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Title Constraints on the implementation of concurrent engineering with suppliers in civil and defence design communities: differentiating design ethos, Volume 1

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CONSTRAINTS ON THE IMPLEMENTATION OF CONCURRENT ENGINEERING WITH SUPPLIERS IN CIVIL AND DEFENCE DESIGN COMMUNITIES: DIFFERENTIATING DESIGN ETHOS'

By

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A thesis submitted to the Luton Business School, University of Luton, in

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Abstract

Successful Concurrent Engineering (CE) with suppliers requires a pre-disposition on the part of the prime company and the supplier to work in this manner. This thesis explores the impact of design ethos on the implementation of Supplier-in-Loop (SIL) CE between an Original Equipment Manufacturer (OEM) and a first tier supplier. Design ethos for the purpose of this thesis is described as 'a characteristic manner or approach to constraints on SIL displayed by personnel involved in the design of new products'.

This research employs a mixed-method to understand SIL constraints across industry sectors. A design ethos framework is developed and a military design community is characterised in terms of anomalies to the existing literature. These anomalies are then tested through a questionnaire and then interpreted in terms of the design ethos framework. The results of this comparison show that some characteristics are common to both the civil and military design communities and some are not.

A case is made that design ethos, in the context of SIL, is primarily determined by: suppliers' aptitude, skill level and contracts; problems with data / information exchange mechanisms; existing processes, relationships and management support; supplier history; technological view of the product; external influences on the process; existing design milestones; visibility of supplier capability; and, continuity of service in terms of skill and data security.

The research concludes that the implementation of SIL is directly impacted by design ethos, and that for SIL to be a success in the military sector design ethos must be managed in line with business objectives.

The contribution to knowledge that this thesis provides is the insight it offers into the human issues associated with implementing concurrent engineering with external suppliers, and the identification of sector-specific issues as well as those which will benefit from cross sectoral learning. It is of value to military and civil OEMs for purpose of change management, also to their suppliers in understanding the different needs of military and civil customers when working in a concurrent engineering manner.

The Candidate

Elly Philpott has a first degree in Physical Science from Coventry University and a Masters of Science in Information Technology for Manufacture from the University of Warwick. She joined Luton Business School in 1997 with 6 years experience of the telecommunications industry gained in manufacturing; quality, purchasing and world wide supply management in the field of electronic components.

The first two years of this study ran concurrently with the EPSRC project, AEROEXTN; in which she was a Research Fellow. In the third year of this research, she was self-funded, while maintaining a role as a visiting lecturer and providing consultancy to academia and industry.

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Preface

Having had experience of the telecommunications and electronics industries world wide, the aerospace industry presented an interesting career move and learning opportunity for the author. Coming from a background devoid of the services or things military, the military environment also presented a 'new world' that demanded further investigation. The military sector's unique viewpoint on the commercial world together with specialist technological requirements appeared to have created what seemed at first to be quite an antiquated and slow moving approach to interdisciplinary design. The sector's seemingly reluctant, rather late interest in supplier involvement in design was surprising and led the author to investigate the reasons behind this caution. Having discovered some of the identified problems to be surmountable, the concept of 'design ethos' was developed in an attempt to explain the remaining problems.

The first two years of the research was funded by the EPSRC in the form of grant GR/L32675. The remaining year was funded in part by the University of Luton through waiver of fees. The author thanks both funding bodies.

Following the EPSRC funded research, continued access to the military design community for the case study was facilitated by Cliff Fowkes (MBD) and Roger Hadfield (BAe). The author wishes to thank these people for their continued interest and support.

Finally, no part of this work has yet been published.

List of Definitions

Abbreviation	Definition
2D	2 dimensional
3D	3 dimensional
ASRAAM	Advanced Short range Air to Air Missile
BAe	BAe Systems – formerly BAe defence
BTP	Build to Print
BTT	Build to Tape
CAD/CAM	Computer Aided Design / Computer Aided Manufacture
CADDS5	Computer aided design system produced by PTC, formerly by Computervision
CAE	Computer Aided Engineering
CASA	Construcciones Aeronautic Sociedad Anonima
CATIA	Computer Aided design system produced by System Dassault
CBI	Confederation of British Industry
CE	Concurrent Engineering
CI	Commercial Imperative
CIPS	Chartered Institute of Purchasing and Supply
CMS	Change Management System
CSC	Computer Science Corporation
DERA	Defence Research Agency
DFA	Design For Assembly
DFM	Design for Manufacture
DOD	Department of Defense (US)
DPA	Defence Procurement Agency
DRS	Design Record System
EC	European Community
ECS	Engineering Change Management
EDM	Engineering Data Management
EPSRC	Engineering and Physical Science Research Council
ERDF	Engineering Research Development Facility
ESI	Early Supplier Involvement[1]
ESPRIT	European Strategic Programme for Research in Information Technology
FMEA	Failure Mode and Effect Analysis
GPS	Global Positioning System
IDT	Integrated Design Team
IFPMM	International Federation of Purchasing and Materials Management
IGDS	Integrated Graduate Development Scheme
IGES	Initial Graphics Exchange Specification
IMI	Innovative Manufacturing Initiative
IPG	Integrated product Group
IPR	Intellectual Property Rights
IT	Information Technology
JIMS	Joint Information Management System
LOL	Limit of Liability
MA&A	BAe Military Aircraft and Aero-structures
MBD	Matra BAe Dynamics (UK)
ME	Mind's Eye
MEP	Major Equipment Manufacturer
MOD	Ministry of Defence (UK)

[1] This is the definition used in this thesis. Other definitions exist e. g., Early Simultaneous Influence (Hull et al. 1996)

Abbreviation	Definition
MOU	Memorandum of Understanding
NC	Numerically Controlled
NIH	Not Invented Here
NPD	New Product Development
NPI	New Product Introduction
NRE	Non Recurring Engineering[2]
NTMS	Non Traditional Military Suppliers
O	Organisational factors
OCCAR	Organisme Conjointe de Co-operation en Matiere
OEM	Original Equipment Manufacturer
P	Problem definition – Problem solving
PDM	Product Data Management
PDS	Post Design Services
PDSR	Process Design Standardisation Ration
PIWG	Producibility Interaction Working Group
Pro-Engineer	CAD system produced by PTC
Pro-PDM	Product Data management system produced by PTC
Rapier	Low level Air defence missile system
RSME	Royal School of Military Engineering
SBAC	Society of British Aircraft Companies
SCORE	Supplier Cost Reduction process at Chrysler
SCRIA	Supply Chain Relationships in Aerospace
SD	Standard Deviation
SIL	Supplier in Loop
Storm Shadow	Conventionally armed stand off missile
SVL	Soft Vertical Launch missile
TFGs	Taken for Granteds
TPC	Task Packet Controller
Ts and Cs	Terms and Conditions of a contract
TQM	Total Quality Management
UPC	Universal Product Code
VA/VE	Value Adding / Value Engineering process at Honda
WAP	Wireless Application Protocol

[2] Other definitions exist such as Non Recurring Expenditure

Acknowledgements

My thanks go to the industrial collaborators who allowed me what must be unprecedented access to their design personnel on a number of projects. My thanks go to the AEROEXTN team, namely Graham Bicknell, Alan Sinfield, Paul Fryer, Roy Vose, Brian Williams, Alan Gaskell, Steve Russell, and to Cliff Fowkes and Bill Broom who gazed from afar, keeping their heads when all around them were losing theirs.

I would also like to thank numerous other people at Matra BAe Dynamics and BAe Military Aircraft and Aero-structures who allowed me to question them not only about their business, but also about their insights into what inhibited their business as well as their own detailed experiences.

I would like to thank Mike Gregory who diligently maintained workshop and meeting minutes, without which my case study would no doubt have been incomplete. Thanks to Ann Anderson who bravely undertook to be my external supervisor. My thanks to Tom Connor for being my second supervisor and to Professor Dave Hamblin, who supported me in my original idea for this research and who coached me in the unfamiliar world of academia. Dave helped me to develop academic and team skills and has continually been a source of encouragement as well as becoming a valued friend and role model.

I would like to thank my Dad and family for their encouragement in unfamiliar territory and the numerous proof - readers who steered me in the right direction.

Finally, I thank my husband Phil for his love and support during this time and my two little girls Christina and Jane for just being themselves and reminding me what really is important in life. One day, I hope they and theirs will be proud.

Declaration

This research followed on from the AEROEXTN project, an IMI supported programme[3] in the aerospace defence industry researching Concurrent Engineering (CE) in the Extended Enterprise, of which Luton University took primeship. This thesis concerns the wider study of the Matra BAe Dynamics (MBD) design community and its suppliers, two of whom also participated in the earlier project.

To support the objectives of the research the author undertook an additional literature survey in the areas of CE implementation, supply chain management, organisational culture and ethos, which was outside the scope of the AEROEXTN project. The development and formulation of underlying constraint groupings and design ethos constructs involving questionnaire development, piloting and evaluation is her unaided work.

The MBD case study is considered to be confidential to the company and for this reason detail will remain author controlled following thesis assessment. In addition to the MBD collaboration, Ford, Vauxhall, GKN Westland Helicopters, BAe Military Aircraft and Aero-structures and Lockheed Martin ASIC completed questionnaires as well as allowing key personnel to be interviewed on specific issues.

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of Luton. It has not been submitted before for any degree or examination in any other University.

Elaine Philpott — November 2001

Elaine Philpott — Date

[3] IMI- An Innovative Manufacturing Initiative of the Engineering and Physical Science Research Council

1 Introduction

This thesis describes the exploration of constraints when implementing Concurrent Engineering (CE) in the Extended Enterprise. It further develops and explores the concept of 'design ethos' and identifies similarities and differences between industrial sectors that may aid practitioners in CE implementation and add to the existing academic body of knowledge.

This chapter describes the reasoning behind the exploration of constraints and design ethos in terms of contextual background. It also outlines the structure of the research methodology in terms of research method, concept formulation, testing and analysis of findings.

Under 'contextual background', this chapter describes the military sector's unique viewpoint on the commercial world and its seemingly reluctant, rather late interest in supplier involvement in design. Problems are identified with the paradigm[4] in the military context and possible solutions are discussed. The author then describes how the concept of 'design ethos' was explored and developed in an attempt to explain the remaining problems.

[4] Paradigm : a set of basic beliefs (or metaphysics) that deals with the ultimates of first principles. It represents a *worldview* that defines, for its holder, the nature of the "world," the individual's place in it, and the range of possible relationship to that world and its parts...(Denzin and Lincoln 1994)
'Worldview' : according to Geertz (1999) is a picture of the way things in sheer actuality are, a concept of nature, or self or society.

The concept of design ethos is of interest to practitioners in understanding the differences and similarities between industrial sectors when implementing CE programmes with design communities. The research content is of interest to academics in that it provides additional case based evidence of constraints when implementing CE that adds to the existing body of knowledge.

1.1 Contextual background to study

This thesis concerns the exploration of the 'design ethos' concept with the Matra BAe Dynamics (MBD) design community and its suppliers, during and following a pilot program implementing CE in the Extended Enterprise.

This exploration of CE constraints and design ethos described in the following chapters followed on from the AEROEXTN project, an IMI supported programme[5] in the aerospace defence industry researching CE in the Extended Enterprise, of which Luton University took primeship.

The author undertook an additional literature survey in the areas of CE implementation, supply chain management, organisational culture and ethos, which was outside the scope of the AEROEXTN project. The development and formulation of underlying constraint groupings and design ethos constructs

[5] IMI- An Innovative Manufacturing Initiative of the Engineering and Physical Science Research Council

involving questionnaire development, piloting and evaluation was her unaided work.

The academic-industrial collaboration undertaken represented an uncommon opportunity to access a military design community. While the literature reflected the CE experiences of many companies from the civil sectors of aerospace (Holmes 1994); car manufacture (Lamming 1993; Twigg 1995; New and Burns 1998); telecommunications and retail electronics (De Graaf and Kornelius 1996; Swink 1996); little was written of the experiences of companies designing military products.

Pennell et al. first described what was meant by CE and outlined the advantages and limitations of CE in a defence context (Pennell et al. 1989):

> Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. The approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements.

In a study of fourteen companies, 10 universities and numerous US institutions and agencies, they found evidence that the application of CE methods achieved improved quality, lower cost and shorter development cycles. However, they also identified 'pitfalls' or limitations with CE implementation in that success required not only management support but also commitment in terms of the 'larger' systems in the business, for example training. They also identified that a customer's requirements with respect to contracting could negatively impact CE success and that anything that acted to decouple production from design in effect stifled continuous improvement.

A further point was the effect CE appeared to have on the product cost profile. In some cases early design stages took greater time and therefore cost more; however, this was compensated for in savings once production had started. Pennell et al. further stated that the inclusion of suppliers in the conceptual phase of development [CE in the Extended Enterprise] was only one of a combination of management initiatives used to achieve CE aims. The others being: emphasising customer needs; improving horizontal integration; promoting employee involvement and requiring engineering comparison of proposed products and competitive offerings.

A further point in the work of Pennell et al. was that there was no one panacea to CE implementation and that various CE methods and tools were used to achieve the same objectives. This point is born out by the work of Prasad who states that there is no 'cookbook solution for integrated product development' (Prasad B 1997).

The work of Pennell convinced the author of the importance of effective CE in a military context while the work conducted in the civil sector made manifest some challenges remaining to practitioners in terms of effective implementation of CE in general.

An in-depth case study was needed to understand CE in the extended enterprise in a military context. The research needed to understand not only the real problems of a military design community in accepting what are predominantly civil practices, but also understand the soft factors at play, in this type of community, that are very often ignored to the detriment of change programmes elsewhere.

Finally, an understanding was required of the differences and similarities between military and civil design communities on both counts. Such knowledge could then be used to inform similar programmes in the military environment and add to the existing body of knowledge that exists through experience in the civil sector.

1.2 Integrating suppliers into design in the military sector – why not?

In the aerospace industry, knowledge associated with individual components will in future reside more frequently in suppliers than in the prime contractor (Anon 1997b, Bozdogan 1997, Scott 1996).

Graham (1995) stated that very little attention appeared to have been paid to the way in which buyer-supplier relationships were shaped and informed by the peculiar political and technological context within which arms production took place. This still appears to be the case especially in the context of applying the concept of integrated product groups across company interfaces. A number of obvious hurdles can be identified. These are as follows:

- Security of information and the restrictions that this may impose for sharing information with individuals, companies and in a true extended enterprise, groups of companies.
- The global market could require work share, or clients could require specific suppliers who may be uncomfortable with such arrangements
- The funding and contractual requirements of defence contracts may provide uncertainty for defence suppliers making them reluctant to commit resource without clear rewards or recompense for work carried out.
- Existing intransigent procedures or personnel may be just too cumbersome and costly to change.
- The buy-profile[6] is such that 70 per cent is with major equipment manufacturers, some of who could be direct competitors in other areas and who are reluctant to collaborate.

The combination of these factors has resulted in design communities that share technological tools and premises, but operate completely different time and cost priorities, and working practices, based on the project priorities at hand. There would appear to be an entrenched view that 'arms-length', or Build To Print (BTP) is the most appropriate way of the design function working with suppliers at the component level in the military sector. Nonetheless, it is apparent that some hurdles are surmountable, indeed issues quoted as specific constraints[7], when investigated, no longer constitute a constraint at all. For instance, suppliers unwilling to commit to a project due to funding uncertainty can be cajoled using appropriate contracts and long term business commitments elsewhere. Intransigent procedures or personnel can be changed with appropriate management methods. Increasingly in Europe, major equipment suppliers who were once competitors are now merging or are merging with their own customers. When this has happened in other industries, e. g., telecommunications,

[6] buy-profile – a company's total monetary spend in terms of acquisition cost for components and sub-systems. Usually excludes: acquisition (transaction) cost, inventory holding costs, stock-out costs and inventory management costs.
[7] Constraint – Issue that confines the actor to the existing circumstance or prevents implementation of the new

major cost reductions are required in terms of synergy of technology and personnel. As such, initiatives that potentially provide solutions in both areas are embraced.

Given that one-time constraints are now shifting perhaps other variables are at play, that would explain this lethargy towards CE in the extended enterprise.

Belbin (1996) argues that very large organizations, consisting of multiple layers of management, are inhibited in their ability to work efficiently in internal teams. Logically, this would extend to intra-company teams. If this were completely true, why are companies comparable in size to defence companies; with all the same types of technological challenges, consistently able to reduce lead-time and cost targets with the help of their suppliers?

This cognitive dissonance (Hiebeler et al. 1998) has led the author to hypothesize the idea of there being an 'ethos' associated with design communities which may or may not pre-dispose them to specific traits[8]. The trait in this case is the predisposition to implement CE in the extended enterprise.

[8] Trait – "… Feature. Distinguishing quality" The Little Oxford Dictionary, 5th Edition, June 79

1.3 The value and pitfalls of cross-sectoral analysis

1.3.1 Best practice

Best practice and benchmarking studies are a pre-requisite for any company striving for world class status. Indeed, some would argue the same is required of any company wishing to maintain or grow market share in what is an increasingly wolf-like global market. In this sea of example, a number of well known companies primarily from the automotive industry (Chrysler: Dyer (1996) and Toyota: Womack et al. (1990)) and the electronics industry, (Motorola and Philips, see Lewis (1995); Cox and Lamming (1999) are held high as examples of supply chain good practice, or at least they were in the early 90s.

'Best Practice' for purposes of this thesis is therefore practice, which appears potentially to improve the company-in-question's process efficiency now to a point that agreed objectives can be met. The company in question, for purposes of this dissertation is MBD.

This author concurs with Hiebeler, Kelly and Kettemans' definition (1999), where 'best' is a contextual term meaning 'best for you' - in the context of a business, a company, a culture, a use of technology, and a competitive strategy. They further describe the purpose of best practice to disturb with new ideas and insights. Disturb is intended in a positive way: where all creative ideas and insights have their origin in the minds of people dissatisfied or puzzled by what they encounter in the world. They go on to describe how this 'cognitive dissonance' demands a resolution to problems, simple or complex and how sometimes discovery comes in a sudden illumination and sometimes over months of trial and error. Having experienced such cognitive dissonance, in the problems remaining with CE implementation with suppliers, the author intended the research to provide illumination for the collaborators.

1.3.2 Generalisability

To resolve this cognitive dissonance, it was perhaps necessary to look further afield than the military sector, or indeed the aerospace sector, for understanding. The major problem with this then became generalisability of findings. While we can be 'disturbed in a positive way' by what is published from other business sectors, we can not pretend that the learning is exemplary across a wide variety of companies, let alone across business sectors. Boyson et al. (1999) state that industry conditions vary widely and industries generate their own unique opportunities and threats. Because of this, they necessitate distinct internal competencies and relationships with enterprise partners. For example, computer manufacturers operate on very small margins in a lightning-fast, volatile consumer market. Given the small size of their margins, these companies place a premium on extended enterprise design that minimises inventory and maximises customisation of finished products for the consumer. By contrast, chemical industry firms operate under tremendous regulatory and civil liability burdens.

These companies place a premium on extended enterprise design that maximises strategic control of risk and seeks to ensure safe and reliable practices of all supply chain partners. Boyson et al. further state that in addition to differences across industries, the extended enterprise must also take into account differences based on the size of the firm. The size of the company in relation to its competitors significantly defines the nature of the strategic actions taken to maximise internal resources. For example, startup firms can combine their own resources and the resources of their supply chain partners to seize new opportunities and reap entrepreneurial profit. These partnerships can exploit competitive uncertainty and market niches overlooked by firms that are more traditional. On the other hand, larger firms with market power and leadership can use their formidable internal resources and those of their supply chain partners to saturate markets and meet large-scale customer demand.

It would seem that aerospace companies are more akin to chemical companies in their needs and expectations of an extended enterprise. However, the aerospace sector can be distinguished from other sectors in the following areas:

- Customer requirements – volume/degree of customisation / frequency of change / environment / total life cost
- The influence of competition
- The design cost profile
- Technology maturity required – reliability / liability (product and infrastructure)
- History – future
- Internal organisation (function/project/distributed/centralised)

The defence aerospace business can be distinguished from the civil aerospace business by a number of further points. These manifest themselves in the stringent and regimented controls adopted for special clients. Governments, as special clients, are not only customers, they are the gatekeepers for business with external clients. Both the UK MOD and the US Department of Defense (DOD) control who their respective defence companies deal with. For instance, the DOD has the Strategic Goods Limitation Act, which explicitly forbids trade to specific countries.

This influence not only affects the business units within companies directly but also reaches the day to day procedures of the technical functions through required standards and individual vetting in the form of the Official Secrets Act in the UK and restrictions on certain types of electronic communications.
In addition to this the special technical requirements for performance of the product e. g., kill on demand, mean that there are special requirements for traceability of goods, availability of information, and supply base management.

In conclusion, where one understands the explicit constraints on supplier integration in the military sector it should be possible to distinguish what is possible and what is not based on an understanding of the military context.

1.4 The Study Aims

The aim of the research is to assess the impact of design ethos on the implementation of CE in the extended enterprise and to identify the implications for practitioners.

1.5 The Study Outcomes

The objectives of the study are as follows:

- Identify the determinants of successful CE in the extended enterprise
- Characterize the military design community
- Assess the impact of military characteristics on the implementation of CE in the extended enterprise
- Develop a design ethos framework for the effective implementation of CE in the extended enterprise
- Differentiate civil and military perceptions of constraints on CE

The MBD case study is considered to be confidential to the company and for this reason detail will remain author controlled following thesis completion.

1.6 Structure

The thesis is introduced by an outline of collaborators (Chapter 2) and working definitions (Chapter 3). The structure of the methodology employed in the research is illustrated in Figure 1-1. To aid the reader, corresponding chapter numbers are shown in brackets.

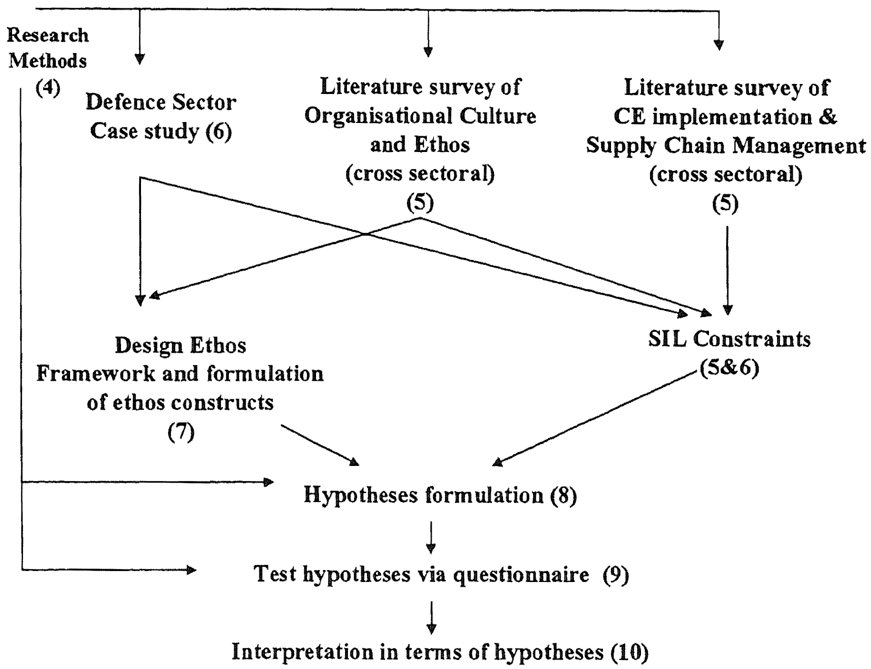

Figure 1-1 illustrating the structure of the methodology employed in the research

This methodology has five parts that correspond to chapters five - ten. Chapter five sets out the literature survey, which is cross-sectoral, exploring the following themes: CE implementation and supply chain management, organisational culture and ethos. Each of these areas is investigated for possible SIL constraints. Organisational culture is explored for documented evidence of variation across and within industrial sectors. The term 'ethos' is explored as to its origins, its popular use, and also for any evidence of its use in an industrial design and defence context.

