively managed. A clear project focus exists that permits appropriate sharing of resources
21	Process flow analysis	No analysis of production or process flows takes place.	Process flow analysis is conducted on 20%-40% of projects. Critical processes have not been identified.	Process flow analysis is conducted on 40%-60% of projects Many of the critical processes and flows have been identified.	Process flow analysis is conducted on more than 60% of projects. Critical processes and flows have been identified. Initiatives are underway to integrate process flow analysis with suppliers and customers	Process flow analysis is conducted on all projects. Critical processes and flows have been identified Process flow analysis is integrated with suppliers and customers.
22	Capacity planning	There is no capacity planning.	Capacity problems are addressed when delivery dates are not met. Some bottlenecks are formally identified There are large variances of work loading and high levels of WIP.	Capacity planning is used within the organisation. Capacity planning is ineffective. Many bottlenecks are formally identified Required capacity changes are slow to action. There are variances of work loading and unacceptable levels of WIP.	Capacity planning is used within the organisation Capacity planning is effective. Bottlenecks are formally identified Required capacity changes are effectively actioned. There are minor variances in work loading and low levels of WIP.	Capacity planning is used throughout the supply chain. Capacity planning is effective. Bottlenecks are formally identified Required capacity changes are effectively actioned There are minimal variances in work loading and optimal levels of WIP.
23	Efficient and effective maintenance	There is no regular maintenance of process and equipment (run to failure). No definite maintenance strategy.	There is a maintenance schedule, however the level of adherence is low. A large proportion of system failures and quality problems are due to poor maintenance. There is no definite maintenance strategy.	Regular maintenance is carried out according to a schedule. Maintenance procedures are not easily accessible nor do they contain relevant levels of fault diagnosis. A definite maintenance strategy is in place.	Regular maintenance is carried out according to a schedule and written procedures. Maintenance procedures are easily accessible. Initiatives are underway to integrate and align customer and supplier maintenance schedules. A definite maintenance strategy is in place.	Scheduled maintenance is carried out on a regular basis. Down time due to quality problems and system failure is negligible Maintenance schedules are aligned throughout the supply chain. Maintenance procedures contain extensive diagnosis information are easily accessible.

Agile operational characteristics assessment matrix/questionnaire

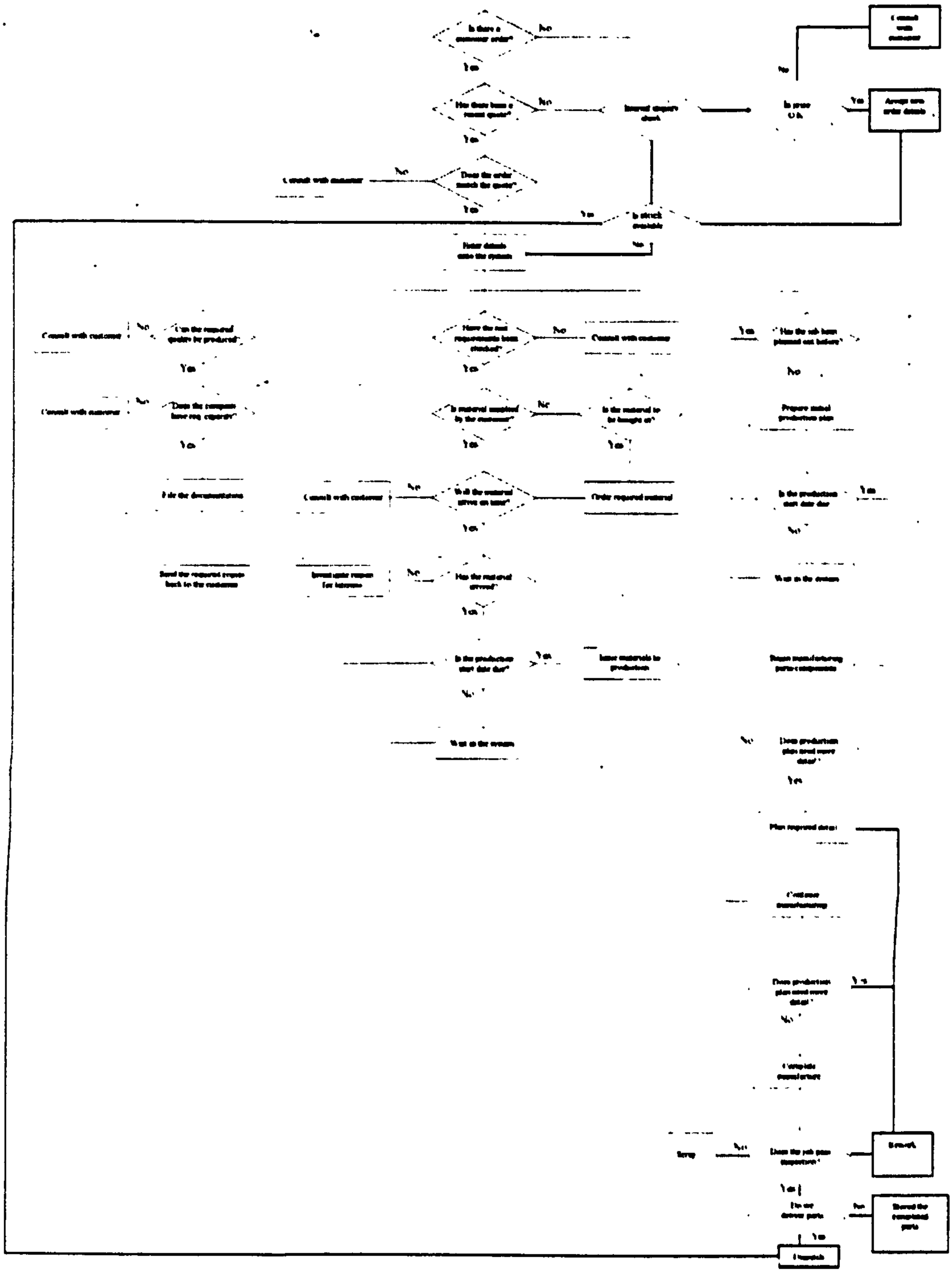