Chapter 6 describes a case study carried out in the defence sector to further understand the real constraints experienced by personnel tasked with working closely with suppliers. This takes the form of an AS-IS study of an OEM and its suppliers, workshops and working groups. This case study also absorbs the learning from a pilot implementation of SIL, which employed action research techniques.

Chapter 7 describes a design ethos framework based on the literature-derived definitions of ethos and the experiences of the case study. The design ethos framework defines ethos in terms of four constructs: Commercial Imperative (CI), Minds Eye (ME), Problem construction and solution (P), and Organisational factors (O).

Chapter 8 describes the consolidation of SIL constraints from the literature and the case study and their relationship to constructs of ethos. It also describes the formulation of hypotheses for statistical testing and the development of the test instrument (a questionnaire).

Chapter 9 describes the testing of hypotheses. Results are analysed for evidence of cross-sectoral differences in view of what constrains SIL.

Chapter 10 describes the results and seeks to interpret and discuss them in terms of design ethos. Conclusions are then drawn in terms of the research questions.

1.7 Summary

This chapter describes the contextual background to the exploration of design ethos and describes how the military sector's particular constraints have brought it to a stage where it views CE in the extended enterprise with caution. It describes how once military – specific problems are now becoming surmountable with a combination of business practice and management techniques and concludes that despite this, a lethargy remains which needs to be understood and overcome if CE in the extended enterprise is to bring real business benefits. The concept of 'design ethos' is introduced as a possible explanation for this lethargy and a research methodology is described which allows the exploration of the concept across business sectors. Finally, the structure of this methodology in terms of research method, concept formulation, testing and analysis is outlined.

2 Outline of collaborators

2.1 Introduction

This chapter outlines the military and civil collaborators in the research. Two levels of collaboration were manifest. Matra BAe Dynamics (MBD) and BAe Military Aircraft and Aerostructures (MA&A) collaborated on the case study and also the questionnaire. GKN Westland Helicopters, Lockheed Martin ASIC, MA&A (Warton, Brough & Farnborough), Ford and Vauxhall collaborated on the questionnaire.

2.2 Military collaborators

The military collaborators in this research are all Original Equipment Manufacturers (OEMs) serving the defence industry.

2.2.1 MBD

The last 10 years has been turbulent for BAe's weapons business. In this time it has downsized and consolidated its defence manufacturing assembly at the Lostock site, where before it existed on three sites.

During this turbulent period, internal CE initiatives have advocated the use of integrated product groups (IPGs). IPGs are directly responsible to projects for development and postproduction support. Key personnel from design and producibility staff move between projects as their current projects reach sufficient life cycle maturity to warrant their move, Lostock then takes ownership for later life cycle activities that are production related.

Over the same period, there has been a concerted effort on the part of the UK procurement function to reduce the supply base and nurture collaborative suppliers for key commodities; however, the integration of suppliers into design teams was in its infancy at the time this research commenced. A joint venture with Lagardere[9] had brought its own complications for sourcing decisions in that the company now had to accommodate not only customer-enforced suppliers but also work-share impact on the supply base. Work–share is a business agreement whereby jointly won business is shared between sister-company locations, and in some cases, between the same function in different sister company locations. Alternatively, the joint business may opt to consolidate certain functional roles on specific sites due to expertise or available resource. In practice, this may mean that for specific products, the new product introduction process may be spread across different locations even though theoretically the entire process could be carried out in one location. Where traditional suppliers have been accustomed to serving specific designers at one location, or procurement personnel at one location, they are at best expected to serve an unfamiliar client, at worse excluded from the supply base in favour of locally preferred suppliers.

[9] Lagardere and British Aerospace signed an agreement in October 1996 to form Matra BAe Dynamics. The company, a combination of British Aerospace Dynamics and Matra Defence began

As a collaborator, MBD is interested in understanding the requirements of successfully integrating suppliers into its design process. However it is concerned that the risks and rewards in terms of cost be well defined, and that such changes should not be undertaken lightly without sufficient understanding of the business need. This research offers MBD some insight into the differences between military and commercial companies, when attempting to replicate what has until recently been a commercial paradigm. MBD took part in this research as both the Case Study OEM and as a participant in the questionnaire.

2.2.2 MA&A

MA&A Chadderton, at the research outset, was part of BAe Defence. At the beginning of the research, Chadderton served both commercial and military markets but during the research period was restructured to concentrate on the spares and repairs requirements of BAe. Chadderton took part in this research as the first tier supplier in the case study. MA&A at Warton, Farnborough and Brough took part in this research as participants in the questionnaire following wide interest in its outcomes of the research from participants at the BAe Supplier Conference 1999.

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trading 1st November 1996 as Europe's premier missile guided weapons business with a turnover of £1 billion and order book of £2.7billion (BAe 1998)

2.2.3 GKN – WHL

GKN Westland Helicopters is the UK's only helicopter design authority, manufacturer and systems integrator (GKN 2000). It designs, develops and produces military and civil helicopters and integrates the associated weapons systems. GKN-WHL is particularly interested in developing inter-functional teams and through its work with the Supply Chain Relationships in Aerospace (SCRIA) group of the Society of British Aircraft Companies (SBAC), has been a leader in providing case studies for the aerospace industry. It is particularly interested in improving supply chain relationships for business benefit, and as such is interested in the outcomes of the study with regard to factors affecting the incorporation of suppliers into design teams. GKN took part in this research as a participant in the questionnaire.

2.2.4 Lockheed Martin ASIC

Lockheed Martin ASIC belongs to Lockheed Martin UK which is part of the US based Lockheed Martin Corporation, a high technology company with a turnover of £18billion (Lockheed 2000). Lockheed Martin Corp is the world's largest defence company. Recent literature reports that as a company it has recently undertaken large-scale outsourcing, consolidation of its supply base and major programmes to integrate both procurement and important suppliers deeply into product development (Stundza 1999).

Lockheed Martin in the UK is primarily involved with systems design, integration and support on the Merlin Helicopter programme, a programme to deliver 44 aircraft to the Royal Navy (DERA 1998). This programme has provided Lockheed with considerable experience of supply chain management in collaborative environments and as such Lockheed is a valued addition to the research. Lockheed Martin ASIC took part in this research as a participant in the questionnaire.

2.3 Civil Collaborators

The civil collaborators in this research are Original Equipment Manufacturers serving primarily civilian product requirements. Both collaborators are major producers in the automotive industry.

2.3.1 Vauxhall

Vauxhall Motors Limited is a wholly owned subsidiary of General Motors Corporation (GM). The company is closely integrated into GM in Europe in terms of products, manufacturing processes and information systems (Vauxhall 2000). Vauxhall produces the Vectra at its plant in Luton (the other UK manufacturing plant being located at Ellesmere Port). It also builds the Frontera in Luton at its sister GM company IBC. Vauxhall reported a consolidated 1998 turnover in excess of £4 billion. (Vauxhall 1998). Vauxhall (Luton) took part in this research by participating in the questionnaire. It continues to be associated with the University of Luton through its degree and postgraduate qualification schemes. Through this partnership, Vauxhall was happy to participate in the research.

2.3.2 Ford

Ford's automotive business consists of the design, manufacture, assembly and sale of cars and trucks. As a global player with revenues $162 billion (Ford 2000), it operates on each continent. Ford has been innovative in management practice ever since its US beginnings, and has been active in adopting and using design (Gate processes, Platform design), Quality (QS9000) and Supply Chain Management techniques (Full Service Suppliers). Ford in the UK forms part of the European operation and is responsible for design, manufacture, test and support. Design, test and support is based primarily at Dunton, manufacturing is based at Dagenham and Bridgend. Ford has recently bought Jaguar and Land Rover. This will increase Ford's European presence again. During the research, Ford took steps to divest its European interests in non-core components businesses, in the form of Visteon. At the time of participation, participants still considered themselves to be very much Ford personnel and internal processes had not changed significantly. For the purpose of this research, these participants from Visteon are considered as Ford employees.

Ford took part in this research as a participant in the questionnaire which was administered through the Ford Integrated Graduate Development Scheme (IGDS) programme, a collaborative Masters programme between Ford and a consortium of UK Universities.

2.4 Summary

This chapter has described the research collaborators in the civil and military sectors. The size and influence of these companies in their respective supply chains, combined with their interest in the research topic lends authority to the subject matter and its importance in achieving business benefit. Lockheed Martin Corporation and BAe Systems are now the first and second largest defence companies in the world. Ford and GM replicate this relationship in the automotive sector.

BAe Systems is consistently the largest exporter within the UK, potentially influencing the margins of thousands of small suppliers in the UK alone. The ability to work effectively with these suppliers in an increasingly competitive supply pool will influence these companies' long term viability and the business work share that is increasingly considered when operating in a global environment. Where work-share demands that unfamiliar suppliers be embraced, the knowledge that this research provides will facilitate the company in its in-house training and also in its supplier development programmes.

3 Development of Working Definitions

3.1 Introduction

This chapter describes the differences between design in the civil and military sectors and defines the collaborator companies in terms of the companies' status within their own supply chains. 'Supplier in Loop' (SIL) is defined by comparison with Build to Print (BTP) and by statement of the aims of working in this manner. 'Design community' is defined by stating a group's collective purpose and by defining its nature as a collection of functions within a company. This chapter seeks to differentiate design ethos from design culture and by defining ethos in a design context provide a working definition of design ethos for use in subsequent chapters. Figure 3-1 illustrates the areas of definition.

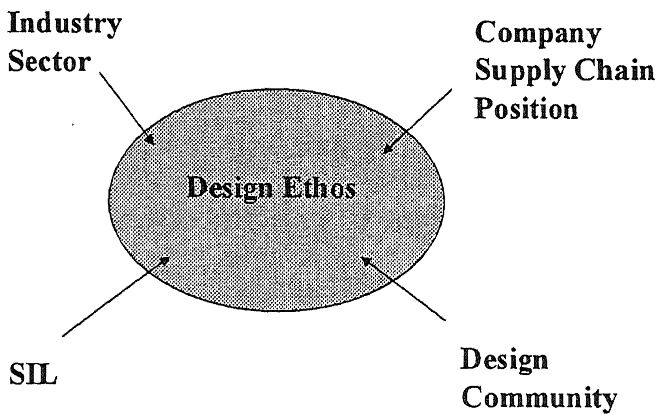

Figure 3-1 illustrating the areas of definition

3.2 Differentiating military design from civil design

Military design is that undertaken by employees within the defence industry. Defence industry however, is a collective term that can include government departments, companies producing military equipment for the nation's or overseas governments, and any number of sub-assembly, R&D and technology providing companies (Dowdden 1990). For purposes of this study, military design is that undertaken by designers working for OEMs in the defence industry. Civil design is that undertaken by designers working for companies not producing military equipment for the nation's or overseas governments, but specifically for the civilian market. To ensure some congruency with respect to company size, these civilian companies are also OEMs.

In an increasingly global market place, civil OEMs may have cause to sell into defence markets. Car manufacturers may be involved in the development of military vehicles or defence companies may spin-off certain technologies to the civil market for financial gain, however, for purpose of this case study and quantitative analysis, this is immaterial.

3.3 Supplier in the Loop (SIL)

CE in the extended enterprise for purpose of this research, refers to the implementation of a manner of working between an OEM's design group and the component manufacturing personnel from a supplier, which has the following aims:

- A will on the part of both collaborators (purchaser and supplier) to work together earlier in the design project to take time and cost out of the delivery of new products;
- A will on the part of both collaborators (purchaser and supplier) to reduce later life costs by the reduction of design change through due care to the design manufacturability prior to initial manufacture.

In this scenario of CE, suppliers / subcontractors are involved at the initial modelling stage of components which is somewhat earlier in the design process than has previously been considered normal practice. Suppliers may take on responsibility for commenting on the product model, for planning the process to achieve the design intent and for completely translating the product model into manufacturing information. This type of CE is henceforth referred to as SIL as opposed to conventional Build To Print (BTP) working. Fig 3-2 illustrates the SIL process. Fig 3-3 illustrates the BTP process.

3.4 A working definition of design community

'Personnel involved in the design of new products' describes not only the design function, but includes (but is not limited to) personnel from the following generic functions:

- Business Project Management
- Design Project Management
- Design Engineering
- Production Engineering
- Procurement / Purchasing
- Component Engineering
- Manufacturing
- Quality

These functions are assumed to be design-related and supplier-facing. Where evidence suggests other functions fall into this category, these functions are

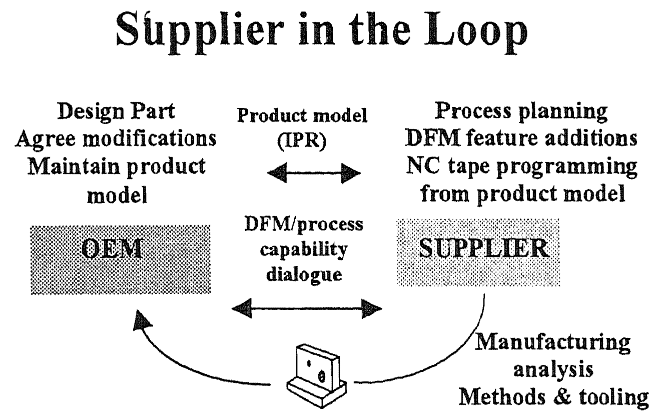

Figure 3-2 illustrating the SIL process

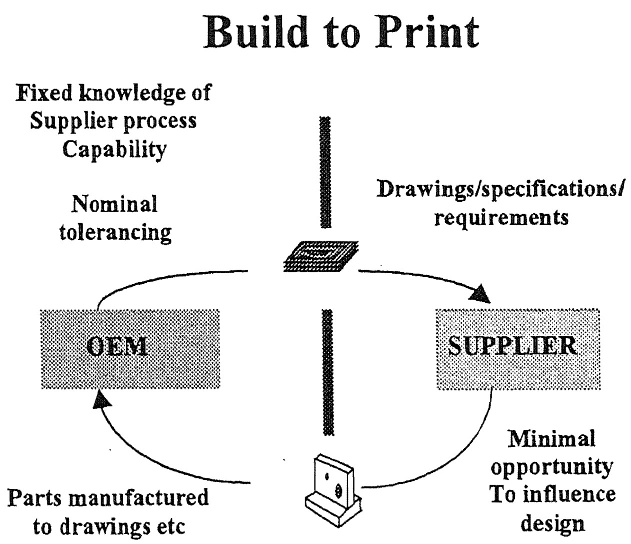

Figure 3-3 illustrating the BTP process

included and allowance is made in the questionnaire and case study for such eventuality. For consistency, the term 'design-related, supplier-facing' takes preference over generic functional descriptions in defining the study group. Personnel involved in the design of new products are henceforth referred to as a 'design community'.

3.5 'Ethos' as an attribute[10]

Ethos has long been attributed to the individual. Aristotle in his Rhetoric described ethos as the most potent means of persuasion (Lawson-Tancred 1991) and the most effective means of proof (Garver 1994), the other means being logos and pathos. Ethos is traditionally associated with the demonstration of knowledge and the use of evidence in its support, with good moral character, and with good intent on the part of the purveyor. Ethos is something largely perceived by others. Garver further explains that a professional ethos of detachment and competence can be both persuasive and appropriate. It is the speaker's argumentative and deliberative ability that creates ethos as a by-product. Further discussion of philosophical interdependence of rhetorical proofs is beyond the scope of this thesis.

Definitions of ethos can be found in the literature:

[10] Attribute – " ... Quality ascribed to person or thing; characteristic quality; object regularly associated with person etc." The Little Oxford Dictionary, 5th Edition, June 79

Ethos – The disposition, character, or attitude peculiar to a specific person, people, culture, or movement.

(The American Heritage Dictionary of the English Language)

Ethos – The character, sentiment or disposition of a community of people, considered as a natural endowment; the spirit which actuates manners and customs; also, the characteristic tone or genius of an institution or social organisation.

(Webster's Revised Unabridged Dictionary)

Ethos – Characteristics spirit of community, people or system

(Oxford English Dictionary)

Ethos – the nature or disposition; "the characteristic spirit, prevalent tone or sentiment of a people or a community"; "ideal excellence"; "numen"; " a presiding power of spirit"; and "the 'genius' of an institution or system"

(Mileham 1998)

Ethos - A people's ethos is the tone, character, and quality of their life, its moral and aesthetic style and mood; it is the underlying attitude toward themselves and their world that life reflects.

(Geertz 1999, 1973)

There is clearly disjoint between early definition of ethos in the context of persuasion as a personal attribute and its later use that describes it as an attribute of a group. Later definitions could imply a degree of either reverence or disdain by external groups – the fact that a group can be distinguished does not make it revered. The earlier definition (or translations of the definition) implies ethos as a positive trait, where reverence by external groups is implied – people are persuaded by the use of knowledge, morals and good intent.

This evolution of meaning is reflected elsewhere. Harris (1997) describes how the term rhetorical, and therefore its constructs, now imply rant, bombast or twaddle, as opposed to rhetoric being the art of persuasion/dissuasion.

Increasingly, the term ethos is used by other sectors of society to convey pedigree, a shared vision and manner, and a fundamental spirit. It is most often found in the language of marketers (Thompson 1998) where a vision or product is being sold. It currently appears to be particularly prevalent in the public sector where its use seems to be to lend credence to new ideas and organisations where its use is meant to persuade the customer. For example, schools and government agencies advertise their ethos in an attempt to gain credibility and encourage others to join or use the body's services. It is however, generally absent from industrial language, the exception being when it is associated in isolated cases with engineering (Brown 1990: Holt 1996).

However, in areas where formal contracts fail us, where behaviour fails to reflect or fit with known models, or where a shift in paradigm is required, we are increasingly embracing concepts and language that were once thought inappropriate. From nature, we borrow chaos theory, fractal organisations, and holistic forms of manufacturing operation. From social theory we borrow team concepts, management of change and the importance of champions, all of which relate to the basic human heuristics. Human issue considerations are increasingly up for debate. As a concept, we borrow ethos from philosophy. If human issues in the sense of how humans relate and act are to be researched, then so should the way individuals persuade others and are persuaded themselves.

A recent legal judgement in construction contract law has recognised the idea of ethos within partnering agreements (Bingham 1999). In this instance, two building companies included mention of a shared ethos in a partnering contract. Ethos was used to describe the characteristics, spirit and attitude intended by a community of people or a system within a contract. During the dispute the Courts considered giving effect to the term ethos thereby giving the term precedent in contract law.

It is again associated with partnering by Deering and Murphy (1998) where it is used to describe whether a particular type of communication is appropriate for a particular type of partnering relationship. This then is some evidence that ethos is recognised as contributory to the success or failure of partnering type relationships. Supplier integration is one form of working that is associated with partnering.

In understanding the effect of the parties' ethos on supplier integration it is important to avoid conveying unnecessary status on those who demonstrate or fail to demonstrate it. In considering ethos in the military, Massey (1999) argues that holding up ethos, as an untouchable good is not a convincing justification for perpetuating idiosyncratic styles, or for maintaining status quo in the face of change. Boyd-Carpenter (1995) argues that the maintenance of ethos must not be equated with preserving a particular pattern. He further describes this state with a traffic light metaphor as 'operating in amber'.

Design ethos as an attribute is explored in this thesis. Whichever definition is used, ethos can be attributed to an individual or to a group. It is characterised by an ability to persuade others and is based on a perception of shared wisdom and authority on the part of the purveyor. Business authors and the judiciary are beginning to recognise its association with partnering and therefore with supplier integration. The military community is striving to define it, while prescribing caution in its use as a panacea for stalling change of any type.

This thesis seeks to understand the effect of design ethos on one particular supply chain practice – supplier integration. Without such understanding it is impossible to be objective as to the importance of ethos, or to the appropriateness of supplier integration for a business.

3.6 Differentiation of design ethos and design culture

Ethos is not the same as culture. Andrew Brown (1998) in his book "Organisational Culture" lists 14 different definitions of culture. Each of the definitions uses culture as a descriptor of an entity at any particular point in time, sculptured by the past, operating in the present and evolving in the future. Ethos is more a manifestation of a specific culture at a point in time, an outlook, and an attitude. Design ethos is therefore not design culture. It is a manifestation of a particular design culture's view on a particular issue – in this instance SIL working. For example, a group of designers and design support staff may exhibit the characteristics of a subculture by sharing an appreciation of technical language. They may share an appreciation of what constitutes good / acceptable engineering practice and share a common appreciation of how to solve problems based on the collective experience of problems that have gone before. Their collective ethos, however, with respect to an issue, would only be displayed or demonstrated in how the group's view and future intentions are stated or inferred, either collectively or individually.

Massey (1999) describes ethos as a system of governing principles that influence and characterise the way in which the members of a group interact with one another and respond to the world around them. He states that this is normally limited in usage to particular groups within society and that it is a step removed from the more general notion of culture.

Whether one group can be distinguished from another based on this attribute is yet to be proven; however, the use of the term ethos in this context would seem to be entirely appropriate given more general definitions of ethos available in the literature.

3.7 Summary - A working definition of design ethos

For the purpose of this thesis, the working definition of design ethos is therefore:

> The characteristic manner or approach to constraints on SIL working displayed by a design community.

The concept of design ethos is further defined in terms of constructs in Chapter 7. The term 'design community' is used later to describe the case study collaborators in Chapter 6 and to describe the questionnaire recipients in Chapters 4 and 9.

4 Research Methodology

4.1 Introduction

This chapter describes the research objectives, research strategy and research methods adopted in order to answer the research questions. It also describes how the literature provides the basis for the study of SIL constraints.

4.2 Research approach

During the AEROEXTN project, the author of this thesis encountered a number of factors affecting SIL implementation that had not sufficiently been explained in the professional literature nor through speaking with the AEROEXTN industrial collaborators. The research approach in this thesis is to explore the **how** and **why** (Yin 1994) of design communities' constraints in implementing SIL. The approach also allows exploration of whether influencing factors are sector specific and explores the influence of dependent (sector), independent (view of SIL constraint) and intervening variables (ethos constructs) (De Vaus 1996) on any differences.

4.2.1 Research objectives and research strategy

The research questions of this study are the following:

- What are the determinants of good SIL practice? (See Chapter 5,)

- How can the ethos of a military design community be characterised? (See Chapter 6)
- Does the ethos of a military design community differ from that of design communities in the civil sector? (Chapter 9)
- Given the above, how might companies prepare themselves for SIL implementation in the future? (Chapter 10)

In order to decide which strategy is most appropriate Yin (1996) recommends consideration of the following factors: the type of research question posed; the extent of control an investigator has over actual behavioural events and the degree of focus on contemporary as opposed to historical events. In considering these factors it is possible to decipher appropriate approaches.

Table 4-1 showing the research strategy using the Yin framework

Question	Contemporary events	Requires behavioural control over events	Appropriate research strategy	Chosen research strategy
WHAT are the determinants of good SIL practice?	NO	NO	Any	History
HOW can the ethos of a military design community be characterized?	YES	NO	Case Study/ Survey	Case Study
HOW does the ethos of a military design community differ from that in the civil sector?	YES	NO	Case Study/ Survey	Survey
HOW might companies prepare themselves for SIL implementation in the future?	YES	NO	Analysis Synthesis Verification	Analysis Synthesis

The research strategy was therefore mixed, or what Gill and Johnson (1991) describe as a multi-method, comprising of literature study, case study and survey, followed by analysis and synthesis of the findings. Verification of the findings was outside of the scope of the research both in terms of time and funding.

Here, SIL constraints are deduced from the literature and from the case study. The theoretical constructs of ethos are then developed and explored by analysing what different industry sectors consider to be constraints when implementing closer working with suppliers.

4.2.2 Literature study

In order to understand industry's experiences of implementing SIL, both good and bad, an in-depth literature search was conducted. Due to the fast pace of industrial change; relatively recent tendency for academics to collaborate with industry and the time delay in getting books and journals published; it was necessary to consult industry journals, industry bodies, on-line sources and counterparts in other universities for their professional insight. Contacts were made at Bath, Glasgow, Warwick, Cranfield, Twente (The Netherlands) and Michigan State University (US) as well as SBAC and the Institute for Defence Studies in London.

4.2.3 Case study design

The AEROEXTN research project provided the author of this thesis with industrial partners who were both interested in the practicalities of implementing SIL and committed to a SIL pilot project. Once initial SIL enablers and constraints were identified, the scope of AEROEXTN did not allow further in-depth study into what were variously described as: human issues, soft issues, culture, and ethos.

The prospect of willing collaborators in an industry that was largely inaccessible for research of this kind, with an opportunity to observe at close hand, had potential for what Yin describes as a 'revelatory case'. Eisenhardt (1989) states that a case study is a research strategy that focuses on understanding the present dynamics in single settings; however she, and Yin (1984) state that case studies can employ embedded design employing multiple levels of analysis in a single study.

Given that SIL constraint (and by definition design ethos) was to be explored with one company and its suppliers, and that no theory was to be tested at that stage, the single case study approach was entirely appropriate in this instance. However, within the case, four different projects were studied and emergent SIL constraints were compiled and compared with the literature using methods commensurate with those suggested by Miles and Huberman (1994). See Section 4.5.4.

4.2.3.1 Case study framework – SIL themes

The framework for data collection for the case study was that developed during the AEROEXTN project (Philpott 2000). The framework was derived using an action research approach (Gill and Johnson 1991) where the academics were tasked with helping the industrialists to implement SIL. Using literature and interview-derived best practice, the group developed a number of SIL themes that were then rated by the industrialists as to each theme's importance to their particular problems in implementing SIL. An 'A' rating depicted that the theme was *highly important.* A 'B' rating depicted that it was *important* and a 'C' rating depicted that the theme *was not important.* Multiples of letters depicted an increasing level of importance to the group. An asterisk depicted that a particular theme was considered more than highly important to one particular member of the group. This rating scheme allowed the group to concentrate on particularly difficult themes for resolution. For clarity, only the themes that warranted an 'A' rating were considered. Table 4-2 shows the SIL themes.

Table 4-2 showing SIL themes and the industrial collaborators' ratings

SIL theme	SIL Rating
Producibility	AAAAA
Design Constraints	AAAA
Design Spec	AAA
Design Ethos	AAA
Modelling	AA*
Cost and schedule awareness	AAAC
Currency on IT	AA
Open communication	AAC
Supply contracts	AAC
Cost of design changes/design effort/tooling changes	AAC
Tiered supplier status	AACC
NRE	A
Quality	A
Change control - sign off	A
Tooling loops	A
Traceability	A
Design information - send and access drawings/models	AC
Enforced suppliers	AC
Cost estimation and control-freedom of customer and supplier to reduce cost	AC
CAD/CAM	ACC
Design release	ACC
IPR ownership	ACC
Program info	ACCC

4.2.3.2 Number of participants and companies

The single case study collaborators were MBD and MA&A. For workshops, the number of participants from each company was generally 4 from MBD and 2 from MA&A. Over time, the personnel attending workshops varied due to the expertise required. For PIWGs and IDTs the average number of participants was 3 from MBD and 3 from MA&A. These personnel did not vary because a specific design project had been specified, budget allocated and personnel assigned to support the research on a regular basis.

4.2.3.3 Relationship to other studies

Few in-depth case studies are known from the commercial military sector. Isolated papers in the academic journals describe some aspects of military design and culture traits (Lloyd 1998a) (Lloyd and Deasley 1998b) (Tranfield and Smith 1996); team working (Valdez and Kleiner 1996) (Singh and Lewis 1997) and business change (Stevens 1997) (Augustine 1997). This work has largely remained in the domain of consultants (Booz Allen, McKinsey, AT Kearney) or professional bodies (SCRIA, Lean Air Initiative, SMART) and is not available for reference within the public domain.

Some magazine articles were specific to SIL (Glaskin 1995) (Stevens 1997) but largely omitted the detail that rigorous research demands. Where articles described SIL implementation, they were mostly from the viewpoint of the OEM, failing to report the supplier's perspective. Scott (1996) described a notable exception.

During the research generic frameworks were published for CE (Backhouse and Brookes 1996) and for early supplier involvement in process/product/service design (Ragatz et al.1997) which could have subsequently been used for case study design. However, neither were available to the author early enough for use in the project (start June 97) and neither of these frameworks lent themselves particularly to application within the military sector. For these reasons, the SIL themes framework was used as a questioning aid for this case study.

This study was an opportunity to explore the design-supplier interface of a military design community and expand the body of knowledge through academic mechanisms to benefit the industry as a whole. The collaboration of MA&A as a supplier during the workshops, Producibility Interaction Working Groups (PIWGs) and Integrated Design Teams (IDTs) provided an in-depth understanding of the issues for both sides, and helped in clarifying what were correctly perceived constraints on the part of the OEM and what were not.

The detail of the case study will remain confidential to the collaborator. However, the learning from the study can be promulgated through normal academic channels.

4.2.3.4 Case study unit of analysis

In the case study, the unit of analysis[11] was the design community, within a UK-based, commercial OEM, within the defence sector (military OEM). OEMs within the defence sector are generally large companies. MBD at the time of study was one such large company and was structured on a matrix basis, where personnel within a design community would retain responsibilities to both function and project. Some functions appeared more integrated into this way of working than others: for instance, procurement involvement in early development appeared to be very much on an as needed basis. During early conversations with personnel it became clear that individual projects could be run quite differently and that management was given a fair degree of empowerment to follow this approach.

In order to capture a broad view of the design–supplier interface, personnel from four project groups were interviewed for the AS-IS study. These were ASRAAM[12], Storm Shadow[13], Rapier[14] and SVL[15]. Personnel who were interviewed possessed a depth of experience when dealing with suppliers. The PIWG, IDT and workshops were however, dominated by personnel from ASRAAM and SVL project teams and the interviewer had relatively little opportunity to observe the Rapier project personnel at close hand.

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[11] Unit of analysis - ...the unit from which we obtain information: it is the unit whose characteristics we describe.
[12] ASRAAM – Advanced Short Range Air-to-Air Missile
[13] Storm Shadow – Conventionally Armed Stand off Missile
[14] Rapier – Low level Air defence Missile System
[15] SVL – Soft Vertical Launch Missile

4.2.4 Questionnaire design

In order to understand whether there were any significant differences between the military and civil sectors with regard to SIL constraints and thereby add to the body of knowledge for future management practice it was necessary to extend the study to other companies in the military and civil sectors. Extending the study gave wider validity to the results.

In order to reach people within companies who would have experience of working closely with suppliers and who would be able to provide insight into the research questions it was necessary to define the target audience. It was recognised, following the literature study that many functions deal with the design element of products and deal with suppliers, and that a design community within any specific industry may be comprised of multi-functional personnel. The method of dealing with suppliers also varies. Monczka et al. (1998) describe three discrete methods: these are 'black box' where a functional specification is given to a supplier and the supplier has responsibility for design and manufacture; 'gray box', where the supplier is involved in the design of the part; and 'white box' where completed drawings/blue prints are given to the supplier containing all the required information to enable the supplier to produce the part. In this context, SIL is akin to 'gray box' and build-to-print would be akin to 'white box'. It was possible that personnel tasked with implementing SIL could have had a background in one, two or all three methods. For this reason, it was necessary to target participants as 'design-related, supplier-facing', which encompassed all three methods.

This in itself presented added problems in choosing a research mechanism, but was entirely necessary to ensure that a representative set of views was obtained within any particular company, and therefore within each industry sector.

Based on knowledge of the individual businesses, the author estimated the population of supplier-facing, design–related personnel in each company to range from 10 to 1000. See Table 4-3. Clearly, the method of data collection would need to be consistent across companies. A requirement of targeting design-related, supplier-facing personnel by statistically sound means further complicated the issue.

Table 4-3 showing industrial collaborators with estimates of design-related, supplier-related personnel

Company	Estimate of design related, supplier-facing personnel
MBD (Stevenage & Lostock)	250
BAe (Chadderton, Warton, Farnborough, Brough)	1000
Lockheed Martin (Plymouth)	10
GKN WHL (Yeovil)	250
Ford (Dunton, Dagenham, Bridgend)	1000
Vauxhall (Luton)	50
Total	2560

After consideration of the logistics of face to face interview, telephone interview and questionnaire, for logistics reasons, a questionnaire was picked as the most appropriate form of data collection. This caused least inconvenience to the industrial collaborators and represented the best possibility of achieving a significant number of responses to enable statistical analysis. This still however required an appropriate distribution list and distribution mechanism.

4.2.4.1 Relationship to other studies

This author found only one recent openly published study that compared supplier interfaces in the military sector with those in the civil sector. Graham (1995) uses a 'multi-method' strategy to explore the buying strategy of military companies and the marketing strategies of smaller suppliers to the military, finding that suppliers who differentiated themselves on technical approach had a greater probability of tender success than suppliers competing on low price. Graham's work provides a strategic framework that links defence industry structural change, defence company strategic adjustment and buyer-supplier adaptation. While being interesting as background to this study, Graham makes only fleeting reference to what he described as SIL during a discussion of the 'integrated value chain'.

BAe and Lockheed Martin had both conducted major benchmarking exercises within the last few years in the procurement area and there was empirical evidence that radical changes had been adopted in both companies to adopt the better civil practices (Stundza 1999); (BAe 1999); (Perella 1997); (Lockheed 1999); (Davies 1998). However, the detail of such studies remains in the private domain. It is not clear if the issue of SIL was addressed in any detail.

4.2.4.2 Questionnaire unit of analysis

In the questionnaire, the unit of analysis was personnel within the civil and military sector. These people were all design – related and supplier- facing. Within the military sector companies were chosen to represent various dimensions of the work of military OEMs in this sector. These dimensions were aeroplane manufacture (MA&A), helicopter manufacture (GKN and Lockheed), and missile manufacture (MBD). Within the civil sector companies represented automotive manufacture (Ford and Vauxhall).

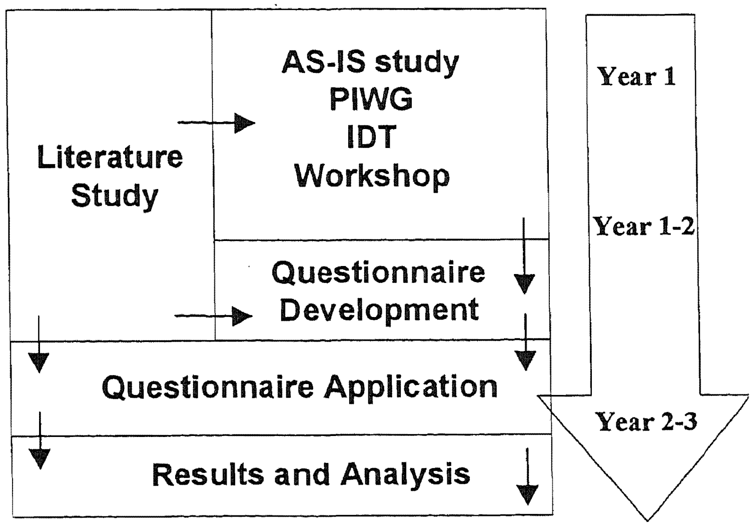

Figure 4-2 illustrating the relationship of instruments

Table 4-4 showing the research instruments and objectives

Instruments	Objectives
• Literature Study	• Understand the issues around SIL constraints, particularly the human aspects of SIL and design ethos.
• AS-IS, Workshop, PIWG, IDT	• Understand the nuances in human relationships within and external to the design community. • Understand the practicalities of implementing SIL – understand human issues, look for evidence of design ethos and its effects.
• Questionnaire	• Assess validity of military perceived constraints in the civil sector.

4.3 Method validity

The study of ethos in the industrial context is new, requiring definition and interpretation in the context of observable behaviour. No well-accepted measures existed, nor were there constructs of design ethos defined, so the author was unable to use either a criterion validity approach or a content validity approach (De Vaus 1996). For this reason the approach was one of exploration of construct validity, where the author evaluated the measure by how well it conformed to the theoretical expectation.

Use was made of a literature definition of engineering design ethos tempered by personal observation of design communities in a variety of industrial sectors over a period of ten years. This definition was then interpreted in terms of literature and case study derived views of SIL constraints. This matrix of views was then used to explore differences between industry sectors. The definition of measures was in two stages:

Stage 1 consolidated the constraints identified in the case study and in the literature, grouped them, and converted them into a manageable number of questions. Stage 2 defined the questions in terms of the literature definition of engineering design ethos. See Figure 4-3.

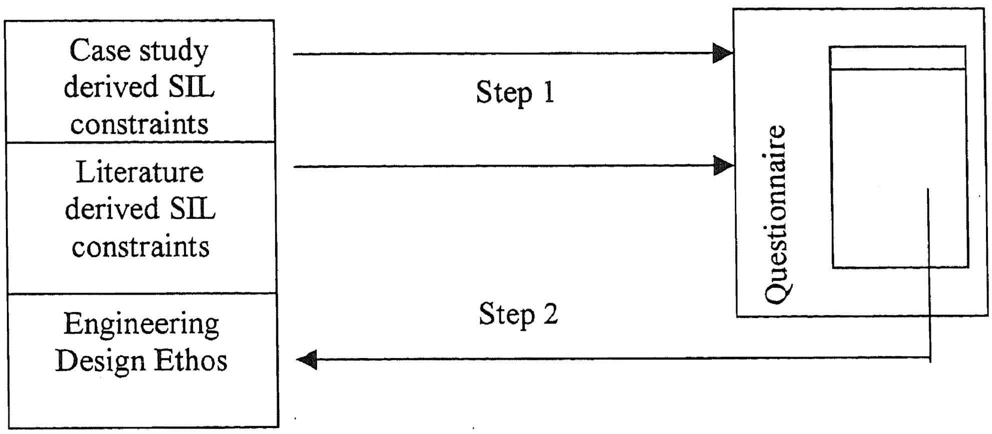

Figure 4-3 illustrating the information used to construct and explore the design ethos concept

4.4 Research procedures – literature study

To conduct the literature survey, use was made of library journals at Luton and Cranfield and direct access was gained to the British Library catalogue. Professional journals and organisations were sought by speaking to professional colleagues within the industry. Reputable journals, conferences and symposiums were gleaned from academic mentors. Contacts were made with other academics researching this area via the academic mailbase (subsequently jiscmail) service.

Frequent reference was made to the CDROM based journal catalogues, particularly ABI-INFORM, IMID, Proquest, Emerald. Use was made of web based databases, particularly EEVL, BIDs, RoaR'n, and Regard. The author attended relevant RAeroSoc, RSoc, BPRC, DTI and SCRIA seminars. Direct contact was made with other academics researching in this area and associated fields via mail, email and conference networking. Finally, Endnote software was used to collate and catalogue key findings.

4.5 Research procedures - case study

Projects and personnel chosen for interview represented different aspects of the business, for example, air born systems (ASRAAM), naval systems (Storm Shadow), and land based systems (Rapier and SVL). The projects not only represented different types of missile system but also covered projects at different states of maturity / life cycle. Rapier for example was an established system, well into the latter part of its life cycle. ASRAAM was at the early production stage, while Storm Shadow was still in design. SVL was a research system and was very early in its life cycle. Interviews were also held at different levels of personnel, for instance junior engineers, senior and principal engineers, managers and executives. The subsequent comparison of constraints across projects gave the author some insight as to the internal validity of the findings. See Table 6-6. The target audience for the case study was all design related and supplier facing personnel on the projects mentioned. Appendix 10 gives detail of the circumstance of data collection and shows contact hours and the function / project targeted.

Senior managers within MBD and MA&A agreed to support the research. Subsequent changes of role within MBD meant that the MBD co-ordinator changed over the period of the research however, the co-ordinator's function in the research was unaffected.

The co-ordinator's function was initially to provide the access point to both people and information. The co-ordinator made initial contacts, but as the study progressed, the researcher made all direct contacts. The co-ordinator continued to be copied on all relevant correspondence and acted as a professional referee whenever the researcher's status was queried. Regarding security status, the research involved the study of the explicit and implicit processes around the design-supplier interface, and not the detail of the products or the products' production. Access to restricted material was not needed. The researcher was allowed to talk with anyone and access relevant information without the need for a higher security status. The absence of a visible higher security status for the researcher did indicate to those being interviewed what could, and what could not, be discussed. Security requirements at each of the sites did however require that the researcher be accompanied at all times. For these reasons the case study contains no restricted information; however, it is likely to contain information that is both sensitive within the companies and confidential to the companies. For this reason, the detail of the case study will remain confidential to the case study research collaborators. This detail is incorporated in Appendix 11.

The AS-IS study, in situ observation, workshop, PIWG and IDT constituted in excess of two hundred and seventy (See Appendix 10) direct contact researcher hours over a period of two years. This equated to in excess of one thousand six hundred total man-hours. Fourteen people contributed to workshops, fifty contributed to the AS-IS study, and six to the PIWG and IDT meetings. Some personnel were involved in all three activities.

4.5.1 Case study methods considered

The action research approach undertaken in the AEROEXTN project largely dictated the case study approach for this author. The collaborators had already chosen the author as opposed to the author having chosen the collaborators, as would have been the case in an ethnographic study (Gill and Johnson 1991). Time scales, together with the logistics of organising defence clearance precluded the author from the role of complete participant, where the author would have attempted to become a fully fledged member of the group under investigation (Denzin 1989). Formal interview was impractical, as an informal approach had already been adopted with participants for the AEROEXTN and it would have been inappropriate to conduct two separate types of interview at one time. The action research method, where the author took the role of participant observer, shared some of the aims of pure ethnography in as much as it focused on the manner in which the collaborators interacted.

The collaborators had provided the author, through workshops, with a framework on which to hang her inquiry. This framework was then re-grouped to provide a basis on which direct investigation could take place. Semi-structured interviews were then carried out with collaborator personnel so that a more complete understanding could be gained in the area of how this design community worked with its suppliers and what might be constraining it from taking this further. Informal observation was conducted during participation in lunches, over coffee and during AEROEXTN related tasks. Examples of such tasks are the baseline analysis[16] and the existing design process review[17]. Meetings also took place out of the work environment. Interviews were carried out with groups of personnel where possible so they were able to corroborate or question each other's responses. Miles and Huberman (1994) describe the circumstance of data collection and how this can strengthen or weaken the quality of data obtained. They consider that respondents in the presence of others provide weaker quality data than respondents who are alone with the field worker. There are clearly advantages and disadvantages to both. The author conducted interviews with both

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[16] Baseline analysis – comprised a paper chase exercise to identify the (concept – design) release history for a specific ASRAAM part.

[17] Existing process review – An exercise undertaken by the author on behalf of the collaborator to identify which existing design standards and procedures would be impacted by the proposed method of SIL working.

lone participants and groups of participants. The author perceived early interviews with lone and group participants to be quite different to those conducted later in the research. Lone respondents interviewed early in the research appeared hesitant to 'open-up' and discuss detail of supply interface working practices. Conversely, in groups the reaction was quite the opposite. Later in the research, when participants became more familiar with the researcher and other participants, the author perceived participants to be less hesitant and more frank about their experiences.

Collaborator personnel indicated that tape recorders were not preferred. The author therefore used logbooks for note-taking; noting dates of meetings, attendees, their roles and responses when describing how they interacted with suppliers. An extract of a personal log entry is included in Appendix 11 to illustrate raw data that subsequently was used as evidence of SIL constraints. The SIL themes framework (Table 6-1) provided the questioning framework although the same questions were not necessarily asked of each project group, the author preferring to investigate each groups experiences in context.

To supplement the interview-gained data, PIWGs and IDTs were also utilised by the author to gain further insight into real time problems experienced by personnel as opposed to those perceived then conveyed to the author during an interview situation. The combination of these methods allowed the author to distinguish that which may have been a possible cause of constraint from that which appeared to be an actual cause of constraint.

The author instructed the collaborators in the use of logbooks. These were to be used for the logging of their own activities during the SIL pilot as well as their own problems, questions or points for group discussion in the PIWG and IDT meetings. Instruction on using the logbooks was kept to a minimum. Logbooks were provided to collaborators as a memory aid as opposed to an activity log. They were meant specifically to aid their own participation in the PIWGs and IDTs. Logbooks were retained by their owners at the end of the research.

Finally, the author was entirely comfortable with the case study approach since she had experience of working with design communities and is a professionally qualified management auditor. Figure 4-4 illustrates the case study methods used and projects studied.

	SVL (SIL pilot)	ASRAAM	STORM SHADOW	RAPIER	GENERAL
PIWG/IDT	*				
OBSERVATION	*	*			
WORKSHOP	*	*	*	*	
INTERVIEW	*	*	*	*	
SUPPLEMETARY INTERVIEWS & ARCHIVE INFORMATION		*			*

Figure 4-4 illustrating the case study methods used and projects studied at MBD

4.5.2 Data collection – the AS-IS study

For the purpose of clarity both in terms of investigating and interpreting the literature, as well as a need for efficiency in interviewing technique with the collaborators, the SIL themes were regrouped so that common areas could be addressed in one hit. See Table 6-1.

4.5.3 Data collection - PIWG/IDT & workshop

Workshops were used to explore human issues of SIL implementation at a project management level. Collaborators were encouraged to raise all issues as and when they arose throughout the AEROEXTN project. The PIWG and IDT were pilot demonstrator specific, dealing with issues appertaining to the development of a specific design (SVL) between the OEM and the supplier. These two methods also served as the main problem-solving mechanisms for the collaboration at a practical level.

Formal minutes were produced from the workshops, PIWGs and IDTs (Gregory et al. 1997-1999), which were verified by attendees. Observational notes were kept in a personal logbook (Philpott 1997-1999). Validation of described processes was undertaken by accessing and verifying company documentation wherever possible. Data collection and analysis is described in detail in Chapter 6.

4.5.4 Case study reliability

Case studies, as a method of research, are subject to a certain amount of criticism in the literature, in that they have little basis for scientific generalisation. However, professional organisations continue to give credibility to the findings of such case studies, seemingly deriving comfort and learning from the trials and tribulations of others pursuing the same general goals. Publishers have recognised this and recent books in the business sector are increasingly case study based (Lamming and Cox 1999; Backhouse and Brookes 1996).

This author's approach has been to study the natural environment of one design community as far as possible. The author recognises that by attempting to reduce her influence on the interest group, it has been impossible to account for all possible extraneous variables, thereby making replication difficult, and as such there has been a trade off between internal validity and reliability in a wider sense. Gill and Johnson (1991) recognise the weakness of this type of research approach:

> ...by increasing ecological validity quasi-experiments and action research trade off internal validity when compared with the ideal experiment. Similarly, in order to preserve the context in which the research in undertaken, this reduction in structure will frequently result in a relative decline in reliability, as it becomes more difficult to replicate.

Another criticism of the case study approach is that equivocal evidence and biased views can influence the direction of the findings and conclusions. The use of the SIL themes framework (Table 6-1) as a questioning aid was an attempt to provide a common framework upon which other researchers can base their inquiries, thereby facilitating, to some degree, replication. Following the case study, the SIL themes framework needed to be expanded because a number of constraints identified by participants were actually outside the original themes. (See section 6.5.)

To aid reliability further and because of the sheer volume of information, extensive use was made of reflective remarks, contrast tables and clustering (Miles and Huberman 1994) in the data selection and qualification process. Reflective remarks and contrast tables are shown in Appendix 11 where they are used to focus on constraints and check for internal validity across project (Tables 6-2, 6-6). The grouping of similar constraints and naming of those groups is effectively what Miles and Huberman describe as 'clustering' and 'making metaphors'. This technique is used in the derivation of military characteristics in section 7.3 (Table 7-1). Clustering is used again to formulate questionnaire questions from constraints in Table 8-1.

The illustration of techniques in tabular form make manifest where the data came from, how it was processed and how conclusions were drawn, thereby aiding replication.