24	Efficient and effective administration	Administrative procedures are excessive.	Administrative procedures are generally considered to be excessive. Some procedures are bypassed in order to complete work. There is poor alignment with customer and supply administrative procedures.	Administrative procedures are considered to be a necessary evil Initiatives are being undertaken to improve effectiveness and efficiency of admin procedures There is still a lack of standardisation between customer and supplier admin procedures.	Administrative procedures are recognised as being an important source of information Initiatives are being undertaken to improve the effectiveness and efficiency of all admin procedures and to align them with both customers and suppliers.	Administrative procedures are recognised as being a vital source of information. Initiatives are being undertaken to improve effectiveness and efficiency of admin procedures throughout the supply chain.
25	Information Quality & Management	Information quality is characterised by -Incorrect/irrelevant information -Variance -Duplication -No traceability	It is necessary to filter accurate information from that which is made available. There is a large amount of variance in the information available Not all information is traceable There is a high level of duplication	It is necessary to filter accurate information from that which is made available. There is some variance of the information available Not all information is traceable There is some duplication	Accurate relevant information is available. All information is traceable There is no variance of information There is some duplication	Accurate relevant information is provided Information is available in a variety of formats. All information is traceable. There is no variance of information. There is minimal duplication
26	System Compatibility (standards, protocols and metrics)	Systems are incompatible, internally and externally with customers and suppliers.	There is a high level of system incompatibility. Efforts are being made to align standards and protocols within the organisation.	There is a moderate level of system incompatibility Efforts are being made to align standards and protocols with suppliers and customers. System performance measures and monitors in place. Procedures are being documented.	There is a high level of system compatibility. Standards and protocols are aligned with suppliers and customers. Appropriate technology is used. System performance measures and monitors in place. Procedures are being documented.	There are no system incompatibility issues.
27	Change deployment	Some changes are proposed but are always doomed to failure.	Management initiatives appear but findings tend to be ignored and the majority of initiatives fail.	Some initiatives are adopted. Most initiatives geared to process changes are successful.	Consultation takes place before initiatives are introduced. Initiatives are successful but there is no ongoing support.	Effective change deployment.