4.5.5 Case study internal validity

Internal validity is defined as the extent to which a researcher's observations and measurements are true descriptions of a particular reality (Kincheloe and McLaren 1994). Denzin (1989) writes that:

> 'objective' ethnography cannot be written. To think otherwise is to engage in the fallacy of objectivism.

This author concurs with this view, and made every effort to draw out responses from participants that reflected their perceptions of their own situation. By ensuring that interviews, workshops, PIWG and IDTs involved multiple personnel, participants had the opportunity to corroborate or disagree with each other's position. To further validate this learning, internal documents and supplementary interviews were sought to support / contradict processes and historical anecdote.

The author had a scientific background, had industrial experience of working with design communities and was a professionally trained management auditor. She was therefore familiar with technical language and was able to understand technical procedures as well as the importance of question technique. This author followed techniques advocated by Alan J Sayle (1988). Sayle borrows Rudyard Kipling's poem 'The Elephant Child' to describe an appropriate format for audit questioning:

> I keep six honest serving men, (they taught me all I knew).
> Their names are What and Why and When
> and How and Where and Who.

Sayle argues that when used properly, these 'six friends' force a response. He further advocates seven other types of question:

- The 'show me' request, following discussion of a particular point.
- The hypothetical question – 'what if'
- The searching question – 'I don't understand'
- The silent question – 'where interviewees are left to volunteer information in moments of silence'
- The dumb question – 'where the question should be so obvious that the question is barely worth asking'
- The unasked question – 'where the interviewer should analyse his own understanding aloud so that the interviewee and interviewer can share the same line of thought.

A further more complex line of inquiry is the inverse question. This can be most commonly used where the interviewee is resentful of being interviewed or is steadfastly against the paradigm shift that the interviewer represents. The author believes that in action research the latter is a more likely case. The inverse question is one that empathises with the interviewee's position and explores the topic of interest by drawing out the interviewee's perceived difficulties with the issue at hand. In this case, working closely with suppliers.

Every effort was made to collect data in this manner; utilising all of the described question types. However, with respect to internal validity, one cannot discount there being some likelihood that misinterpretation could have occurred through the author's interpretation and transcription of her notes. The use of tape was not an option for this study. Denzin states:

> Texts are made, or constructed. They are based on rhetoric, allegory, the choice of metaphors, writing style, the author's gender, politics, and ideology

This being the case, to further validate the AS-IS study, an academic research colleague, who was familiar with the collaborator's business, was asked to review the report for accuracy. Two points were queried. The research colleague then independently checked these points with collaborator personnel and found the report to be an accurate account. Workshops, PIWGs and IDTs were all formally minuted and participants were given opportunity to correct, add or remove points that were inaccurate. Logbooks kept by the researcher remained private. Any reports produced by the author following interviews that were subsequently drawn upon for this thesis, where openly edited by participant peers for accuracy.

Due to the fact that three different mechanisms were used for data capture (AS-IS study, PIWG and IDT), with different personnel, it was possible to analyse data for corroboration and contradiction. This allowed the author to grade constraints in terms of confidence and therefore indicate whether she considered the particular constraint to be internally valid within the OEM.

The target audience for the case study was all design related and supplier facing personnel on the projects mentioned. Appendix 10 gives detail of the circumstance of data collection and shows contact hours and the function / project targeted.

4.5.6 Case study external validity

External validity is defined as the degree to which descriptions can be accurately compared with other groups (Kincheloe and McLaren 1994). Webb et al. (1966) and Denzin (1989) state that generalisability has three dimensions: unique characteristics of respondents [participants]; instability in the population over time; and, instabilities in the population arising from spatial or geographical differences.

Instability in the population over time - the participants in the case study and in the wider European defence industry, were undergoing massive restructuring. One could argue that this unstable period changed the influences and targets of businesses on a day to day basis. If a more stable period evolved, there might be merit in repeating the research to establish generalisability.

Instabilities in the population arising from spatial or geographical differences – The essence of the case study approach and its basis, founded on participant observation in an action research environment, suggests that in isolation its outcomes are not generalizable. Geographic culture differences, as evidenced by the case study itself, would suggest that multiple case studies are needed to afford generalisability to the concepts developed. However, in combination with other research techniques that are more spatially and geographically diverse, the outcomes can be generalised to a wider population. See Section 4.6.6.

Unique characteristics - the participants in the case study all belonged to an OEM in the defence industry. They were also familiar with CE principles and expressed an interest in the factors that affected implementing CE with suppliers. Uniqueness is difficult to quantify. One might say that every company is unique given the large number of factors and people that shape it. To further aid the user to compare his or her own business circumstance with that of the case study company, a team characterisation of the PIWG and IDT group was conducted. Such an assessment affords a company in the wider population some insight into the uniqueness of the case study group. Further to this, an assessment using the same approach will allow other SIL teams to baseline their own circumstance. This approach is supported in the literature by the theories of Guba and Lincoln (1981) who describe the importance of what they call 'fittingness' in replacing the general concept of generalizability; and, Goetz and LeCompte (1984) who introduce the concepts of comparability and translatability.

4.5.6.1 Team characterisation

In order to ensure that the demonstrator yielded the maximum benefit, the industrial collaborators wished to characterise the working team. This was to understand whether there were any special characteristics of this particular team that would need replicating in the wider roll out of this way of working. The collaborators were concerned that the process was not only robust but also that the process was repeatable. This could perhaps be affected by the team's character.

An exercise was undertaken with the intent of characterising this particular team. The results are by no means generalizable to other teams; however, the method may be of interest to others in a similar situation.

The author drew upon current thinking in the literature (Macbeth and Ferguson 1994; Tranfield et al. 1998, 1999a, 1999b, 2000; Belbin 1996) taking a three - pronged approach to characterisation. This can be described as follows:

- Exploration of the business dynamic – the business relationship between the parties
- Exploration of the business archetype
- Exploration of the mix of characters within the team

4.5.6.2 The business dynamic (the collaborators' perceptions)

The Relationship Maturity Grid (Macbeth & Ferguson 1994) was used to assess the collaborators' perceptions of their business relationship. This tool allowed a relationship to be characterised as adversarial, transitional or partnering. It was based on the assessment of the following criteria: quality, delivery, cost, innovation, strategy (in this instance, that of the customer), capability (in this instance, that of the supplier), information flow (in this instance both technical and commercial), nature of the relationship, and business outcomes. The original relationship grid and the adapted relationship grid are illustrated in Appendix 6. Appendix 6 also illustrates how the results were assessed in terms of inspection of a scatter pattern of responses across the grid.

Macbeth and Ferguson state that the maturity grid does not capture the detail of their academically developed Relationship Positioning Tool, and, that the grid in its original form only captures the view of one organisation, not both partner companies. Its use is advocated for companies who would wish to gain insight into their own relationships with others. This author has developed the maturity grid in applying it across two companies in the context of a SIL environment. The tool is used to explore the inter-company relationship and to provide some control for interpretation of subsequent results. The author's utilisation of an adapted tool has some reliability because others can use the tool. Further work, on a wider sample within each company would be needed to confirm the tool as a valid measure of the current circumstance. This work was beyond the scope of this thesis.

4.5.6.3 The business archetype (the academics and the collaborators' perceptions)

A Team Archetypes tool (Tranfield 1999a) was used to measure the team's orientation to team working. The assessment included the views of the author and of academic colleagues because the academics were considered to be facilitators within the team. This tool had previously only been used in a single company context and its use across two companies was strictly experimental. This tool allowed the assessment of a team as to whether it considered itself lean: project orientated: or self empowered. Individuals were asked to answer a number of questions. Points were then allocated based on their answers. By combining the points in each category (lean, self-directed, project) it was possible to make a preliminary assessment of the team. Appendix 7 describes team archetypes and their characteristics.

If the tool is administered in the same way, the tool itself would be a reliable means of measurement; however, it should be noted that the author is not qualified in the administration of psychological testing and that the use of this tool was purely experimental. Its use, however, did grant the author some insight into how the team perceived itself and provided a control for interpreting subsequent results.

The tool itself has been independently validated. Tranfield et al. (2000) report that over 300 manufacturing managers have been involved in the validation of the models resulting from this [team archetypes] research.

4.5.6.4 The team mix (the academics and the industrialists' perceptions)

A Belbin Self Perception Questionnaire was administered to the team to understand the individual characters within the team. This is a common tool used for team characterisation. Its interpretation concentrates on the type of mix of people within the team. Through extensive research Belbin (1996) discovered that certain types of mix of characters affected whether individual teams were successful.

Issues within the questionnaire address the following areas:

- What the participant believes they contribute to the team
- What the participant believes to be his/her possible shortcomings in the team

- The participant's attitude in a project with other people
- The participant's characteristic approach to group work
- What the participant gains satisfaction from when working on a job
- How the participant reacts to a difficult task with limited time and unfamiliar people
- How the participant reacts to problems when working in a group.

Each participant is asked to assign ten points over a maximum of three statements in each section. Answers to questions in each section are then cross-tabulated with what Belbin describes as 8 team roles, to yield a team role distribution score. Participants can then be described in terms of their strongest features based on the points system. Team roles are: company worker, chairman, shaper, plant, and resource-investigator, monitor evaluator, team worker and finisher. Belbin believed that successful and unsuccessful teams could be differentiated by the mix of roles they contain.

The self- perception questionnaire is reliable only insofar as it is a standalone tool. Caution should be exercised however in reapplying such a tool where participants might be already familiar with its outcomes. Participants can feasibly skew the results to represent themselves in a different light by answering the questions in a different way.

Belbin has found the tool (and its descriptive roles therein) to be valid in that when administered retrospectively, under controlled conditions, it can be successful in predicting the success of teams. More recent work (Partington and Harris 1999), based on empirical evidence conducted on forty-three teams, found no significant relationship between team role balance and team performance.

Partington and Harris' work, however, did find that the presence or absence of certain team roles could have a positive or negative effect on performance.

4.5.6.5 Summary

This particular cross - company team displayed the following characteristics:

- **The business dynamic** - a transitional relationship between the companies. See Appendix 6.
- **The team archetype** - almost equally split between project-orientated & self-empowered. The description 'lean' was rated on a points system to constitute far fewer points than the other two descriptions. See Appendix 7.
- **A 'balanced team'** by Belbin definition following the basic pattern of seven team roles, although interestingly, no clear 'Chairman' / 'Co-ordinator' (Belbin 1996). This is an interesting finding given the work of Partington and Harris, who found a relationship between absent roles (particularly co-ordinator) and team performance. Unfortunately, its investigation was outside the scope of this research.

This author believes that such a team is not unique in the defence industry at this time. This method and not the outcome of this assessment allow this aspect of external validity to be verified. Schofield (2000) has stated:

> A consensus appears to be emerging that for qualitative researchers generalizability is best thought of a matter of the 'fit' between the situation studies and others to which one might be interested in applying the concepts and conclusions of the study. This conceptualization makes thick descriptions crucial, since without them one does not have the information necessary for an informed judgement about the issue of fit.

This team characterisation provides the AS-IS study with one such 'thick' description. The team characterisation together with the description of projects and business circumstance equip practitioners to understand the fit for their own situation.

4.6 Research Procedure - questionnaire

4.6.1 Summary of questionnaire companies

Largely due to restrictions on funding and thesis duration, companies known to the author were used for the questionnaire. Buy-in was sought and acknowledged by senior management in three UK- located civil OEMs – Nortel, Ford and Vauxhall, and five military UK located OEMs – MA&A, MBD, GKN Westland Helicopters, Lockheed Martin ASIC, and GEC Marconi Naval Systems. GEC Marconi Naval Systems was unable to participate due to the pressures associated with its subsequent merger into BAE Systems. Nortel was unable to participate due to the outsourcing of its mechanical design group at Harlow to C-MAC. An overview of participating companies can be found in Chapter 2. Where companies existed on multiple sites, participants were sought from each site. Appendix 8 outlines the site profile of respondents.

4.6.2 Piloting the questionnaire

The survey was proof read for instruction clarity, style and format by academic colleagues from two universities and for question clarity by two independent engineering managers from the following two industrial sectors: IT services and electronics test management.

The questionnaire was then piloted on a mixed group of design related, supplier facing automotive professionals, who were familiar with the basics of supplier selection, concurrent engineering and new product introduction processes. They were briefed as to the questionnaire intent and asked to complete the questionnaire and offer comment on any areas that were difficult to interpret, difficult to answer due to double meaning, unclear due to terminology or statement structure (Easterby-Smith et al. 1991) (Oppenheim 1996). They were also asked to make additional comment about any further factors, omitted from the survey, or which constrained the way in which they worked with suppliers. The amended questionnaire was then used for the wider research.

The inclusion of what Oppenheim (1996) describes as 'long shots', in the questionnaire, in the form of participants' previous functional experience is included to provide insight into individual responses and insight into any possible variance in ethos within and between sectors.

The distribution of questionnaires across civil and military sectors allowed comparison of responses but introduced added complexity in the interpretation of responses. For simplicity, non-parametric testing was used to determine dissimilar responses between sectors. Factor analysis and rotation were used to determine key issues across the business sectors. These factors were then analysed in terms of ethos constructs. Cluster analysis was used to provide further insight into grouping of issues around significant factors. These results were then interpreted using functional experience data from each sample.

4.6.3 Reliability

Reliability of a questionnaire is the measure of how the questionnaire behaves consistently with itself (Oppenheim 1996). A reliable questionnaire should return results that depict the underlying variables with a minimum of error, and not differences due to inconsistencies in the questionnaire itself (language, appropriateness to target audience, management of the 'don't know' circumstance), or to changes in external conditions. Controlling for all external conditions is almost impossible in a dynamic system like a business, however, proximate variables like function and experience can be controlled both by the distribution mechanism and within the instrument itself.

Inconsistencies - Badly worded questionnaires can be a source of unreliability in a questionnaire. Poor reliability in a questionnaire can mean that participants completely misunderstand the meaning of the questions; the same response is coded incorrectly for analysis by the researcher; participants give errant answers which affect the analysis of the questionnaire; or that people will give different answers over time to the same questionnaire.

External conditions - There are of course other reasons why answers should vary over time. In order to improve the reliability of the questionnaire, the language used in the questionnaire was piloted with academic peers, design related and supplier facing personnel from the automotive and aerospace sectors, and two independent engineers from the automotive supply chain and the IT services (serving design) sector. The target audience was selected to ensure that they would have a view on the issue in question, and the Likert scale, incorporating a 3 – 'don't know' answer, was used to capture the undecided response. Additional effort was made in this area to guard against errant answers by including an additional question as a reliability test.

4.6.4 Repeatability

The format of the questionnaire was largely based on the author's interpretation of the research methods literature tempered by the needs of the industrial participants who required that the questionnaire be quick to complete, containing familiar language, and be convenient to return.

The successful repeated application of the questionnaire within the same sectors is possible; however, one must consider that studies of the same participants over time have been known to show variance (De Vaus 1996). One must also consider that the dynamics of a business will also influence participant's views, and that familiarity with a tool, like a questionnaire with specific objectives, may invoke reflexivity – where the participant writes what he or she perceives that the researcher wants to see. Alternatively, they may deliberately do the opposite, fail to respond, or respond with random answers.

Regarding the mechanism of distribution, this requires the support of senior executives and key personnel within each company. Key personnel within each company must be able to identify correctly design-related, supplier facing participants.

4.6.5 Internal validity of the questionnaire

The dynamics of business over time are likely to affect the internal validity of the questionnaire over that period. During the period of research, all of the collaborating companies underwent some form of major structural change. BAe Dynamics became part of a joint venture with Matra, BAe at Chadderton changed from BAe Aero-structures to MA&A; BAe at Warton became part of the wider BAE Systems. Some Ford employees, as Visteon, became suppliers to Ford when it spun off a large part of its component business. It is likely that over time, as employees are trained in the new objectives of their parental businesses, their own views of how they can deal with their suppliers will change. Therefore, the repeatability of such work with the same people would and should be called into question. For this reason, exploratory work of this type should be considered very much a snap shot of a sample of the industries in question, and outcomes should only be used with the business circumstance and supply chain position of the collaborators firmly in mind.

4.6.6 External validity of the questionnaire

The questionnaire was piloted with engineers from industries other than aerospace and automotive and the questionnaire questions were compiled from the literature and from the military case study. The literature reports cross-sectoral experience of SIL[18]. For these reasons, it is envisaged that the issues described have some degree of external validity. Evaluation of the extent of this is outside the scope of the research.

4.6.7 The problem of meaning

A Likert scale (strongly agree - strongly disagree) was used in the questionnaire. Care was taken to make the questionnaire as impersonal as possible and to ensure that the marking scheme was consistent to indicate constraint. It was recognised that strongly negative or positive propositions could be answered with the same response, however, by giving the initial statement "the following factors constrain ...", the situation and proposition intent is clarified. The outcome of this is that the constraining factors indicated by the participant may still require further investigation, in order to understand the underlying perceptions and experiences, but the question is as direct as possible.

Statement of the verb in isolation in the proposition does not normally define the factor sufficiently unless the author and the sample population share know-how of the process. While the author considers herself to have some insight into the design processes, having had industrial experience with design groups and having

[18] Where the literature described particular problems in industry the majority of the researchers had studied industry at close hand. Boddy and Hartley for example use studies based in the electronics sector, Monczka and Ragatzs' work is cross sectoral, Liker and Wasti, Twigg, New and Burns are all automotive based.

conducted interviews with four separate design groups with the collaborating company, parallel insight cannot be assumed. For this reason, negative verbs are used to guide the response towards known identified areas of constraint only. E. g., "knowing supplier capability" can be interpreted as knowing or not knowing. If the participant knows supplier capability and is unhappy with it, he may respond with a "strongly agree". Similarly, if he knows and is unhappy, he may respond - "disagree". If he doesn't know supplier capability, he may feel that this is a constraint and therefore " strongly agree". In summary, "strongly agree" could be the answer from two different participants, but infer completely different perceptions. Therefore by phrasing the proposition " not knowing supplier capability" the proposition is more focused. If however, the participant is basing his response on historical experience there is the possibility that not knowing supplier capability may or may not have constrained supplier working. It may have been a non-issue for him previously. Either way, by phrasing the proposition in this way the response is more meaningful and descriptive of the participant's perceptions.

In order to reduce misinterpretation of meaning, explanatory notes were added in the form of footnotes. Participants were given the opportunity to explain question responses and add background to those responses in a notes section at the end of the questionnaire. While this does not in itself allow for different agendas and experiences in terms of attitude and belief (Oppenheim 1996) it does however allow some insight into where local meaning may vary. Twenty six percent

(30/115) of respondents volunteered additional comments providing insight to their particular experiences. See Appendix 9.

4.6.8 Questionnaire distribution

Distribution of questionnaires was via key people who were given a list of generic functions that may be appropriate design related, supplier–facing personnel in each company. This list was as follows:

- Subcontract Management
- Design / Project Management
- Design/Development Engineering
- Business/Project Management
- Procurement /Purchasing
- Quality/Reliability
- Manufacturing
- Production Engineering
- Component Engineering

It was made clear to the co-ordinators that this list was not inclusive and was meant as a generic aid only.

Actual numbers of returned questionnaires was very much dependent on the following factors:

- How many questionnaires each key person accepted responsibility for distributing.
- The good will and effort these people were able to commit on the researcher's behalf both in locating design-related supplier-facing personnel.
- The effort these people were able to commit on the researcher's behalf in getting the questionnaires completed and returned.

The distribution mechanism was therefore crucial in reducing the effort of these key people and in maximising the response rate. The researcher offered the questionnaire to the industrial collaborators in the following three formats:

- Hard copy, with a SAE for the questionnaire return.
- Soft copy, in rich text format and Word 6, with a return email address.
- On line, via the web page and via CDROM for distribution on company intranets.

It was initially envisaged that the online version would provide a convenient option for design communities; however, the hard copy approach proved to be more reliable in the time scales. This was due to the following reasons:

- Security restrictions for web access
- The managerial complexity in launching a web page on a controlled internal company intranet
- The effort required on the part of the participant to complete the emailed version

Based on the return postmarks of questionnaires, it would appear that some participants posted the questionnaires outside of company premises. This perhaps infers that there was a tendency to take them home to complete.

Given that key people were located as questionnaire distributors and were allocated a number of questionnaires, this method was comparable to a quota sampling (De Vaus 1996) approach; however, the actual number of questionnaires distributed by each key person was not statistically representative of the target population. Estimates of target population within each company were made but there was no rigorous way to validate these estimates due to the changing roles of personnel within each company. This was exaggerated in the case of four of the collaborators who were undergoing massive organisational change at the time.

For these reasons, sampling methods such as systematic sampling, stratified sampling and quota sampling were inappropriate. Even if estimates of population size could be used, there was no guarantee that the required quotas of questionnaires could be obtained in the thesis time scales.

4.6.9 Questionnaire sampling

The inappropriateness of formal sampling methods is illustrated in Table 4-5.

It was estimated that the MBD population of people falling into the category " design related, supplier facing" was around 250. In the absence of any other information a normal distribution of responses was assumed for any one question. Therefore to utilise formal sampling methods, for a 95 per cent certainty, n=2500/E2, n=100. However, because N (250) isn't much greater than n (100).

N' = n/ (1+n/N) = 71

Table 4-5 showing the sample size achieved and the estimated population

Company	Estimate of population**	Number Sent Out	Number back	Sample
MBD (Stevenage & Lostock)	250	32	18	17
BAe (Chadderton, Warton, Farnborough, Brough)	1000	25*	24	24
Lockheed Martin (Plymouth)	10	10	6	6
GKN WHL (Yeovil)	250	10	9	9
Ford (Dunton, Dagenham, Bridgend)	1000	45	45	43
Vauxhall (Luton)	50	20	13	12
Total	2560	142	115	111

Key * 25 hard copies sent out; however, distributed internally on company network by email.
** Population refers to design- related, supplier- facing personnel

Of those participating, the response rate on questionnaires sent out was in excess of 77 per cent perhaps indicating the importance of the role of the co-ordinator within each company. This figure may however be artificially high due to the author not being informed of the exact circulation list within BAe and the likelihood that where the questionnaire was emailed internally a massive target audience is possible, e. g. one recipient may forward the questionnaire with ease to others. It is impossible to track an accurate hit rate where this happens.

Oppenheim states that sample accuracy is more appropriate than its size. This is particularly important when attempting to interpret differences between groups as is the aim of this research. The literature and case study had led the author to believe that military responses to the Likert scale would be in the 1-2 (strongly agree / agree) region for all of the questions, questions derived specifically from the military case study may draw differing responses from the civil sector. The expectation on response therefore is that the means for each variable will not differ significantly within any sector. The preliminary study has in effect reduced the prospective variance in responses already. If we assume that 95 per cent of the population is expected to give this particular answer, (De Vaus 1996) shows that sample sizes as low as 76 can produce a sampling error of around 5 per cent.

4.7 Summary of research approach

The methodology of study can be described as a mixed method, and hence goes some way towards comforting those who would view a case study alone as a 'less desirable form of inquiry' (Yin 1994). The use of a questionnaire, to explore the case study and literature derived concepts further, is an attempt to provide an efficient way of creating a variable by case matrix for a larger sample (De Vaus 1996), where the construct of ethos constitutes the variable of interest.

As a mixed-method it is both exploratory and explanatory in that the questionnaire can be analysed in quantitative ways. The external validity of such quantitative analysis however, would need to be considered in the context of the industrial sectors to which it is intended. The questionnaire draws heavily on both the literature study and the case study. Practitioners who wish to use the findings could use the case study team characterisation for comparison to their own circumstance.

The mixed-method approach involved the following:

- A literature survey
- A single case study of the interface between a military OEM and its suppliers (AS-IS study) together with an in-depth study of a characterised interface between the same OEM and one particular supplier when engaged in implementing SIL
- A questionnaire with the participation of military OEMs and civil OEMs

5 Literature Survey

5.1 Introduction

The objective of the literature survey was to understand whether design ethos was recognised within the context of industrial design and furthermore what issues needed to be addressed specifically when implementing concurrent engineering in the extended enterprise. The terms 'human issues' and 'organisational culture' are starting to be used in the context of concurrent engineering as causal explanations of failure or sub-optimal performance (King and Majchrzak 1996) (Duffy et al. 1995).