28	Product Innovation	No innovation in product.	All innovation is imported from outside the company.	Some innovation is generated internally.	New products or versions of product have been generated internally.	Effective marketing of innovation to customers and impact on customer product lines
29	Risk	There is no attention given to the appropriate distribution of risk. Problems are fought as they occur. There is no risk management	Risk between customers, suppliers and partners is unevenly distributed. No efforts are made to readdress the balance. Risk management is ineffective.	Project risks are discussed at the beginning of a project but are not readdressed. There is realisation that risks change through the project life cycle. Risk management techniques are used.	Project risks are discussed at the beginning of the project and at set points in the project life cycle. Initiatives are being pursued to distribute and manage changing project risks. Risk management techniques are used effectively.	Project risks are discussed with customers, suppliers and partners throughout the project life cycle Risk is effectively distributed Risks are managed effectively
30	Responsibility	There is no ownership of responsibility. Responsibilities are not effectively distributed. Decisions are not made.	Responsibilities are discussed at the beginning of a project. Responsibilities are not effectively distributed Decisions made are not effective.	Responsibilities are discussed at the beginning of a project but are not readdressed. Responsibilities become unevenly distributed. Decisions are made but are not managed effectively	Responsibilities are discussed at the beginning of the project and at set points in the project life cycle Initiatives are being pursued to distribute and manage changing responsibilities	Responsibilities are well defined throughout the supply chain. Responsibilities are evenly and effectively distributed Decisions and change are effectively managed.
31	Integration within the Business Strategy	None of the above categories are included within the business strategy	Less than 50% of the above categories are included within the business strategy Initiatives are underway to include the remaining categories within the business strategy	Over 50% of the above categories are included within the business strategy Initiatives are underway to include the remaining categories within business strategy	Over 80% of the above categories are included within the business strategy Initiatives are underway to include the remaining categories within business strategy	All the above categories are included within the business strategy
32	Use of Metrics	Metrics are used to monitor 0%-20% of the above categories. There is no alignment of business performance metrics	Metrics are used to monitor 20%-40% of the above categories. There is some alignment of business performance metrics	Metrics are used to monitor 40%-60% of the above categories. Initiatives are being pursued to align performance metrics down through the supply chain.	Metrics are used to monitor 60%-80% of the above categories Initiatives are being pursued to align business performance metrics down the supply chain.	Metrics are used to monitor 80%-100% of the above categories. All business performance metrics are aligned with customers and suppliers.

Weighting matrices

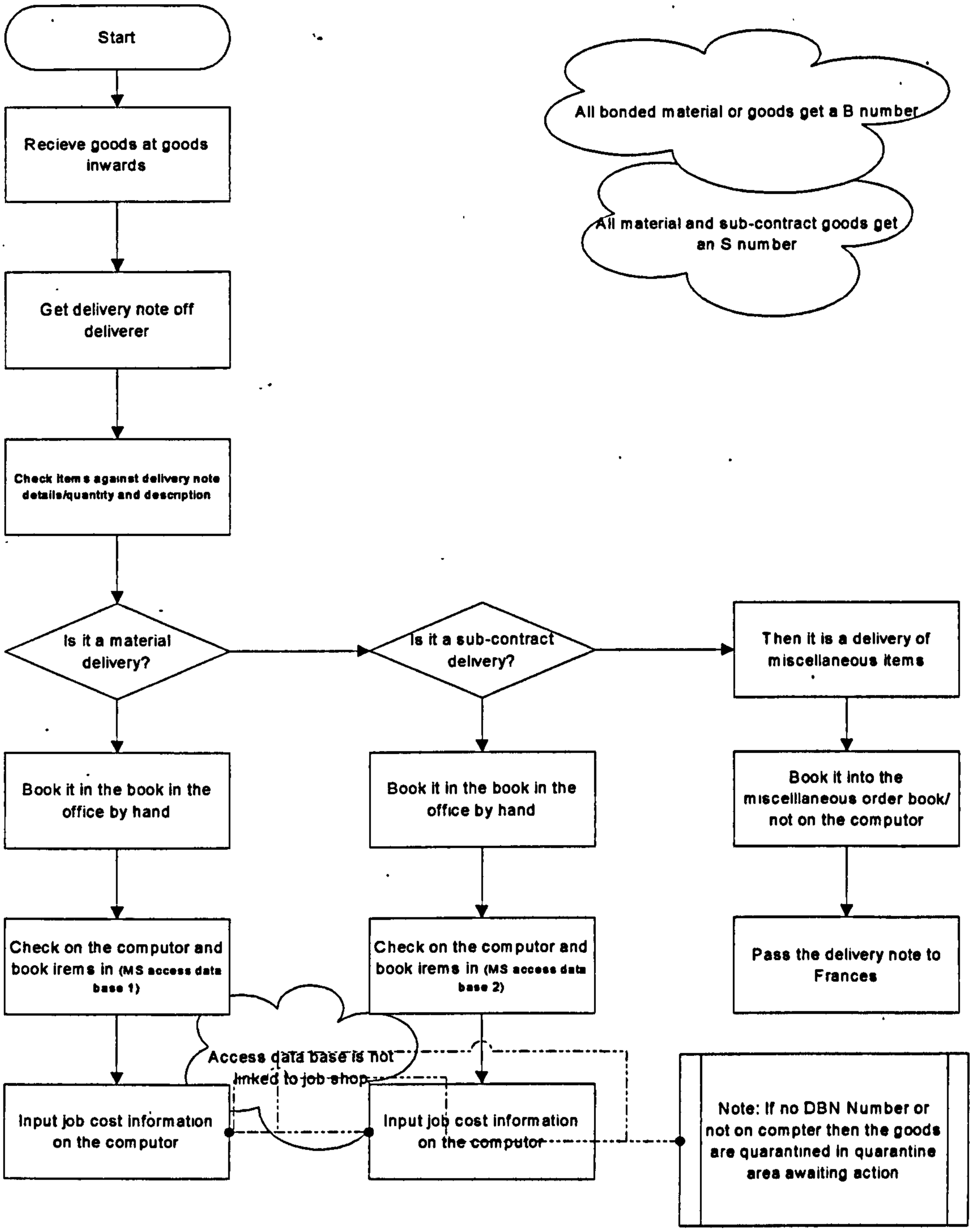
	Agile Practice/Topic Area \ Agile Operational Characterisitic	Knowledge Management	Effective Information Systems	Change Management	Effective Enterprise Integration	Real Time Production Management	Waste Management and Elimination	Weighting per topic area	Percentage contribution toward operational characteristics
1	Working environment	1	32	32	32	243	243	583	2.05%
2	Waste Time	1	32	32	32	243	243	583	2.05%
3	Waste Space	1	1	32	1	32	243	310	1.09%