The approach to the literature was to conduct research under 4 themes. The first two themes were selected in order to develop a critical awareness of matters relating to implementing concurrent engineering between companies, and, in particular, any possible constraints. The next two areas were chosen to look for evidence of what the author hypothesised to be 'design ethos'. Personal experience of the civilian telecommunication, retail electronics and automotive sectors suggested that 'design culture' differences and the factors that affect this might well provide further insight.

The 4 literature areas chosen for further investigation are as follows:

- Concurrent engineering implementation;
- Supply chain management ;

- Organisational culture and subcultures;
- Ethos.

On completion of the survey, the literature was then categorised into sub-themes. This literature survey follows the form described in Table 5-1.

Table 5-1 showing the form of the literature survey

Section	Theme	Sub- theme
5.2	CE implementation	Why? The advantages and limitations of SIL? How? Constraints - evidence
5.3	Supply Management	Partnering Role politics - issues Constraints – evidence
5.4	Summary	Constraints
5.5	Organisational Culture	Organisational culture Subcultures Cross sectoral variations Norms & Taken for Granteds (TFGs) Engineering design as a subculture Norms & TFGs in engineering design Military culture & ethos
5.6	Ethos	Relationship of culture to ethos Ethos – Use in engineering design

5.2 Concurrent engineering implementation

5.2.1 Why?

Companies large and small strive to ensure business health. Whatever the objectives of the company, be it return on investment for share holders or business growth in an increasingly competitive market, companies are prudent to continually monitor the competition, reduce waste and improve process efficiency in order to remain competitive and achieve maximum benefit. TQM, CE and lean manufacture are examples of such initiatives.

There is also an increasing realisation that there is an obligation on the part of senior executives to lead by example and make provision within companies to retain and nurture employees who directly contribute to a company's well being. Recently this has spawned the concept of 'learning organisations' and increasing academic interest in the impact of human factors on business performance and organisational culture.

As companies grow and expand, there is a need to understand how to manage juxstaposing cultures both intra and inter organisations. At the same time, global lead times are reducing as new players enter the market place and technological advances in IT, communications and processing technology mean that products can be made cheaper, faster and more fit for purpose than at any time in history.

Where an OEM moves from a vertical organisational structure to flatter horizontal structure there is realisation that the company must foster relationships with suppliers, customers and even competitors. This is necessary in order to meet market demands and to ensure continuity of supply of its products in local and foreign markets, as well as to ensure continuity of supply of technology know-how where this is no longer in the company. Twiss (1992) believes that technology has been and will remain the prime stimulus for change in our society and that managing technological innovation for profit is now the biggest challenge for business. Where such potential innovation is in the hands of suppliers, where perhaps processes have been deemed to be non core to an OEM's business needs, such management becomes increasingly difficult.

Effective SIL working is an attempt to meet increasingly tight business targets through effective collaboration at the design phase between a company and its selected suppliers. This requires a thorough appreciation of the issues mentioned:

- The business objectives (access to technology, reduced change, time to market, development cost, life cycle costs)
- The importance of company personnel to the process
- The importance of good relationships in and outside of the company
- The importance of early recognition, adoption and use of new technology with all of its standards, training requirements and forward planning (technology path).

The benefits of SIL have been reported as reduced time to market, reduced component cost, reduced cost of postproduction change and harnessing supplier innovations. The implementation of concurrent engineering with suppliers is described in the literature as Early Supplier Involvement (ESI) (Dowlatshahi 1998) although the extent to which one can involve a supplier in design varies both in terms of timing and objective. Encouraging a supplier to contribute to concept development in an open forum (for example for the identification of show-stoppers or for pricing estimation) is not the same as one-on-one involvement in the development of a component, sub-assembly, or sub-system. It was important therefore to keep in mind a definition of Supplier-in-Loop (SIL) working. The nature of SIL as observed during the AEROEXTN project can be characterised by the following features:

- A will on the part of both collaborators (OEM and supplier) to work together earlier in the design project to take time and cost out of the delivery of new products.
- A will on the part of both collaborators (OEM and supplier) to reduce later life costs by the reduction of design change through due care to the design manufacturability prior to initial manufacture.

Various studies have examined why companies are moving towards this way of working with suppliers. One international study on three continents which studies the uptake of this practice outside of the automotive sector concluded that the obsolescence of internal competencies appeared causal (Bidault et al. 1998); however, these results were based on a very small sample (24 questionnaires).

Certainly, within the current climate, internal competencies can become obsolescent for many reasons: loss of tacit and explicit knowledge through the departure of employees; the deliberate policy of outsourcing certain functions; the loss of employees to competitors or to other industries (Jordan and Jones 1995); the promotion of employees to senior positions or secondment of employees to remote projects (Philpott et al. 1998). Boyson et al. (1999) infer that working collaboratively with suppliers can be one way of acting strategically to maximise one's own internal resources. Pallot and Sandoval (1998) state that the growth of networks [in the context of extended enterprise] allows people to realise that information is a source of value when it is shared. When two people communicate, they each can be enriched, and unlike the traditional resources, the more they share, the more they have. Pallot refers to this as Metcalfe's Law. Prasad et al. (1993) state that 80 per cent of the life cycle cost is driven by the decisions made in the first 20 per cent of development effort.

Ullman (1992) states that during the early stage of new product development (NPD) over 75 per cent of the total project costs may already be built into the product before any manufacturing is commenced.

5.2.2 The advantages of SIL

The advantages of SIL are in the areas of quality improvement, cost reduction, development speed reduction and innovation. The type of SIL process employed will be contingent upon the industry and market requirements of a particular OEM.

For example, SIL may involve a supplier in a design capacity or as a contributor of manufacturing know-how. In the first case, the aim may be to innovate or to maintain access to skills no longer within the OEM, while in the second, the aim may be to reduce time or cost.

Bonaccorsi and Lipparini (1994) outline the benefits from partnering [of which SIL is one element] at the NPD level. These are:

Cost

Early availability of prototypes
Standardisation of components
Visibility of cost-performance trade-offs
Consistency between design and supplier's process capabilities
Reduced engineering changes
Target price contractual agreements

Quality

Consistency between product tolerances and process capabilities
Refinement of a supplier's processes
Availability of detailed process data
Concurrent Engineering of activities
Early identification of technical problems

Time

Reduced suppliers process engineering time
Acquisition of supplier's production capacity

Innovation

Design partnership
Incentive to development efforts sustained by suppliers
Reduced adoption risk

Examples of financial gains are reported widely both in industrial journals and in the academic literature; although few papers detail how the financial gains are actually formulated and what, if any, assumptions are made in order to compile these figures.

Deitz (1996) reported that engineering change orders were reduced by seventy percent, saving approximately three hundred thousand manufacturing labour hours on the McDonnell Douglas strike fighter. Anon (1997b) describes savings at Chrysler in reducing the lead time to market from five-six years to two-three years; savings of twenty per cent on the Honda Accord programme through value added/ value engineering suggestions; and reduction in change errors and rework by fifty per cent on the Boeing 777.

Monczka et al. (1997), reported world-wide survey results dealing with supplier integration, where twelve of the one hundred and thirty four questionnaire responses were from aerospace companies. The overall median performance improvement results of questionnaire participants were:

Purchased Material cost (n=71)	15%
Purchased material quality (n=52)	20%
Development Time (n=65)	20%
Development Cost (n=54)	15%
Functionality /features/technology (n=53)	10%
Product manufacturing cost (n-49)	10%

There appears to be a very distinct difference in how the supply-management – related literature views savings, and how design-related literature views savings through supplier integration. For example, cost reduction initiatives like Honda's VA/VE scheme (Anon 1997b) or Chrysler's SCORE system (Dyer 1996) are quite different to initiatives which achieve benefit through time improvement to the existing design process. In this type of initiative savings in cost and time are achieved by reduction in design change and reduction in manufacturing cost through early communication with suppliers. In terms of our SIL definition both types of initiative have a role to play in achieving benefits, however, the literature suggests that the prima facie reasons for moving to SIL are the following: retaining access to competency external to the company; to allow more efficient usage of internal human resource; and to reduce total life cycle costs by considering and eliminating cost adding elements early in a product's life cycle.

5.2.3 The limitations of SIL

From the literature it would seem that the limitations of SIL lie in two distinct areas. These are the marrying of SIL aims and outcomes for all parties and the appropriateness of SIL as a panacea for all industry types. To consider the issue of SIL aims and outcomes, one must address each of the known SIL aims independently:

Reduced cost - Littler et al. (1995) found that 40 per cent of experienced collaborators considered that collaboration makes product development more costly, more complicated, less efficient, more time consuming and more difficult to control and manage. Rochade (Reengineering of Complex Aircraft development process in a distributed environment), an ESPRIT project gathering together Daimler Benz Aerospace, BAe and CASA, recognized that about 40 per cent of the overall development costs are accounted for by collaboration overhead, harmonization, and information exchange, which are in fact non-value added activities (Pallot and Sandoval 1998). Given this type of overhead, it would seem there is further need to understand not only the advantages of SIL working in terms of efficiency and cost, but also the limitations in terms of cost.

Sririam & Mummalaneni (1990) expressed the view that the supplier needs to see downstream benefits or adequate recompense to be accepting of SIL. According to New and Burns (1998) the more an activity is focused on the supplier, the more likely it is that the supplier will pay the costs and the customer will reap the benefits. Conversely, the more an activity involves changes in both the customer's and the supplier's operations, the more likely there is to be an even distribution of costs and benefits.

In the literature, where metrics are quoted in terms of SIL benefits, they are ill defined. This immediately raises the likelihood of 'creative- accounting'. Brownwell's process design standardisation ration (PDSR) may be an alternative approach to the common metrics used e. g., change cost, and transition time to manufacture. Dowlatshahi (1998) defines this as a means to measure the effectiveness of implementing the ESI activities in the product development process. PDSR = Total current cost to design / Total prior cost to design.

A methodological concern, based on the experience of the AEROEXTN pilot project, is that when questionnaires are completed, it is unlikely, given the difficulty of measurement, that any one participant could have access to all of the facts and figures required. As such there could be some reasonable doubt as to the accuracy with which any benefits are proffered. Combine this with well meant marketing on the part of the interviewed, and the enthusiasm of champions and journalists to report the success of new paradigms, and we have a recipe for at worse misinformation, at best exaggerated successes.

Reduced time - It is possible to meet lead-time targets at enormous cost; it is also possible to meet cost targets at enormous project risk. Where metrics are applied in isolation, isolated successes and failures are the consequence. SCRIA, the supply chain research arm of SBAC has identified the need to develop more appropriate performance measures when supply chain efficiencies are the aim (SBAC 1999). This author considers that the same is true of individual instances of SIL working.

Improved (maintained) quality and innovation - Kessler and Chakrabarti (1996) consider there to be limited scope for enhanced product quality or technological advancement with supplier integration. Ittner and Larcker (1997) have suggested that of all the concurrent engineering processes considered that early supplier involvement is the least clearly beneficial. Hartley et al. (1997) found, in a study of small to medium sized companies, that of the three techniques most commonly used to integrate suppliers into development processes, only early supplier involvement was significantly related to the perception of an increased contribution by the supplier. While this was the case, they found that the supplier's actual contribution had little practical influence on the projects technical success.

There appears to be empirical evidence to suggest that both the nature of competition within an industry and the organisational norms of an industry affect the uptake and success of SIL:

Industry type - A study by Loch et al. (1996) suggested that development process performance [presumably in terms of objectives like cost, time quality and innovation], depended on the nature of competition in each industry. The study also implied that in certain industries supplier-involvement is still a source of advantage as opposed to a competitive necessity. Swink et al. (1996) appeared to corroborate this by stating that product characteristics, customer needs and technology requirements appeared to dictate CE approach. Case study research (technically sophisticated products) had shown that aggressive product cost goals necessitated intensive interaction between design and manufacturing [possibly SIL] and highly innovative products required early supplier involvement and joint engineering problem solving. This SIL 'requirement' approach appears to contradict that of Kessler and Charabarti whose findings are that this type of CE is ineffectual given the same aims. In summary, the literature still appears to be contradictory in this area. The author suspects that this variety of findings is contingent upon the research methods employed combined with the vastly differing industrial sectors studied.

A further limitation of SIL may be that discussed by Liker et al. (1999). They found that 'tall hierarchies' and 'job specialisation' were negatively associated with design-manufacturing integration, particularly for new designs. This suggests that where SIL is used for the purpose of capturing manufacturing know-how to reduce time and cost, certain types of company organisation issues may limit success.

In conclusion, on balance, when one considers what can be achieved through SIL when it is combined with other management initiatives indicated as necessary in the literature, it still remains a viable business option for many businesses attempting to achieve aggressive business targets.

5.2.4 How?

Backhouse et al. (1995) drawing upon Wheelwright and Clarks' initial work together with heuristics deduced from industrial case study proposed a framework and a set of heuristics to support NPI managers in optimising performance in CE. This work is based on the notion that the form of CE used in a company is contingent upon the external forces acting upon the company. More recently, Poolton and Barclay (1996) put forward the idea that the level of a company's CE need is governed primarily by the level of complexity of the product to be produced. To this end, a framework is put forward that could be used to assess CE needs. By this approach, the primes of the aerospace defence industry would gain from introducing dedicated teams with their own location. Poolton and Barclay also argue that computer networks are critical to the NPI process. While this is true of most aerospace design communities, it does not answer the question of whether suppliers should share common equipment or how far we should bring suppliers into internal business processes.

Backhouse and Brookes (1996) take a top down approach to implementation and advocate a generic framework for implementing CE change. This is based on 7 key steps and makes no assumptions about the contingent nature of any business variable. This approach can be applied to CE in the extended enterprise but remains generic in nature. More recently the need to tailor CE to a particular business need has been reported by both Backhouse and Brookes (1997). This paper recognises the difference between applying CE at a tactical and strategic level and puts forward a framework for expressing a variety of CE solutions describing what sort of solutions work where. This is based on elements of Process, People, Tools, Structure and Control. See Figure 5-1.

The framework illustrates the five forces acting on a company's product introduction process and how they relate to the pressures it experiences to introduce new products. The product introduction process is described by the five elements of Structure, Process, Tools, People and Control. 'Structure' describes how people are organised; for example, they may be hierarchical by function or may be grouped by the type of operation they perform. Alternatively they may be product or programme orientated, or more recently a mixture of the two.

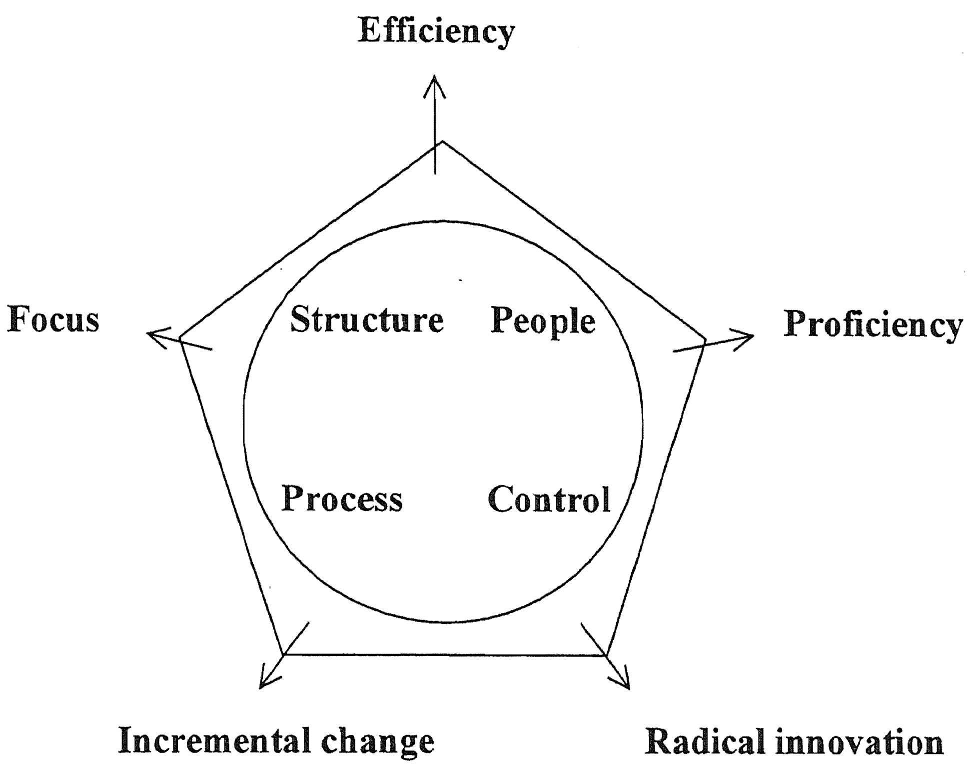

Figure 5-1 illustrating the Backhouse et al. CE framework

Backhouse's definition of 'Process' is specific to whether a company operates parallel or sequential processes, or a mixture of the two. 'Control' refers to the way in which projects are planned and measured and also to the mechanisms in place to encourage wider initiatives. Backhouse's description acknowledges that such systems can be manual or automated. 'People' refers to the roles that people take within organisations and the skills they require referring specifically to how the individual participates/contributes, as an individual with specific skills or as a team members with a wide skill base. 'Tools' refer to the full range of tools and techniques employed in the product introduction process. These may be for CAE, EDM, communications and quality monitoring. The 'Tools' definition also includes information in the form of procedures; product related information – new and old. Finally, 'Tools' also includes manufacturing equipment that by its nature has an impact on the process.

Backhouse's framework is generic and like all such frameworks justifiably has somewhat narrow definitions. Similarly, events that arise in a real environment may involve two or more of the issues proposed. If a user were to look to this framework for guidance in determining an overall implementation approach, some effort would need to be made to correctly categorise the issues at hand.

Paashuis and Boer (1997) advocate a framework based on specific areas of business direction. This approach does cover a number of decision areas highly applicable to CE in the extended enterprise such as organisational design, size of design budget and customer demands, but does not address wider enterprise issues such as inter-organisation communication.

Hull et al. (1996) investigated the relationship between three forms of CE implementation to determine what made CE effective. This work highlighted the importance of combining early simultaneous influence in product design decisions (effectively cross-functional teams) in process design controls and computer information technology. However, this research was single company based and like the other studies did not address the added dimension of a supplier being part of the cross-functional team.

Other sizeable and rigorous studies worthy of note are those of Monczka et al. (1997); Monczka et al.'s study formed part of the Global Procurement and Supply Chain Benchmarking Initiative of the Eli Broad School of Management of Michigan State University, US. The survey itself was a three-stage project studying industry strategies and most effective practices for integrating suppliers into the product value chain. This study concluded with a 'World Class Excellence in Supplier Integration profile' which is as follows:

- Aligned objectives and compatible company cultures between the buying company and the supplier
- Clearly defined and agreed upon (by buying company and supplier) technical performance measures and targets for the project
- Clearly defined and agreed upon (by buying company and supplier) business performance measures and targets for the project
- Supplier involvement in the establishment of technical and business performance targets for the project
- Minimal changes to technical requirements/specifications after the initial agreement has been reached
- Appropriate use of co-location for personnel during the project
- A high level of management support for the integration effort in both the buying company and supplier's organisation
- Strong commitment to the project on the part of the supplier
- Formal and equitable arrangements for sharing the risks and rewards of the project between the buying company and the supplier
- A high degree of clarity in both the buying company and the supplier's organisation regarding the roles and responsibilities of each organisations personnel in the project
- Open, direct, and extensive communication and information sharing (including technology and customer requirements information) between the two organisations during the course of the project
- An active decision making/problem-solving role for the supplier on the project team. (Monczka et al. 1997)

In a study of fourteen companies conducting fifty cross national projects, Haupman and Hirji (1996), found that four behaviours of engineers and manufacturing members of cross-functional product development teams were found to be reliable predictors of development projects' success. Success was measured in terms of cost and quality, project schedule, budget performance and project team satisfaction. The four factors are:

- Two way communication
- Overlapping problem solving
- Readiness to make decisions on the basis of uncertain and ambiguous information
- Readiness to release uncertain and ambiguous information

A further interesting point from this paper was that all participants were not co-located - a point which appears to corroborate the Monczka findings of 'appropriate use of co-location'. Hull et al. (1996) further addressed the issue of co-location. In a study of a range of companies in a range of industrial sectors, although no aerospace companies, Hull found that co-location was not significant to the extent of early supplier involvement. These findings are particularly interesting as a dedicated and frequently co-located project team is a recurring 'CE ingredient' in the literature. Kahn and McDonough (1997) appeared to reiterate this finding in their study of the relationships between co-location, integration, performance and satisfaction. Their findings indicated that co-location facilitated collaboration between R&D and marketing, but not between manufacturing and other departments; however, there remained links between collaboration, performance and satisfaction.

A cross-functional team, whether co-located or remote is certainly an ingredient for CE success, however, there are still relatively few case studies reported where suppliers are part of the cross-functional team, one notable and relevant exception being Valdez and Kleiner (1996). The principle behind cross-functional teams is that representatives of parties to all the later life cycle decisions are involved with development. The knowledge gained from experience of production and use of prior products inform the up front decisions. Cooper (1995) found that the most sound business practices that help profitability also lead to fast-paced, on time products. Cooper's study showed that cross-functional teams were influential in this.

Philpott (2000), described the implementation tasks and pre-requisites required for CE implementation at a tactical level. This implementation plan advocates the early formation of a inter-company team comprising representatives of procurement, design, quality and engineering at the OEM, and production, engineering and business management from the supplier, which is largely in line with the Todd (1995) description of an appropriate team structure. The AEROEXTN team was not co-located. The paper specifies that once SIL processes are in place, day to day SIL working should be conducted directly between OEM design and supplier production personnel using meetings, phone, fax and email. . Pre-requisites for SIL working are described as:

- Senior Management supports at BOTH companies.
- Recognition and commitment to change culture in both companies
- Some form of commercial Ts & Cs (formal/informal)
- OEM functional buy-in: Design, Configuration control & systems, Procurement, Quality (receiver of the parts from the supplier)
- Supplier functional buy-in: Manufacturing engineering, Project Manager / Sales Manager, Engineering development

Philpott 's work concurs with the work of Dowlatshahi (1998) in the area of SIL pre-requisites. Dowlatshahi describes pre-requisites for SIL as:

- There has to be a formal plan and structure in place for ESI implementation...

- Only suppliers with long term relationships and partnerships with the buyer should be expected to participate in the ESI programs. This necessitates that suppliers be certified and prepared to commit themselves on a long-term basis.
- The ESI process requires an effective interdisciplinary team. The team members should be drawn from design, procurement, suppliers, and manufacturing groups...
- Effective ESI requires the support and involvement of top management.

A further possible constraint to SIL working is the academic argument regarding restriction on creativity that is imposed by forcing a designer to work in a certain manner with certain people, design tools, standards, etc. The argument is that an over-insistence on formal procedures and detailed justification for ideas still in their infancy can seriously affect the creative process (Twiss 1992). The argument against SIL is that we invite 'dual book keeping' by encouraging a designer to share immature designs with suppliers. The designer may be tempted to share a sanitised version thereby decreasing process efficiency, and at worse, encourages a less radical line of thought – which can be shared without fear question and embarrassment. Kessler and Chrarbarti (1999) while advocating a contingency approach to speeding up innovation [no 'one best answer'], also suggest that limiting the degree of design for manufacturability is one way of accelerating projects. This would suggest that initiatives such as SIL might be inappropriate where the supplier is only contributing manufacturing know-how.

There is evidence elsewhere of the importance of the fluidity of the design process. Court and Ullman (1998) found that while studying the provision of information to engineering designers, the efficient delivery of information to designers within the NPD is of vital importance to the overall success of the project. This point was further re-iterated by Duffy and Salvendy (1998).