4	Waste Materials	1	1	1	1	32	243	279	0.98%
5	Communication within Groups/Teams	32	243	243	243	32	1	794	2.79%
6	Communication between Groups/Teams	32	243	243	243	32	1	794	2.79%
7	Multidisciplinary Teams	32	32	243	32	32	1	372	1.31%
8	Customer Relations	243	243	243	243	243	32	1,247	4.38%
9	Supplier Relations	243	243	243	243	243	32	1,247	4.38%
10	Customer Knowledge	243	243	243	243	32	32	1,036	3.64%
11	Supplier Knowledge	243	243	243	243	32	32	1,036	3.64%
12	Customer Focused Production	243	32	32	243	243	32	825	2.90%
13	Strategic Alliances	243	243	32	243	32	1	794	2.79%
14	Rapid Collaboration	32	243	243	243	243	1	1,005	3.53%
15	Process and project visibility	32	243	243	243	243	32	1,036	3.64%
16	Capability planning	243	32	32	243	243	32	825	2.90%
17	Skills and Competencies	243	32	243	32	243	1	794	2.79%
18	Education and Training	243	243	243	32	32	32	825	2.90%
19	Dynamic project scheduling	32	243	243	243	243	1	1,005	3.53%
20	Utilisation of Resources	243	32	243	243	243	243	1,247	4.38%
21	Process flow analysis	32	32	243	243	243	243	1,036	3 64%
22	Capacity planning	32	32	32	243	243	32	614	2.15%
23	Efficient and effective maintenance	32	32	32	243	243	243	825	2.90%
24	Efficient and effective administration	1	243	32	243	32	243	794	2.79%