> ... the knowledge for problem solving provides an anchor, in a sense, for the CE team". "Anecdotally it appears that the people, particularly those in manufacturing, who have more experience and familiarity with solving similar problems gain the credibility and trust of the rest of the team. When using the tools to enable the success, those team members, particularly design members, only want 'problem specific' knowledge that is available within a certain reasonable amount of time and search effort.

Duffy further suggests that the manufacturing team members should have ready access to the relevant and strategically useful information. And that they should provide the designers, when possible, with information related to the new product development effort that would help highlight the 'cost drivers' prior to the design of the manufacturing process.

Other authors emphasise the importance of the human-human relationship for problem – solving (Wheelwright and Clark 1994) (Lewis 1995) and the importance of using common tools to conduct such a dialogue. Singh and Lewis (1997) identified a major requirement for the successful implementation of concurrent engineering systems to be the development of a shared understanding of the product development process and associated computer tools among the groups using, building and maintaining these systems. Singh and Lewis also outline the importance of having a documented CE process in terms of flow diagrams, process models etc.

Fruchter et al. (1996) proposes a conceptual framework for inter-disciplinary communication of design information in the conceptual design stage and presents a prototype called Interdisciplinary Communication Medium (ICM). The important concept of ICM is that of a common graphical environment. This idea of the importance of a common, or shared, graphical environment is a recurrent theme in the literature. Where case studies are reported, the use of common CAD tools or CAD related tools (Martin 1997) (Anon 1997c) (Burns and Szczerbicki 1997) (Meyer 1997) (Roser 1995) and increasingly the use of group-ware for common access to design information, management of project issues, and administration (Dijkstra et al. 1999) (Knoai 1997) (Stevens 1997), appears to be important.

5.2.5 Constraints

The work described thus far gives the reader some considerable insight into what is required for successful SIL. The pre-requisites, management practice and day to day working practices described can be classed as both CE enablers and CE tools (Prasad 1997). Therefore by logical deduction one may propose that the absence of enablers or tools or a combination of the two, will constrain CE, and especially SIL working.

Papers describing such constraints can be found in both the engineering literature and the supply chain management literature. Generally CE enablers or tools or the absence of CE enablers and tools are examined at a strategic and a practical level. Both areas are of interest in exploring the human issues of implementing SIL.

Another constraint for SIL working is the ability of an OEM to maintain up to date knowledge of supplier capability. This, together with the recognition that repetitious design activities can be easily done by computer, has spawned the area of Knowledge Based Engineering (KBE). In KBE formal systems of data gathering are used to compile process related information, both explicit and tacit, so that it may be made available to prospective users. At its heart is a generic representation of the product type for which the application has been created (Cooper et al. 1999). Repetitious jobs are simplified using the power of the computer. The importance of tacit knowledge in design and the management of valued knowledge within companies and inter-company are also the subject of an increasingly large body of publications in the area of knowledge management. Boyson et al. (1999) states:

> Leading companies orchestrate not only their own activities and capabilities, but also those of their supply chain partners (i.e., suppliers/vendors, service providers, alliance partners, customers.) This orchestration requires the enterprise to have very sophisticated knowledge and understanding of its supply partners.) This understanding encompasses organisational structures and capabilities, physical network assets, technology/information management systems, and so on.

Component complexity and the conceptual form (3D / 2D) of components are also cited as a potential constraining factor for concurrent engineering success. Burns and Szczerbicki (1997) in a study of CE implementation in Australia found that the conceptual identity of a component arose as a major indicator that could be used to distinguish between design techniques that would enable growth of CE and those that would provide sub-optimal implementations. Burns further advocates that EDM and data type CAD systems promote a fundamentally different view of the design process. Instead of a designer creating the identity of a component by defining its shape and size (as with traditional drafting or CAD systems), a component's characteristics slowly evolve as an independent entity. This is due to the interaction of the members of the design team with a computer database that represents the component.

5.3 Supply Chain Management

5.3.1 Partnering

In SIL, suppliers are involved at the initial modelling stage of components, which is somewhat earlier in the design process than has previously been considered normal practice. Twigg (1995, 1998), in a study in the automotive sector, describes how an increasing demand for new technologies and an acceptance that single companies can no longer retain in house all the necessary design and process capabilities, has brought about a new set of relationships between motor vehicle manufacturers and their suppliers. Twigg distinguishes between supply chain management and what he calls 'design chain management'. He argues that design is a special type of supply transaction, characterised by high task uncertainty, requiring of joint problem solving and involving the transfer of often-incomplete information.

> Design chain management is defined as the management of the participants, both internal and external to a focal firm, that contribute the capabilities (knowledge and expertise) necessary

> for the design and development of a product which, on completion, will enable full-scale manufacture to commence. (Twigg 1995)

Distinguishing design chain management from supply chain management because of its inherent nature is commendable on an academic level; however; the two remain inextricably linked on a practical level.

To 'enable full-scale manufacture' by contributing manufacturing know-how, SIL requires a way of working which does not sit naturally within adversarial UK contract law (Macbeth and Ferguson 1994). Over the last ten years, many industries have endeavoured to emulate Japanese style Keiretsus. (Dyer 1996) (Labich 1999). This seemingly effective way of working spawned the concept of 'Partnering' or 'Partnership Sourcing' in the west. The CBI defined partnership sourcing as:

> A commitment by both customer and suppliers, regardless of size to a long-term relationship based on clear, mutually agreed objectives to strive for world-class capability and competitiveness.

The supply management community has been seen to promote partnering (Lamming 1993) (Lamming and Cox 1999) of which SIL is one element. Western companies find this type of relationship legally difficult to agree due to:

- Grey areas in the interpretation of competition legislation (EC 85[81]); (EC86[82]); (Cini and McGowan 1998);
- Internal and external company pressures on an OEM's supply base, causing supplier nervousness and fluctuating commitment on the part of the OEM (e. g. Joint Venture, enforced suppliers, economic pressure, technology requirements (Bozdogan 1997); (Velocci 1997);
- The need for a 'leap of faith' in terms of culture and procedural change (Philpott 2000).

More recently, a CBI delegation to Japan to study the status of the business supply chains (Cherrett et al. 1999) would appear to draw somewhat different conclusions about the altruism and success of such arrangements than were reported just a few years ago.

> It is clear that Japanese firms have not developed 'partnering' in supply as it is recognised in the West. The dominance of customers still appears largely benevolent but not to the point of shoring up weak suppliers, nor flouting market forces.

There would now appear to be an air of caution within the supply management community, in advocating the ideals of partnering without endorsing the need to understand and accommodate the very different requirements of western suppliers, and the very different human issues at play. The literature is unclear as to whether SIL is synonymous with partnering, although where partnering is the aim, it would appear that SIL is one mechanism used to reduce costs and thereby improve competitiveness. There is also an emerging body of thought within the literature primarily from the motor industry, and construction industry that questions the WIN-WIN aims of partnering relationships (New and Burnes 1998). Spekman et al. (1999) also makes the point that attempts at partnering have met with mixed success.

Boddy et al. (1998) are particularly insightful in describing which factors contribute to success and failure when implementing partnering type relationships. They considered the change management literature for evidence as to whether this particular approach has been beneficial for supply-chain related initiatives. Based on a sample of one hundred questionnaires from three hundred and fifty companies a number of barriers to partnering were identified which could perhaps be equally applicable to SIL working. These were:

- Understanding the scale of change which partnering involves
- Underestimating the turbulence surrounding partnering
- Priority constraints left unresolved
- Over-reliance on good inter-personal relations
- Cost, benefit and value adding models not defined
- Insufficient focus on the long term

The first point deals with the underestimation of the change in the division of tasks between the partners, changes in IT, and changes in communication within each of the partners. Change in this context was with respect to roles, relationships, reward systems and the provision of resources.

The second point deals with turbulence. This is the tendency for projects to be blown off course and the need for not only project initiation but also monitoring and control. In most large companies employees are managing any number of projects at one time. Existing reward systems and short-term fire fighting tends to compete successfully with longer-term business improvement initiatives unless kept in check.

The third point – priority constraints left unresolved- re-enforces the prior point at a more personal level. Fire fighting with the business need in mind is commendable; however, Boddy et al. point out that people bring personal agendas to such decisions as well. If personal status or a long-term career plan is affected then individuals may act to diminish the change.

The fourth point – over-reliance on good interpersonal skills – addresses the issue of champions. Boddy et al. found that the nomination of a strong champion to push through the changes was not in itself a guarantee of success. The treatment of the importance of personal relationships is less than sound, as they give no consideration to the impact of transitory roles – for instance, other authors, amongst them (Christopher and Juttner 1998), consider the fragility of 'boundary spanning employees' as contributory to the success or failure of such initiatives. Further to this, the emergence of the importance of 'know-how' engineers (Calabrese 1999), 'information managers & design consultants' (Northrop 1998); 'Rudis' (Stewart 1998); 'technological gatekeepers' and 'information stars' (Twiss 1992) in the literature is another point worthy of consideration when considering the appropriate character and background for such champions.

The fifth point - cost, benefit and value adding models not defined – deals with the need to assess cost drivers in the sets of processes involved in both organisations.

The sixth point – insufficient focus on the long term - addresses the need to continually communicate the company need for improvement in quality and delivery performance. It also addresses the need to continually resource the change program in view of the projected gains, and to recognise/act upon larger scale opportunities which may involve more wide ranging stake-holders.

5.3.2 Role politics – issues

'Differing agendas' between functions, predominantly procurement and design is dealt with fleetingly in the literature, although one suspects that this will be an increasing topic of papers in the future as more companies embrace the global stage. Liker at al. (1999) give an example of one type of issue which may cause friction between purchasing and design:

> ...for example, detailed steps mandated in purchasing approval for sourcing can create bottlenecks in the process and may not allow for decisions appropriate for specific circumstances.

Industry bodies such as SBAC have started to uncover discontinuities between functions within aerospace companies. (SBAC SCRIA 1997/8) reported the following, amongst others issues, as key issues that needed to be addressed:

- Buyers – not close enough to the business
- Buyers often involved too late
- Buyers have to negotiate done deals
- Buyers often have 'just part of the story'
- Variable standards in negotiation skills
- The need for better team working
- Cross functional communications

This point was also re-iterated at a SCRIA-sponsored aerospace industry workshop on 'Commercial issues of early supplier involvement in design', July 1999 (SBAC 1999) which was facilitated by the author. The following factors were identified as constraints in involving suppliers early in design:

- Participants debated the need for contracts for early supplier involvement in design. It was felt that existing types of contract had very long lead times to complete and were hardly consulted when projects ran well. Contracts were only consulted when things went badly between the parties. The question was asked as to whether an ESI contract was just another contract with the same problems.

- Participants in the workshop expressed the view that clarity was needed in the type of contract required when suppliers are to be involved early in the design process. One needed to distinguish between product, project, and type of relationship.

- Participants felt that there was a need to make the purpose of and reason for the contract clear. Often, it was felt that contracts were merely used as 'a big stick', 'a shadow' over the product, the project, the relationship. The tool of Memorandum of Understanding (MOU) was debated at this point. Users' experience suggested that it could be used as a vehicle to facilitate early supplier involvement in design. One view was that MOU could give parties 'a warm feeling' as a pre-contract device. Some discussion followed as to whether MOU was a form of legal contract.

- Participants believed that there were specific problems of security when attempting to involve suppliers early in the design process that were particular to the defence sector. Unlike the civil sector perhaps, sharing information with specific companies, specific functions within companies, specific locations and even specific individuals within companies needed to be managed.

- Participants believed that the absence of a common language down the supply chain was a potential obstacle to involving suppliers early in the design process. During the workshop, participants debated the need for a common language in terms of standards. However, it was felt that the possible benefits needed to be weighed against the cost and added bureaucracy of the thing: there was a risk that such an exercise would be seen as non-value adding and therefore unpopular in the current climate of lean supply.

- Participants viewed the requirement for competition in the supply chain, required by customers, as generally militating against building relationships. Competition down the supply chain could be a requirement of UK government and foreign governments on all supply contracts. This was considered a serious problem that prevented this type of work practice.

- Participants felt that managing "the better offer" was an issue for early supplier involvement in design. There was some concern as to how to manage the situation with the chosen supplier if a better technical solution came along while the part was in development. The concept of Limits of Liability (LOL) was discussed as one method to cope with this situation. In such agreements, a LOL is agreed at the outset of the project in terms of money. Where either party chooses to cancel the agreed working relationship for specified reasons, recompense in terms of LOL is applicable. In a Build to Print process, one supplier would simply be dropped in favour of another.

- Participants felt that different agendas between commercial people and those tasked with involving suppliers within companies did not bode well for early supplier involvement in design. Experience had shown that at a "hands on" practitioner level, there was enthusiasm for working this way between OEM designers and a supplier's production people, once the process and a personal relationship was established. It was felt that without clear support from superiors, and/or a formal contract, commercial people remained uncomfortable with the relationship.

- Participants felt that a personal relationship at the commercial interface was essential for early supplier involvement in design. In itself, it could facilitate without the need for contract. The problem with this was that people and roles changed and that dependency on such relationships was by inference fragile. It was also stated that some suppliers however, always require some form of contract to feel comfortable in any type of business relationship.

This forum highlighted a number of important constraints in SIL working, some of which were perceived to be defence specific. SCRIA also highlighted separately that the 'MOD bidding/supply rules/procedures' actually work against the aims of SCRIA (SBAC SCRIA 1997/8) which was to promote a Code of Practice for working in a co-operative supply chain. This author's experience in the telecommunications and electronics sectors suggests that client-OEM relationships in the civil market are somewhat more liberal with regard to requiring OEM's to cascade client (design-specific, process-specific) requirements to lower level suppliers. Indeed, where new procurement initiatives on the part of the MOD are working to remedy these types of inefficiencies (White 1998) (Moore 1998) (MOD 1999) there is still considerable delay in the message getting through to OEMs. This was evidenced at the 1999 SCRIA conference where less than 10 per cent of the audience were even aware of the web site which explains about the MOD's new procurement initiative – SMART.

A further point that may be hindering this process, and therefore constraining SIL in the supply chain, is the method by which new policy is broadcast to suppliers. Compare for example the methods of defence companies and the DOD in the US, with those of the UK DPA. In the US, new military procurement policies are published on the web (Perry 1999), and readers are instructed to act upon the new policy. In the UK policy objectives are published, but specific instructions have to be interpreted from up-issued standards (MOD 1999).

Initiatives such as SIL can be spearheaded by any function. The literature shows however that this is predominantly design or procurement. There is however a realisation that the largest savings to an OEM in terms of design costs and component life costs, (hence benefit in terms of longevity of business to a supplier and reduction in disruption costs) comes through pre-manufacture collaboration. This specifically requires design's buy-in rather than traditional post manufacture, logistics-based, procurement support. The literature is clear as to the benefits of internal cross-functional teams involving procurement with design, however, there is increasing realisation that for procurement to be effective in this role, there are perhaps new skills to be learned (Lamming and Cox 1999) (Wynstra et al. 1999).

Monczka et al. (1998) outline a 1988 survey where engineers' most frequent problems with buyers included a lack of product knowledge, buying strictly based on price, poor follow-up and feedback, buyer inflexibility and an unwillingness to try new suppliers.

Traditional procurement roles and skill requirements are being eroded away. The implementation of increasingly automated supplier selection systems, the adoption of long term business contracts with large suppliers (Scott 1996)

(Bozdogan 1997) (Haddad 1996) (Stundza 1999) and the abdication of management of lower tier suppliers have taken away a lot of the traditional roles of the procurement staff within OEMs. E-commerce in the logistics field; a propensity to view total life costs as opposed to short term piece part costs; and, a relative absence of formal mechanisms to do this (De Beer 1998); have all acted to make commercial contracts, management of risk, and supplier audit the last bastions of procurement practice. Where design acts to adopt some of these practices in the interests of effective SIL working, it is perhaps not surprising that procurement's 'commercial issues' become a constraint to SIL. Similarly, where procurement staff are now wanting to contribute to make/buy decisions, proffer a cost based opinion on appropriate technology paths, or insist on preferred suppliers – design start to question the skill levels of procurement staff to contribute. This too can perhaps be a constraint for SIL working. In truth, both are perhaps operating outside of their traditional skill areas.

Wasti et al. (1997) found in studies of Japanese involvement of suppliers in design (although notably, a study which excluded suppliers of machined parts), buyers were the main decision makers in design collaboration efforts with suppliers. Based on the evidence available in the literature, and the problems identified through SBAC, it would seem that this is not the case within the UK aerospace business.

5.3.3 Constraints

Wasti's work also found that a trusting relationship was essential for success although no relationship emerged between the success of the effort and the level of trust that existed between the two companies prior to the suppliers involvement – suggesting that a prior poor relationship did not necessary constrain SIL working.

Effective use of commercial agreements covering IPR, risk and reward, and confidentiality, correlated positively with the development of trust during the project and hence the success of the project. Effective use of contracts features elsewhere in the literature. Lewis (1995) describes relationships between Chrysler and its suppliers and Motorola and Molex. While describing the need for contracts in certain 'arm's length' relationships, he states that the idea is not to have a legally enforceable contract, but to have clear understandings. He describes how Motorola maintains written guidelines – often prepared with the advice of its suppliers – describing the rules of conduct for important joint activities like early design participation. Hughes has also applied this principle to its Integrated Product Teams, which can involve suppliers (Valdez and Kleiner 1996).

Further supply management constraints are described in the literature which largely concur with issues described in the wider change management literature. Lewis describes Not-Invented-Here (NIH) behaviour (the aversion to new concepts) as having a number of roots. These are wounded pride or a fear of being displaced, a tendency for people not to want to admit that others are equally able, a feeling that their work will be judged, or worse yet, belief that co-operation will lead to job losses. He goes on to say that often, new ideas are rejected because they appear too difficult to implement or they do not appear to fit patterns in the organisation. Finally he notes that outside ideas have no chance to be accepted if no one is aware of them, inferring that this can be a deliberate policy on the part of some individuals.

Another constraint can be a lack of standards for exchanging information. Spinardi et al. (1996) describe a number of social repercussions of applying standards to data exchange between companies. They state that such standardisation is political, both in the sense of governments having competing interests, as well as the differing requirements of military and civil users and of different industrial sectors. Second, the emphasis on data sharing threatens existing hierarchical inter-organisational relationships and the retention of proprietary knowledge. Third, the complex nature of the data to be exchanged in many cases requires companies to change their internal systems to be compatible with the standards.

Failure to develop a trusting relationship and what constitutes trust between companies features in the literature as possible constraints to SIL. Spekman et al. (1999) state that to trust is to believe that one's partner will act in a predictable manner, that one is reliable and "my word is my bond". They state that trust is essential to developing and sustaining alliances of all kinds, not only those found in a supply chain context. Where trust is absent, there is likelihood that self-serving behaviour will emerge and partners will be unable to lever each other's skills/capabilities.

Spekman et.al also quote Anderson and Wertz –

> Trust builds through a process of mutual adaptation that occurs only by repeated interaction.

Liker et al. (1996) take this further when describing the trust exhibited in relationships between Japanese auto companies and their suppliers. They describe how in their studies, auto-makers in Japan were much more likely [than US auto-makers] to repeat prototype tests conducted by their suppliers at all tier levels. They found that trust in this case came from reliability demonstrated over repeated interactions, as well as the shared knowledge that the parties needed each other. Liker et al. perhaps recognise that in attempting to emulate 'trusting relationships'; this type of trust is indeed tempered by the pragmatism of experience. This would perhaps suggest the need for previous dealings for SIL to be a success.

Game theory provides some relevant insight to the procurement managers' dilemma. SIL requires a relationship to be nurtured and equilibrium of understanding to be reached. (McMillan 1990) states:

> Repetition means that co-operation can occur; but it offers no guarantee that it will occur. There are also outcomes in which each player rationally seeks all short-run gains. No one player by himself can ensure that a co-operative equilibrium is played; to move from a "bad" equilibrium" to a "good equilibrium" one

> would require a co-ordinated change in all players' strategies. The significance of this is that co-operation that can result from ongoing relationships is fragile; the system can instead be stuck in a situation in which no co-operation occurs in the absence of formal contracts.

Certain companies have implemented guidelines for working closely with suppliers (Motorola, see (Lewis 1995), Hughes, see (Valdez and Kleiner 1996), which inform participants of their expected behaviours. This perhaps has helped guard against self-serving behaviour, while attempting to cultivate a trusting environment, or at least manage distrust. Rousseau et al. (1998) describe 'deterrence-based trust' in the following form.

> … belief in the absence of "negative intentions" is not the same as beliefs in the presence of positive ones - the latter being a necessary condition of the generally accepted definition of trust. Deterrence based trust, therefore, may not be trust at all but may be closer to levels of distrust.

The concept of 'deterrence-based trust' is perhaps more appropriate to SIL relationships. The Spekman paper is also important because it differentiates the successful sharing of information – as has previously been described for SIL success – from the formality of a commercial relationship.

> Information sharing does not always imply a 'business partnership'. Related research shows that formal alliances (relationships based on norms of collaboration) are not essential to the effective sharing of procurement relevant information… Buyer and seller can effectively co-ordinate and exchange workflow information and never reach the level of collaboration founded in a supply chain partnership

This would appear to be empirically supported by the findings of the SCRIA workshop. Here, participants described how technical people - at a "hands on" practitioner level – showed enthusiasm for working this way once the process and a personal relationship were established and that this could occur without commercial buy-in where commercial people (procurement) were still uncomfortable with the situation. Something similar is described by Jassawalla and Sashittal (1998) when they describe organisational factors that affect a company's ability to collaborate internally between functions. In describing 'level of trust' they describe how participants who exhibited higher levels of trust were motivated to collaborate intrinsically instead of waiting for senior management's directives. Where one function is abdicated to a supplier, the same factor may be at play. The implication of these observations is that a trusting relationship perhaps requires one of three things: a personal relationship, confidence formed through a history of previous working or a clear directive to trust.

5.4 Summary of constraints and the determinants of good SIL CE practice

Possible constraints on SIL working as identified in the literature are described at the end of this chapter. From these constraints it is possible to identify the determinants of good SIL practice. Table 5-2 sets out these determinants.

5.5 Organisational culture & sub-cultures

The Change Management and Business Process Re-engineering literature provided some insight to organisational culture. This avenue was explored because the move to SIL from conventional build-to-print represents massive change to some companies; it also involves considerable re-engineering of processes.

Table 5-2 showing the determinants of good SIL

Determinants of good SIL
• Agreed metrics, objectives, rules of conduct, risks and rewards • Shared technology path and knowledge of technical capabilities • Compatible IT (design to manufacture) • Open, frequent communications • Efficient delivery system, secure data transfer • A long term relationship, previous relationship, trust, non-adversarial based procurement approach • Individual control of proprietary information • Formal plan and structure, management support, clear roles and responsibilities, stability of staff, no discontinuities between internal departments – all bought in • Design control, common 2D/3D capability, common understanding of the complex nature of the design, the design's fluid nature and the ambiguity of the design process and work practice, supplier involved in decision making • A common technical language • Overcome NIH, willing to change/evolve culture to incorporate other work methods • Appropriate co-location • No client constraints • Business need, e. g. restructure, down size, cost and time savings required

Hofstede (1991) describes organisational cultures as phenomena per se, different in many respects from national cultures. He describes an organisation as a social system of a different nature than a nation if only because the organisation's members usually have a certain influence in their decision to join, and are only involved during working hours, and may one day leave it again.

Campbell and Kleiner (1997) describe culture in an organisation as a self - reinforcing set of beliefs, attitudes and behaviours. They go on to say that spontaneous, futile attempts to change culture will undoubtedly fail unless the old values, beliefs and rewards are no longer being encouraged, enforced and rewarded.

Trompenaar and Hampden-Turner (1997) describe culture in general as consisting of three layers:

- Explicit culture consisting of the observable realities, e. g. language and structures
- Norms and values, where norms are described as the mutual sense a group has of what is right and wrong and values which define good and bad
- The third 'core' layer is comprised of assumptions about existence. Assumptions about existence are derived from past and present experience of problems to be solved. See Figure 5-2.