25	Information Quality & Management	243	243	243	243	243	243	1,458	5.12%
26	System Compatibility (standards, protocols and metrics)	243	243	32	243	243	32	1,036	3.64%
27	Change deployment	32	32	243	243	32	1	583	2.05%
28	Product Innovation	243	32	243	243	1	1	763	2.68%
29	Risk	243	243	243	243	243	1	1,216	4.27%
30	Responsibility	243	32	32	243	32	32	614	2.15%
31	Integration within the Business Strategy	243	243	243	243	243	243	1,458	5.12%
32	Use of Metrics	243	243	243	243	243	243	1,458	5.12%
	Total score per operational characteristic	4,456	4,549	5,213	6,237	5,002	3,035	28,492	100%
	Maximum possible score per operational characteristic on agile questionnaire	22,280	22,745	26,065	31,185	25,010	15,175		
	Minimum possible score per operational characteristic on agile questionnaire	4,456	4,549	5,213	6,237	5,002	3,035		
	Max-Min per operational characteristic on agile questionnaire	17,824	18,196	20,852	24,948	20,008	12,140		

Company A process mapping example

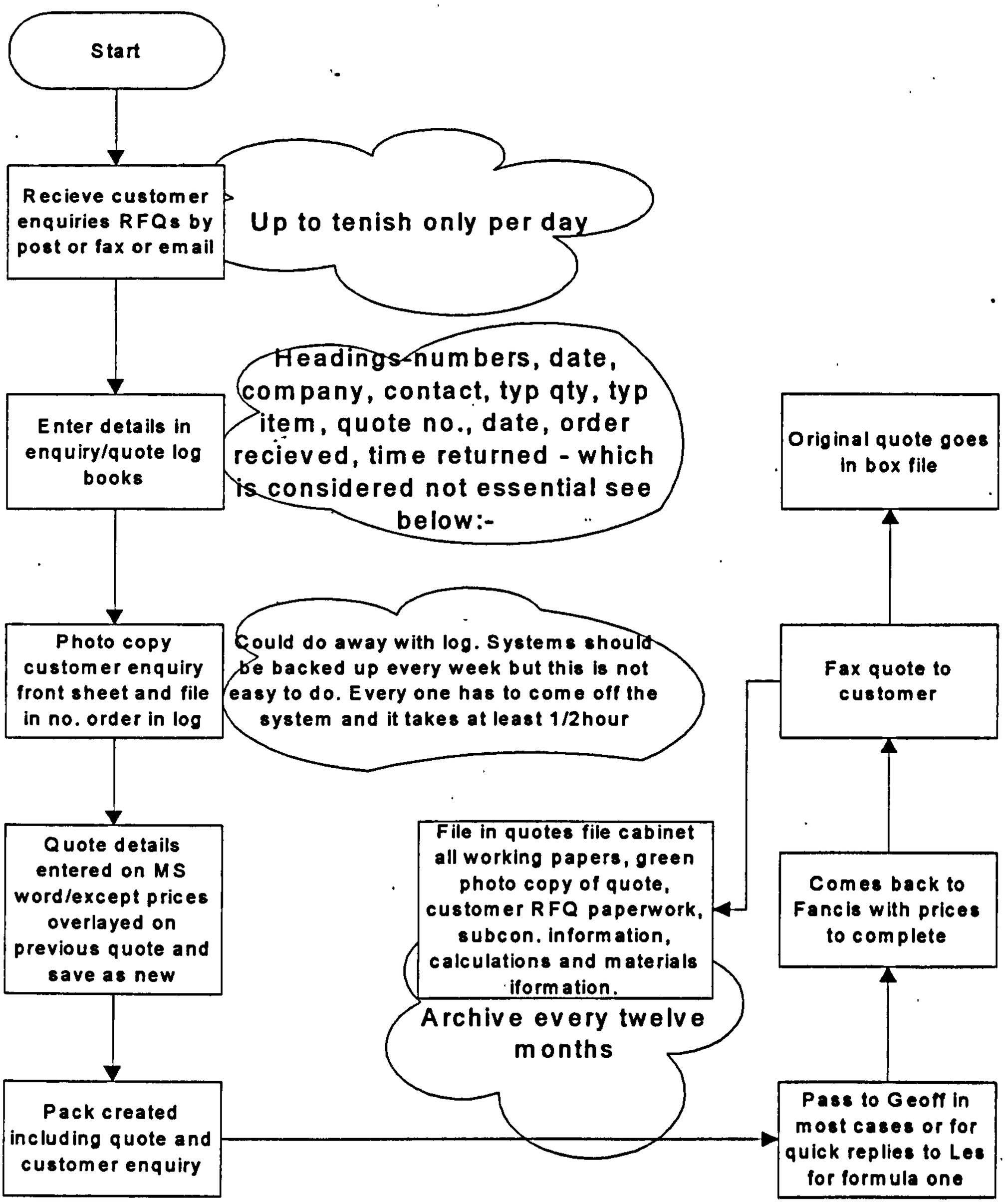
Customer Order Processing:



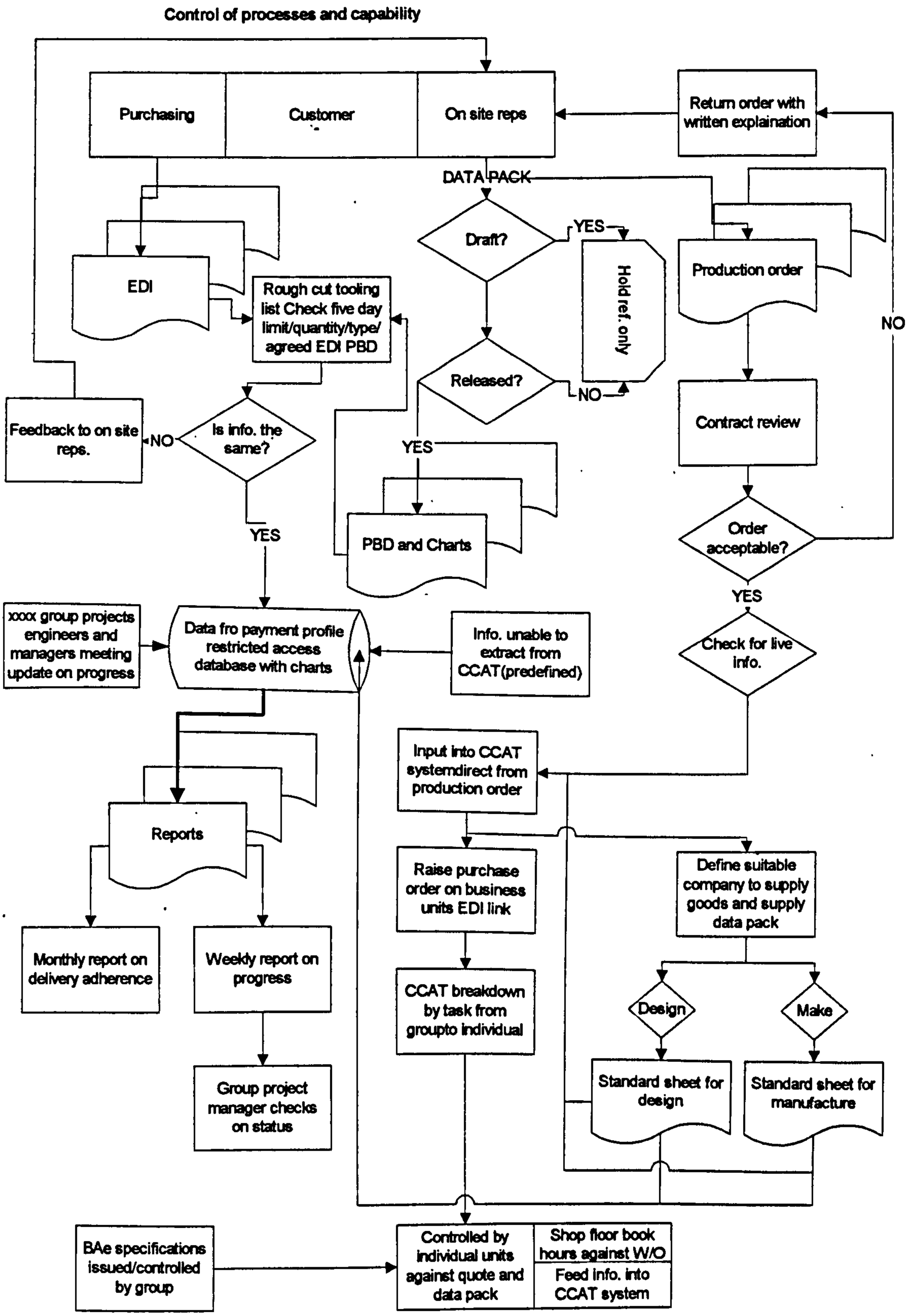
Company C process mapping examples



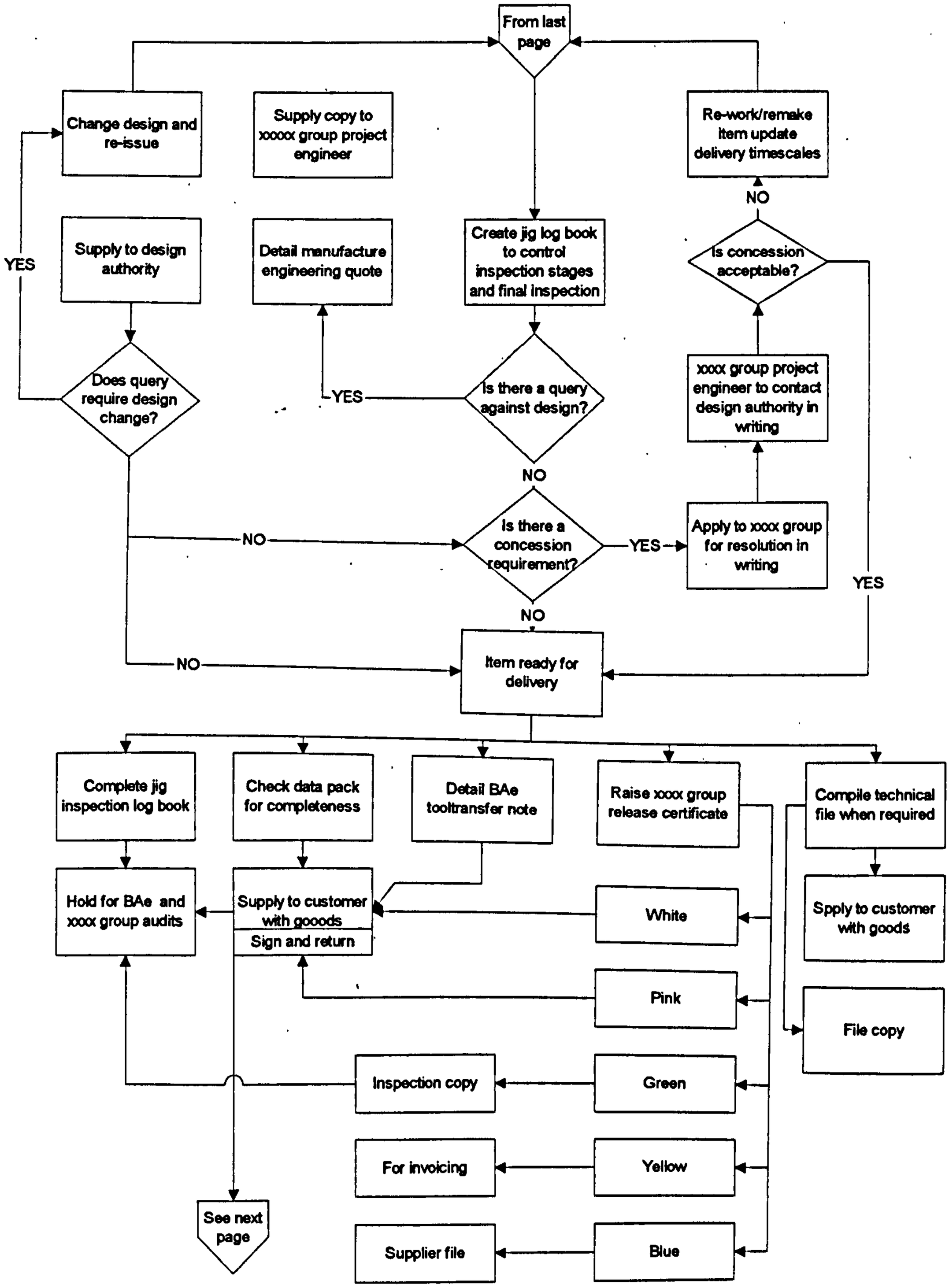
Company C process mapping examples



Company D process mapping examples



Company D process mapping examples



Company D process mapping examples