They argue that organizational culture or functional culture is nothing more than the ways in which groups have organized to solve the problems presented to them Carnall (1990) quotes guidelines for those engaging in culture changes and by doing this emphasises that peer group consensus will have an important influence on acceptance of change. He holds that typically, people do not feel strongly opposed to a given change. However, social ties can be such that resistance to change can build within social groupings and networks and it is important to build support within these networks. Figure 5-3 illustrates the characteristics of organisational culture as identified in the literature.

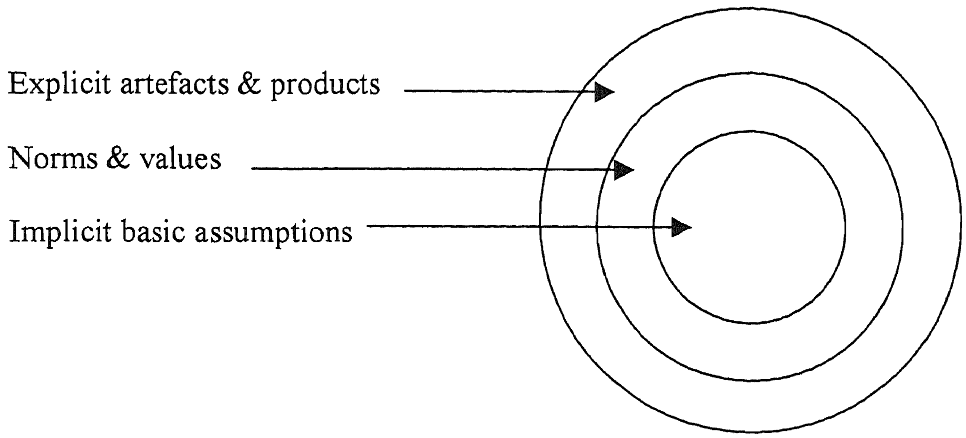

Figure 5-2 illustrating Trompenaar and Hampden-Turners' model of culture

5.5.1 Subcultures

Subculture is described in the literature as a sub-division of a national culture, composed of class status, ethnic background, common urban residence or religious affiliation (Gordon 1997). The implication is that the combination of these factors has an impact on a participating individual. However, researchers recognize that functions within a business can develop their own subcultures. Hofstede (1991) found in his research that some units studied contained quite varied sub-cultures, within one organisation.

> … potential sources of internal cultural divisions are functional area (such as, sales vs. production vs. research), product/market division, country of operation, and for organisations having gone through mergers, former merger partners. (Hofstede 1991)

Martin and Siehl (1983) describe how conflicting subcultures can arise. Cultures can serve differentiating rather than integrating functions by, for example, expressing conflicts among parts of society. Instead of being monolithic phenomena, organisational cultures are composed of various inter-locking, nested, sometimes conflicting subcultures (Martin and Siehl 1983).

They further state that there are at least three types of subculture: enhancing, orthogonal and counterculture. An enhancing subculture adheres to core values of the dominant culture. An orthogonal culture accepts the core values of the dominant culture and a separate un-conflicting set of values particular to themselves. A counter-culture may have core values that challenge the core values of the dominant culture and is most likely to emerge within a structural boundary, and may have a charismatic leader.

Frost et al. (1985) describe what they call 'loci of culture' in businesses. Stewart (1998) describes 'communities of practice' which are groups that learn. He furthers states.

> ... Groups that learn, communities of practice, have special characteristics. They emerge of their own accord: Three, four twenty, maybe thirty people find themselves drawn to one another by a force that's both social and professional; they collaborate directly, use one another as sounding boards, teach each other, strike out together to explore new subject matter. They are among the most important structures of any organisation where thinking matters; but they are, almost inevitably, subversive of its formal structures and strictures.

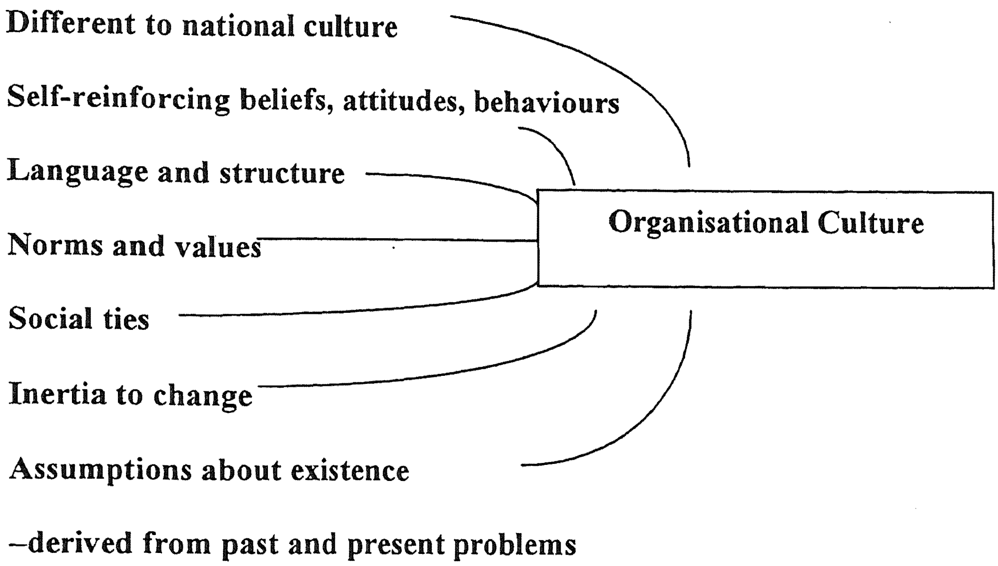

Figure 5-3 illustrating some characteristics of organizational culture

Communities of practice and loci of culture may be manifestations of subculture in an industrial context. They certainly appear to have some elements of what Martin and Siehl describe as orthogonal or counter-culture. In summary, subcultures in the industrial context appear to share a number of characteristics:

- Social and professional surroundings appear to influence the individual to act in a particular way (Gordon 1997).
- They are territorial - Stewart for instance describes the Engineers at National Semiconductor banding together to protect hidden key people. Hofstede describes different territorial functions. (Stewart 1998 ; Hofstede 1991)
- They appear to evolve without visible orchestration or facilitation within the company.

Hofstede's published work on subcultures involves considerable case based work at IBM. Stewart's example is taken from National Semiconductor although further inference is made to the same phenomena within the chemical industry.

One should then perhaps ask whether this phenomenon is sector specific or whether it is simply a manifestation of normal engineering practice in any industry?

5.5.2 Cross-sectoral variations

Dickson (1996) while reporting on the informal information exchange that takes place between co-operating firms, found that the sector imposes a form of behaviour on the individual; and that individuals do not choose their trade, nor the way they do business according to any prior personality traits. See Figure 5-4. Dickson's work is particularly important because it is both cross-sectoral and inter-company in nature so is particularly relevant to SIL and the implementation of SIL in different industry sectors. Dickson et al. (1997) further describe differences between business sectors –

> Some sectors are competitive, but open and reciprocal with a well-established network, which makes the individual reputation of a firm important in finding projects and partners. If an industry is closed and secretive, and firms are suspicious of collaborative work, the problems of linking up with a competitor make collaboration difficult, and even entering into a project with a customer or a supplier can be tricky. This situation tends to be characterised by lack of trust, detailed legal contracts, and means that good inter-personal relationships are crucial to success.

There is also further evidence in the literature of functions and workgroups displaying differing cultures. Baba et al. (1996) describe 'Ethnocentric assumptions' on behalf of designers where that failure to use electronic info was "directly due to lack of skill on the part of operators." Baba et al. also state –

> Cultural discontinuities between work groups inhibit the flow of electronic information just as surely as technological incompatibility. Process integration across cultural boundaries requires nothing less than cultural change.

Baba et al. further state that work cultures appear to grow out of work practices and experiences. This point is analogous to Trompenaar and Hampden-Turners' work at the organisational culture level that states that assumptions about existence are derived from past and present experience of problems to be solved. More and Irwin (1995) highlight what they call diverse technocultures and the problems of communicating between the diverse technocultures of the aeronautical research laboratory and the commercial marketplace.

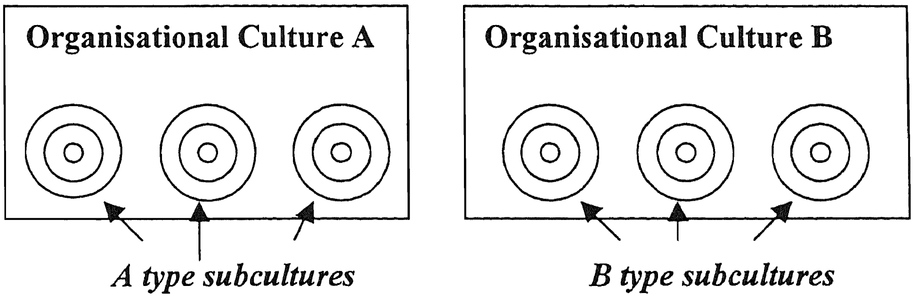

Figure 5-4 illustrating possible variation between organizational culture and subculture in different industry sectors

5.5.3 Norms and TFGs

Bidault et al. (1998) distinguishes industrial sectors from one and other in terms of 'norms'. Norms exist for industries as well as national cultures. Some industries for example, have low levels of contractual formality relative to others for reasons that cannot be explained by economic rationality (e. g. the construction industry versus distribution). Others have long traditions of linking multiple expert suppliers together in the assembly of large and complicated products, such as aircraft manufacture. It is also known that international competition and globalization influence industry norms.

This idea of norms is addressed differently by Trompenaars and Hampden-Turner who equate the norms of cultural groups with a sense of what is right and wrong. This definition of norms is more akin to what Tranfield and Smith (1996) describe as Taken for Granted (TFGs) in the context of culture.

> Increasingly we have come to view culture as the shared, Taken For Granted (TFG) assumptions of the members of the company... Culture is a difficult concept to grasp when defined as shared TFG assumptions, and a number of points are worth noting. Whilst on the one hand it is shared TFGs that make social and organisational life possible, on the other hand it is these same TFGs that provide structure and security and hence inhibit change and adaptability. Often they are implicit and can only be inferred from behaviour, being rarely up for scrutiny, and making overt appearances only when some infringement occurs. However, they do tend to permeate the whole of organisational life, giving a sense of overall purpose, and enabling members of the organisation to identify with the whole, as well as being a source of control over individual behaviour.

Argyris (1993) also mentions the concept of TFGs while describing his 'Theories in Use' model –

> ...Individuals' theories in use are so internalised that they are taken for granted. They exist tacitly because they are used skilfully. We call behaviour skilful when it appears effortless, and is produced automatically, without much conscious attention to process.

The 'theories in use' model is interesting from a SIL perspective because it can be differentiated from what Argyris calls 'theory espoused'. Theory espoused comprises an individual's beliefs, attitudes and values, while 'theories in use' are theories that are actually employed. Argyris found that there were often 'fundamental, systematic mismatches' between individuals espoused and in use designs. A further interesting point is that there was almost no variance in theories in use, while theory espoused varied widely. Four governing values can describe the theories in use model:

- Achieve your intended purpose
- Maximise winning and minimise losing
- Suppress negative feelings
- Behave according to what you consider rational.

If theory espoused is based on beliefs attitudes and values, then by definition they must be related to group norms (Trompenaar and Hampden-Turner), whereas Argyris himself relates theories in use to TFGs.

Combining the work of Dickson and Argyris, it would seem that the industrial sector does not affect theory espoused (norms), but could affect theories in use (TFGs). Where this is the case, it is perhaps possible that organisational culture dictates espoused theory while subculture evolves out of theories in use. Where espoused theory and theories in use are in juxtaposition, we witness a subculture that can be described as an orthogonal or as a counter-culture.

5.5.4 Engineering design as a subculture

In summary, the literature provides us with evidence of the following:

- Individuals' behaviours maybe affected by their industry sector (Dickson)
- Some industry sectors are by implication more distrusting than others. (Dickson)
- Subcultures are an observable facet of organisational culture (Hofstede)
- Industries can be distinguished by their respective norms (Bidault)
- Organisational culture is related to norms and TFGs (Bidault: Tranfield
- The industry sector may affect an individual's 'theories in use (TFGs)' but not their 'theories espoused (norms)' (Dickson: Argyris)

Given the above points, the literature was further explored for evidence of engineering design as having norms and TFGs for SIL. The idea of engineering design groups having distinguishable theories in use was intriguing.

5.5.5 Norms & TFGs in engineering design

Henderson (1999) describes design culture as a 'visual culture'

> ...here, the world of engineering drawings - makes practices so powerful that they become interlocked with a particular way of seeing. This is a visual culture; a way of seeing that simultaneously both reflects and shapes how members render the world.

She further suggests that such culture can foster conflict in collective projects –

> A shared visual literacy and ability to read encoded meanings can facilitate co-ordination or can foster conflict in collective projects. Visual objects not only shape the final products of design engineering but also influence the structure of the work and who may participate in it. These situated collective

> practices create a visual culture that, in turn, constricts and constructs the literal ability to see and imagine.

Henderson implies that where this is missing in collaborative projects, conflicts result.

A visual culture is interesting because it shares elements of being both a norm and a TFG. A shared visual culture –as a norm- requires some kind of shared belief in how form can be represented; however, it may be a TFG within a particular industry sector through a shared language, understanding of a shared objective, or appreciation of a working environment. The importance of a shared language is also recognised by Monczka et al. (1998) who describe the importance of a common language between engineering design departments and their own procurement departments.

> Some engineers also feel that buyers do not speak their language and therefore cannot contribute to the engineering design process in any meaningful way. This attitude is especially prevalent in high-tech organisations that are engineering driven.

Evidence is also found in the CE tools literature of the need to ensure that design intent is conveyed accurately (Bennett 1997). Here, design know-how is a TFG and positive action is alluded to for ensuring that scope for misinterpretation is reduced to a minimum. King and Majchrzaks' work on CE tool suppliers' failure to account for human issues also mentions this aspect. They show that a common misconception on the part of CE tool suppliers is that a common representation can exist for cross –functional design activities. They find that a common representation is both difficult to achieve and highly constrained. If therefore a common means of design representation is a TFG, than failure to achieve this may result in conflict. One of the major findings of King and Majchrzaks' work is that designers operating in a CE environment want only information that is critical to their problem solving assignment, they also go on to describe difficulties with digitally represented data. They describe the fact that engineering knowledge contains both analytical (quantifiable) and qualitative information, as well as tacit knowledge that is not obviously accessible to outside observers. This is best described as an engineering norm, in that it is dependent upon a shared belief and understanding of design representation. It is likely then that a supplier's failure to share this norm may invoke the types of territorial behaviour described earlier. Figure 5-5 illustrates possible manifestations of Norms and TFGs in engineering design.

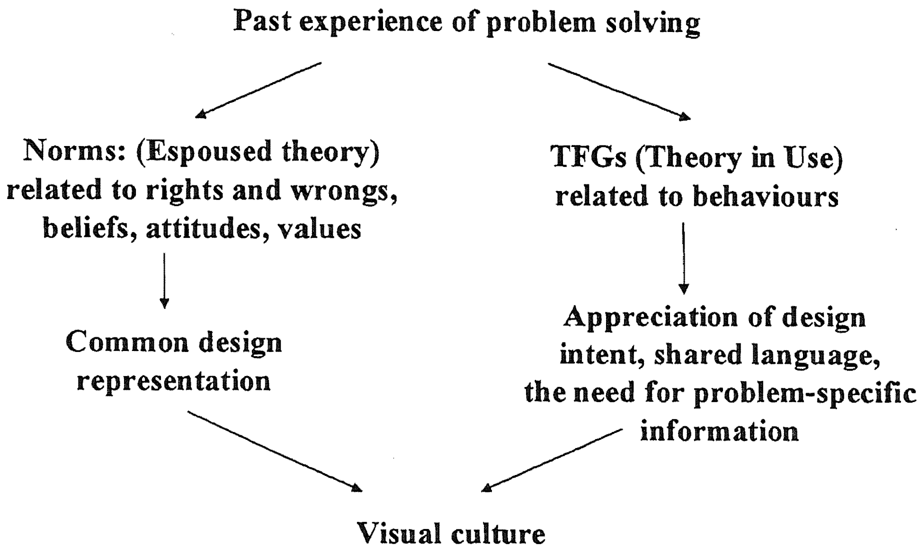

Figure 5-5 illustrating possible manifestations of Norms and TFGs in engineering design

5.5.6 Military culture and ethos

Engineering design cultures appear to have norms/TFGs. There is also some evidence for the emergence of conflict between parties that do not share norms/TFGs in business. Do military designers share a set of TFGs/norms that are distinguishable from civil groups? In order to explore the military element of any engineering design culture it was necessary to understand what the literature had to say about military culture.

Few accessible authors write on the subject of military culture at the OEM-supplier level of the supply chain; however, the concept is recognised by the UK government, (client/OEM level) (Spellar 1997), where its context is that of culture manifestation within forces training. Military ethos is also recognised in an armed services context both in the US (Hillen 1997) and in the UK by (Mileham 1998). Mileham also describes ethos variously as, "the nature or disposition"; "the characteristic spirit"; " prevalent tone or sentiment of a people or a community"; "ideal excellence"; "numen"; "a presiding power or spirit"; and "the 'genius' of an institution or system". Mileham contends that in order to understand the character of any institution, (and by inference cultivate a required ethos) it is often helpful to analyse not only the corporate dynamics but also the internal tensions and ambiguities. This would be akin to understanding the sources of conflict, and perhaps the organisations norms and TFGs. In analysing the British Army, points of conflict were:

- traditionalism – functionalism
- global view- geo-strategic capability
- determinism - voluntarism
- offensive action - security
- youth – experience
- collectivism – individualism

The last point is common to Hofstede's organisational cultural framework, where individualism describes how people see themselves as part of a larger whole or as individuals within a system. The other five points are not as easy to correlate with Hofstede's work (e. g. power-distance, uncertainty avoidance, masculinity-femininity, and Confucianism-dynamism) and may therefore differentiate military culture from civil culture.

Mileham describes the style of the British Army as being a style where 'commands and instructions are of the best, correct and where this approach will lead to success.' He states that 'precise actions follow orders'. This approach is analogous to BTP working between OEMs and their suppliers.

Mileham quotes a 1994 unpublished Defence Fellowship thesis by Lieutenant Colonel Charles Kirke, which identifies four social structures that dynamically sustain the way the Army really works as well as how it works officially. These are:

- Formal command
- Functional
- Informal
- Loyalty

Kirke argues that without the latter two unofficial structures, the Army would probably be less than human or indeed militarily ineffective. Unfortunately, the nature of these structures is not further described. The concept of informal and loyalty structures does however beg comparison with the previous descriptions of subculture. Further investigation in this area is unfortunately outside the scope of this thesis.

While this work is really at the client-OEM level of the supply chain it would seem that military culture and its relation to a military ethos is recognised. The importance of military ethos down the supply chain is only just being recognised. Recent studies on military ethos are concerned with its dilution, (Simpson and Ainslie 1999) and decline (Beaumont 1997) (Massey 1999). As traditional supply relationships are called into question, dilution is expected because of the following:

- The increasing partnering envisaged with private sector companies to realise cost benefits through improvements in management efficiency (application of best practice & reduction of labour costs) (Butcher 1998); and
- The recognition that Non Traditional Military Suppliers (NTMS) (Horn et al. 1998) will need to be used because of reductions in military funding; and
- The increasing dominance of NTMSs in important technological areas; and
- The growth in international technology management such as Organisme Conjointe de Co-operation en Matiere (OCCAR) in Europe; and
- Government requirements that military companies fund more of their basic research themselves; and
- Government aims to transfer technology and scientific know-how from the military to the civil sector (MOD 2000). An example of this in the UK would be the transition of DERA to a self funding agency.

In 1988, the Royal School of Military Engineering RSME) set up a working group to discuss the consequences of the first point described (Simpson and Ainslie 1999).

An issue of major concern within the working group, was the need to ensure that changes brought to the military ethos of the RSME, should not undermine or be detrimental to the quality of the product destined for its principal customers - the Royal Engineers regiments in the field.

Simpson and Ainslie contend that Robert F Mager's "Goal Analysis" - could offer a valuable method for measuring and quantifying military ethos in order to identify and set minimum 'safe' levels of military input and content.

> Rather than trying to directly measure undiluted abstractions such as attitude and ethos he advocates breaking them down into the key actual behaviours that one would expect to see from, for example, a salesperson exhibiting a positive attitude towards customer." ... This whilst the positive attitude of the salesperson in itself cannot be measured the visible behaviour and the results of that behaviour generated by the positive attitude can be

> observed and quantified. In precisely the same way, military ethos in itself cannot be measured but the visible behaviours displayed by soldiers generated by their military ethos can be observed. This is the essence of the RSME/RETDT approach to the whole question of the qualification and measurement of military ethos.
>
> … This characterisation of observable behaviour is the bedrock of Goal Analysis.

Simpson and Ainslie subsequently created five sub-goals for their military ethos framework: -

- Behaviour patterns towards superiors (respect discipline - vertical relations)
- Behaviour patterns towards peers (cohesion/bonding - horizontal relations)
- Behaviour patterns towards sub-ordinates (leadership - vertical relations)
- Military engineering applications (decision making/supplying skills on operations)
- Military socialisation (pride/history/customs/other cultural norms)

There is concern about loss of proprietary knowledge with OEMs in the commercial sector as they involve suppliers in their own design processes. With military OEM's this extends to concerns about maintaining security and ensuring shared objectives. This would appear to parallel concerns at the client-OEM level in on the part of the Military. Simpson and Ainslies' framework and the observational method whereby the framework is used are of particular interest. Firstly, the framework includes the aspect of 'military socialisation' and the cultural norms therein. This suggests an association between military ethos and norms/TFGs because the organisational culture literature equates visible behaviours to TFGs. Secondly, the framework and theory underlying the framework support the formulation of ethos by the characterisation of observable behaviour.

5.6 Ethos

5.6.1 The relationship of culture to ethos

D'hanis (1994) links culture to ethos when discussing the change associated with Business Process Re-engineering, she states:

> In a business, the culture is therefore the stable foundation on which not only everyday action but also radical projects can be built without upsetting the whole. Culture is therefore associated with 'ethos', standards and customs, with dialogue and interaction.

Brown (1998) links occupational subcultures with ethos:

> Members of occupational subcultures are overwhelmingly likely to have their organisational allegiances tempered by the demands of their occupation, its training, rules and ethos.

Massey (1999) differentiates culture from ethos by assigning it a degree of momentum:

> Ethos' thus describes a system of values and governing principles that influence and characterise the way in which members of a group interact with one another and respond to the world around them. Normally limited to particular groups in society, it is a step removed from the more general notion of 'culture'...

If culture, or subculture is the entity that defines ethos, then ethos is more a manifestation of a particular culture; its outlook; its predisposition to specific paths ahead.

5.6.2 Ethos in engineering design

Ethos, as a manifestation of a particular design culture will be associated with an engineer's outlook. Holt (1996) describes the influences on an engineer's outlook as being education, employment in industry and commerce, and the shared interests and attitudes of engineers as an identifiable group in society.

> Together with professional education and the commercial reality of engineering jobs, a fairly diverse but enduring heritage creates a certain ethos that empowers and guides day to day engineering practice.

He describes engineering ethos as being made up of three factors:

- A world of problems (defining a problem, solving a problem)
- The commercial imperative (dealing with other groups, managing fit- for - purpose)
- The minds eye (Visual non-verbal communication, technical change is good)

Holt's model would appear to largely concur with the literature on TFGs, Norms, culture and subculture. Figure 5-6 illustrates the author's consolidation of the origins and possible constructs of engineering design ethos.

This literature survey has shown that dealing with other groups particularly as cross-functional teams is essential for initiatives like SIL. Twiss (1992) states that organisational structures are normally found to have adapted to a traditional technology profile and that the nature of the projects undertaken has relevance to the coupling of departments within an organisation. This implies that projects with traditionally long gestation periods – like missile projects – would have a loose coupling of departments. In addition, certain industrial sectors seem to ensure that designers are highly focused with regard to product costs and hence are able to manage the fit-for-purpose decision easily, others are less enlightened. Twiss (1992) also describes how 'market orientation' is still woefully absent in many design decisions and that this is a major source of failure even in the most technologically advanced companies. This author considers 'market orientation' to be akin to what Holt describes as the 'commercial imperative'. Twiss further states that such difficulties stem from the education and value systems of both technologists and marketing managers as well as from the environments within which they work.

The importance of visual communication in engineering design has already been recognised (Henderson 1999). Ferguson (1992) also recognises that visual thinking is necessary in engineering and that a major portion of engineering information is recorded and transmitted in a visual language that is the lingua franca of engineers in the modern world. He, like Holt refers to this as the 'minds eye'. Ferguson goes further and describes the importance of the relationships between the modern designer and the skilled man who manufactures the parts he has designed. He implies that designers are becoming ignorant of manual skills and that there is value in time spent in observing, adding to the visual knowledge, sensual non-verbal knowledge and subtle acts of judgement are crucial to successful industrial production.

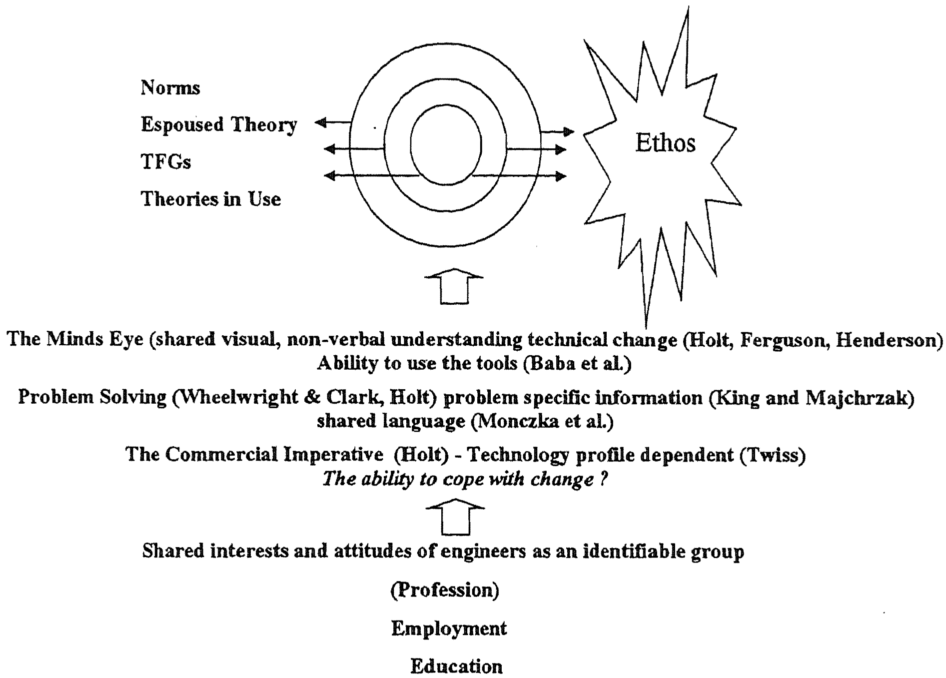

Figure 5-6 illustrating the origins and influences on design ethos

This author considers that Holts' work is weak in its treatment of change. The prospect that a designer fundamentally considers change to be good, independent of its type, is naive. This author's experience of design communities and a wealth of change management literature would suggest otherwise. Technical change may be welcomed in principle, however, where it is generated externally to the designer's immediate work environment or where it involves change to a designer's environment or procedures, it is usually unwelcome. The ability to deal with changes to the design system should perhaps be included as part of the commercial imperative, as most change of this sort is commercially driven. One would need to segregate technical change from business change.

5.7 Summary of literature

This chapter describes the issues that need to be addressed when implementing SIL in terms of enabling factors, tools and constraints. Particular attention is paid to those issues that require human-human interaction and those issues that are influenced by organisational type. Broad areas of accepted understanding are summarised in Table 5-3. The literature however, remains weak in the area of rigorous cross-sectoral comparisons and on the drivers of differences in design practice.

SIL constraints - the variable quality of evidence - In order to gain an overall picture it was necessary to consider a wide cross section of reported cases from professional bodies as well as academic journals and trade publications. The problem with this approach has been the poor quality of research data available. Opinion based on personal experience abounds. Where large studies are undertaken, for example, the Global benchmarking Initiative carried out by Michigan State University, they are based on relatively few responses from each industrial sector and are investigating commonality between sectors as opposed to difference. Other studies base their conclusions on statistically small sample sizes thereby suggesting to the reader that conclusions drawn may well be based on chance as opposed to underlying factors. Trade forums such as SCRIA, while allowing open debate, are usually attended by senior managers who are no longer themselves experiencing the 'coal face' problems of making supplier-in-loop work and are possibly somewhat distanced from the task. Where case studies are reported, they rarely have the luxury of real time sectoral comparison. In addition to this, case studies from the military sector are rarely reported in academic literature due to security considerations and concerns about competition. Constraints that have been demonstrated with some academic rigour are highlighted in Table 5-3. The author's assessment of academic rigour is based on the following criteria:

- Large scale research design, multiple authors, academic journals
- Triangulation – multiple methods employed to reach conclusions
- Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals.

What may be happening of course is that the academic world through traditional research methods is failing to recognise and report current constraint issues. This may be for a number of reasons. These are:

- Academic focus is as yet elsewhere due to research funding/research emphasis being elsewhere
- Rigorous, environmentally valid studies of this type are too difficult to initiate/run/report.
- The possibility that companies do not wish to investigate why something should not be done, preferring to try and fail quietly.
- A predisposition to use consultants for such work due to the infancy of industrial-academic collaboration.

For these reasons, the author did not use the academic rigour analysis in the development of the questionnaire issues, giving equal status to rigorous and non-rigorously derived constraints. This approach with the literature was appropriate because of the likelihood that the formal literature was failing to report the most current issues for business, which were reported through professional bodies and isolated case studies. Also, the research sought to explore SIL constraints and to identify whether sectors differed in their views of constraint. It did not seek to corroborate constraints, although by default, with the exception of one constraint, (See section 9.6.1.2) it did.

Subcultures and ethos – lacunae - With regard to organisational culture, the literature is unclear as to whether the emergence of subcultures is sector specific or whether it is simply conspicuous of normal engineering design, or other functional practices. What is clear however, is that subcultures can inhibit flow of information in and between companies.

One influencing factor, therefore, that could affect SIL is the industry type, in as much as the industry's drivers may influence how product characteristics (e. g. fit-for-purpose) are managed and also the power base between functions e. g. procurement .v. design).

With regard to ethos, if culture, or subculture, defines ethos then ethos is more a manifestation of a particular subculture; an outlook; a predisposition to specific paths ahead. This complements the existing models of culture and can perhaps be further explained in terms of a combination of artefacts, norms and values and specifically implicit basic assumptions about past and present experiences of problems to be solved. An acute understanding of the fallibility of systems in an engineering-driven culture may influence the enthusiasm with which major process change is undertaken.

With regard to a possible military ethos, that is, an engineering design ethos influenced by the nature of the military product and subsequent working environment; existing work in the military sector, while interesting, is concentrated on characterisation of military personnel. The study group is therefore too remote a group to stand direct comparison with the author's definition of 'design community', despite the obvious analogies between their respective changes in paradigm.

However, the idea of defining the ethos of a group by the characterisation of observable behaviour can be borrowed and it is this concept which this author uses in the case study approach. This idea is further carried forward to the discussion on the application of a design ethos framework in Chapter 10.

In conclusion, the author is confident that the concepts carried forward for further analysis are grounded in work that has preceded this research; however, preceding work in organisational culture and ethos is immature in the area of cross sectoral comparison. 'Ethos' is therefore described in terms of a borrowed construct that remains to be validated in a design community context. Design ethos constructs are carried forward towards a design ethos framework in Chapter 7. Lacunae from the literature; in the area of cross-sectoral differences, is taken forward for hypothesis formulation in chapter 8, where SIL constraints are also developed into questionnaire issues.

Table 5-3 showing SIL constraints from the literature

Key: * = Large scale research design, multiple authors, academic journals
** = Triangulation – multiple methods employed to reach conclusions
*** = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals
C= Some degree of industry consensus

Constraint	Description	Literature Source	Evidence of academic rigour
1	Suitable metrics/acceptable to both sides	(SCRIA 1999); (Siriam and Mummalaneni 1990); (New and Burnes 1998); (Monczka et al. 1997)	* ** ***
2	Common objectives	(Monczka et al. 1997)	* **
3	Client constrains	(SBAC 1999); (SBAC SCRIA 1997/8)	C
4	Absence of shared technology path	(Ragatz et al. 1997)	* **
5	External forces – 'business need'	(Backhouse et al. 1995); (Paashuis and Boer 1997)	* ***
6	Knowing/keeping abreast off supplier capabilities	(Boyson et al. 1999);	*
7	Absence of Computer Integrated Manufacturing	(Hull et al. 1996)	* ** ***
8	No common language	(SBAC SCRIA 1997/8)	C
9	Problems of security of data transfer	(SBAC 1999)	C
10	Absence of a documented CE process/ 'rules of conduct'	(Singh and Lewis 1997); (Lewis 1995)	***
11	Fear of losing proprietary information	(Ragatz et al. 1997)	* **
12	Absence of formal plan and structure/priority with respect to other projects	(Dowlatshahi 1998); (Boddy et al. 1998)	* ** ***
13	Absence of open communication/frequent communication/efficient information delivery/common tools/ CIT/CAD/CAD-related	(Monczka et al. 1997);(Haupman and Hirji 1996);(Court and Ullman 1998); (Duffy and Salvendy 1998);(Liker et al. 1996) (Singh and Lewis 1997); (Fruchter et al. 1996); (Hull et al. 996); (Martin 1997); (Anon 1997c); (Burns and Szczerbicki 1997); (Meyer 1997); (Roser 1995); (Dijkstra et al. 1999);(Knoai 1997); (Stevens 1997);(Schwendinger 1998); (Spinardi et al. 1996);(Glaskin	* ** ***

Constraint	Description	Literature Source	Evidence of academic rigour
	tools/GroupWare/ common standards for data exchange	1995)	
14	Absence of design controls	(Hull et al. 1996)	* ** ***
15	Component identity – how it is designed (2D.v.3D)	(Burns and Szczerbicki 1997; Martin 1997)	***
16	Discontinuities between internal functions within the OEM/supplier	(SBAC SCRIA 1997/8); (SBAC 1999); (Wasti et al.1997)	C * ***
17	No existing/long term relationship between supplier and buyer	(Dowlatshahi 1998)	
18	Not Invented Here (NIH) syndrome	(Lewis 1995); (Ragatz et al. 1997)	* **
19	Common culture/will to change	(Monczka et al. 1997);(Philpott 2000); (McMillan 1990)	* ** ***
20	Absence of management support on both sides	(Monczka et al. 1997); (Philpott 2000); (Dowlatshahi 1998); (SBAC 1999)	C * ** ***
21	Existing – adversarial based procurement practice	(SBAC 1999)	C
22	Absence of trust/ previous dealings/	(Spekman et al. 1999); (McMillan, 1990); (Liker et al. 1996)	* ***
23	Component complexity/frequently changing designs/ambiguous designs(newness)	(Poolton and Barclay, 1996);(Monczka et al. 1997);(Haupman and Hirji 1996);(Ragatz et al. 1997); (Liker et al. 1999)	* ** ***
24	Appropriate co-location	(Monczka et al. 1997); (Hull et al. 1996); (Kahn and McDonough 1997)	* ** ***
25	Supplier not involved in decision making/problem solving	(Monczka et al. 1997);(Haupman and Hirji 1996); (Duffy and Salvendy 1998); (Wheelwright and Clark 1994); (Lewis 1995);(Singh and Lewis 1997)	* ** ***
26	No clear roles & responsibilities/ changing roles	(Monczka et al. 1997); (Boddy et al. 1998); (Calabrese , 1999); (Stewart 1998); (SBAC 1999)	* ** ***

Constraint	Description	Literature Source	Evidence of academic rigour
	over time / people in key roles		
27	Absence of cross functional teams/ team skills	(Hull et al. 1996); (Cooper 1995); (Todd 1995); (Philpott 2000); (Dowlatshahi 1998); (IPSERA 1999)	* ** ***
28	Absence of risk/reward (cost/benefit) to both sides, clear/some form of appropriate contract/long term situation etc.	(Monczka et al. 1997; Philpott 2000); (Boddy et al. 1998); (Lewis 1995);(SBAC 1999) ; (McMillan 1990)	C * ** ***

6 Case Study Research Evidence

6.1 Introduction

This chapter describes and analyses the case study research evidence from the AS-IS study (in-situ observation and semi-structured interview); the workshops prior to, and during the pilot demonstration of SIL between industrial collaborators and from the Producibility Interaction Working Groups (PIWGs) and Integrated Design teams (IDTs) during the pilot demonstration of SIL. The reliability and validity of the case study is discussed in sections 4.5.4, 4.5.5, and 4.5.6.

Data collection techniques are described as are the decision rules for data selection in terms of agreement among participants (AS-IS study, PIWG and IDT), researcher confidence in the conclusions drawn [in terms of corroboratory and contradictory evidence] (Miles and Huberman 1994).

A summary of the findings in terms of case study derived SIL constraints is shown in Tables 6-3, 6-4 and 6-5. Chapter 7 then analyses the existing literature to explore how revelatory these findings are and identifies possible anomalies to the existing body of knowledge. Chapter 8 then carries the findings forward for testing in a wider civil and military context.

6.2 Over view of case study methods

Appendix 11 (Confidential) shows the case study analysis and Section 6-4 describes the case study detail. The case study is reported in line with the SIL themes framework shown in Table 6-1.

Table 6-1 showing re-grouped SIL themes as question framework

Themes	Data summary-Section location	Analysis - Appendix location
Producibility	6.4.1	11.1.1
Design Constraints	6.4.2	11.1.2
Design Spec	6.4.3	11.1.3
Design Ethos	6.4.4	11.1.4
Design Release	6.4.5	11.1.5
Design Quality	6.4.6	11.1.6
Cost and schedule awareness	6.4.7	11.1.7
Programme information	6.4.7	11.1.7
Open communication	6.4.8	11.1.8
Design information - send and access drawings/models	6.4.8	11.1.8
Modelling	6.4.9	11.1.9
Currency on IT	6.4.10	11.1.10
CAD/CAM	6.4.10	11.1.10
Supply contracts	6.4.11	11.1.11
Enforced suppliers	6.4.12	11.1.12
Tiered supplier status	6.4.13	11.1.13
IPR ownership	6.4.14	11.1.14
Cost of design changes/design effort/tooling changes	6.4.15	11.1.15
Change control - sign off	6.4.16	11.1.16
Tooling loops	6.4.17	11.1.17
Traceability	6.4.18	11.1.18
Cost estimation and control-freedom of customer and supplier to reduce cost	6.4.19	11.1.19
NRE	6.4.20 / 6.4.20.1	11.1.20 / 11.1.20.1

6.2.1 The AS-IS study

The AS-IS study took place prior to and during the AEROEXTN pilot. Much of this observation was done during interviews at Lostock, Stevenage and Chadderton and during associated exercises at those sites. Fifty people, from all levels within both companies, contributed to the AS-IS study. See Appendix 10.

During AEROEXTN the author undertook an investigation to define a baseline project against which the pilot could be measured. This involved a comparison of an ASRAAM part with that of a SVL part chosen for the pilot. In order to get access to this information discussion was entered into with a number of staff at both sites, some which were openly aggressive about the prospect of SIL for a whole number of reasons. SIL objectives were outlined and reservations were discussed. This exercise, although acutely uncomfortable at times was an excellent opportunity to explore this design community's perceptions of explicit constraints with SIL. It was also an enormous insight into the soft networks at play when such changes are proposed. The in-situ observation and interview data are reported within the AS-IS study. The AS-IS study is reported in line with Table 6-1.

6.2.2 Workshops

Workshops were held, prior to the pilot, to prioritise the project aims and share best practice as it became available. Workshops were also held during the pilot to solve outstanding issues raised during the pilot, elicit further direction and validate project results prior to dissemination. Fourteen people contributed to workshops over a two-year period.

During these workshops 'cultural issues' at a general level were captured. The term 'cultural issues' described a number of issues which can be summarised as those akin to 'issues of difference' between nations, between different geographical locations, between different companies, between different job disciplines.

6.2.3 The PIWGs and IDTs

The Producibility Interaction Working Groups (PIWGs) and Integrated Design Team (IDT) problem solving sessions conducted during the pilot presented a further opportunity to capture 'cultural issues' at a practical level. Examples of this are the problems caused when people are expected to learn new skills, challenge accepted authority or accept continuous change when still smarting from previous experiences. Over a six-month period, six people consistently contributed to the PIWG and IDT meetings.

6.3 Data collection

Data was collected through formal methods in the form of minutes for the PIWGs and IDTs, semi-structured interview and informal observation was used for the AS-IS study. Formal minutes produced from the workshops, PIWGs and IDTs (Gregory et al. 1997-1999), were verified by attendees. Observational notes were kept in a personal logbook (Philpott 1997-1999). Validation of described processes was undertaken by accessing and verifying company documentation wherever possible. In addition to this the AS-IS report was validated independently by a research colleague who was familiar with the collaborator's business. Figure 6-1 illustrates the research observations in terms of data collection method.

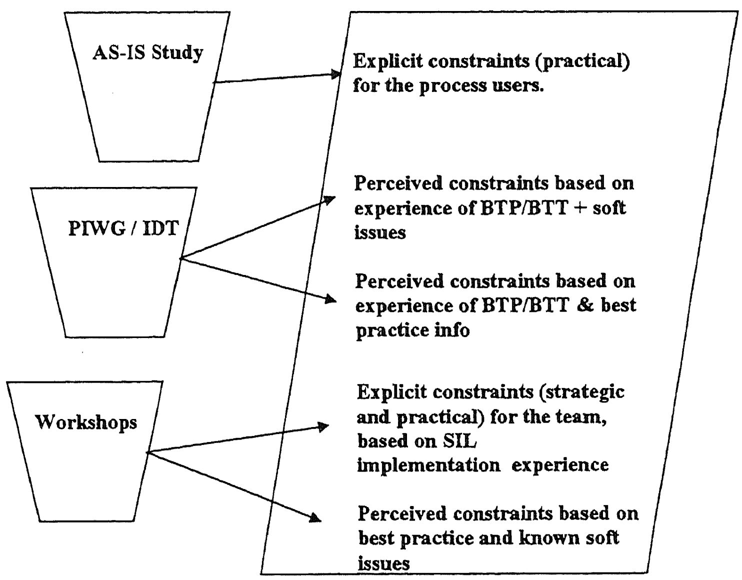

Figure 6-1 illustrating research observations in terms of data collection methods

6.4 AS-IS summary – (MBD and MA&A) (Collaborator Confidential)

6.5 Workshops (Collaborator Confidential)

6.6 PIWG and IDTs (Collaborator Confidential)

Sections 6.4, 6.5 and 6.6 (Pages 151 – 183) are considered **Collaborator Confidential** and remain author-controlled. Data analysis is however included in Section 6.7.

6.7 Data analysis

Analysis began with a review of logbook notes and reports, particularly quotations combining accounts from different respondents and noting any contradictions. Responses were categorised together in line with the SIL themes framework that had been used as a questioning aid for the interviews and workshops. Possible SIL constraints[31] were identified from this work, See Appendix 11.

The workshop, PIWG and IDT minutes, and observations were also reviewed for evidence of SIL constraints. A matrix was constructed using a combination of the constraints formulated and the original notes to explore constraints in terms of internal (in-case) validity across projects. Table 6-2 shows the background to author confidence in each constraint found. Tables 6-3, 6-4, and 6-5 show the

[31] SIL constraint - Issue that confines the participant/s to the existing circumstance (BTT/BTP) or prevents participant/s implementation of SIL

constraints identified. The internal validity of each constraint is shown in Table 6-6.

The exploration of original notes in terms of constraint, on a project by project basis, ensured that all possible constraints had been captured. This method was similar to that used by Brown and Eisenhardt (1996), where their data were revisited as case specific constructs emerged. Brown and Eisenhardt describe how they used interviews and secondary sources to write up each case study, noting similarities and differences in passing. Further analysis was left until case write-ups had been completed in order to maintain the independence of replication logic. A similar approach was used by this author.

It should be noted however that not all projects within the case study experienced the same problems dealing with suppliers for example there was some contradictory evidence as to whether design contact with manufacturing suppliers had been limited and whether suppliers were willing to work with early information. Possible reasons for this were: the different life cycle stages that each project was at; experiences with different suppliers; the differences in management between projects; and, differing proficiency and enthusiasm to use available resources, e.g. other functions, new CAD tools and data management tools.

The value of interviewing project teams at different stages in their life cycle is illustrated by the knowledge gained from including Rapier personnel. The main interview for the Rapier project was with a high level employee who viewed SIL very much from a strategic level and retrospectively. Rapier perhaps more than any other of the projects was experiencing problems associated with obsolescence and hence could appreciate the benefit of closer working with suppliers in the early life stage. Despite this, there remained scepticism about whether such collaboration would have been possible given the recollected business priorities at the time.

In summary, while it may have been interesting to assess internal validity of SIL constraints across projects at similar points in their life cycle, it was impractical due to availability of such projects. The inclusion of projects at different points in their life cycle gave the author insight into areas which otherwise would not have been uncovered. Such knowledge increased the content validity.

6.8 Summary of case study evidence

The case study derived SIL constraints are summarised in Tables 6-3, 6-4 and 6-5. The constraints identified during the workshops, PIWG and IDT served to corroborate some of the findings in the AS-IS study as well as extend the SIL themes framework. For instance, the original themes did not seem to cover constraints 54, 56, 58, 59 and 60 specifically.

Where corroboratory evidence existed, e. g. point 61 – observed both through interview and in PIWG with different personnel - this gave the author high confidence that these constraints were consistent across projects. Where contradiction existed, or where there was very little evidence from different methods – this gave the author low confidence in the particular constraint. Table 6-2 shows the reasoning behind the author's confidence level in each constraint based on consistency across projects and perceived contradiction.

Having developed a list of constraints, these were then compared with the literature derived constraints. A significant number of anomalies were apparent. These are described in Chapter 7. The full list of constraints was then carried forward for testing in a wider civil and military context to understand its wider validity and to investigate possible differences between sectors. Development of the questionnaire instrument is described in Chapter 8.

Table 6-2 showing background to author confidence in each constraint

Author Confidence level	Reason	Example
High*	Externally validated (outside the case study company) by interview	e. g. , MBD and Lockheed both described constraint 41: MBD described suppliers as not wanting to 'bare their chests to problem solve'. Lockheed described the same constraint as 'opening the kimono'.
High	Corroboration across projects Or No contradictory evidence (ASRAAM, Storm, Rapier)	e. g. , Constraint 32 was evidenced through workshop, personal log observations of SVL team, interviews with ASRAAM team, supplementary interviews and through investigation of archive information
Medium	Evidenced through SVL (a SIL pilot project) by different methods e. g., workshop and observation Contradiction within one project does not infer wider internal validity	e. g. ,Constraint 37 was evidenced through workshop and personal log observations of the SVL team. The author has less confidence in this constraint because the same personnel were involved in both events
Low	Evidenced by one method only e. g., observation Or Contradictory evidence (ASRAAM, Storm, Rapier)	e. g. , Constraint 33 was evidenced only in personal log observations of the SVL team, e.g., Constraint 34 was evidenced only in ASRAAM interview e. g., Constraint 60 was evidenced only in PIWG, e.g., Constraint 56 was only evidenced in a workshop environment Constraint 33, 40 - appeared varied across projects/personnel.

Table 6-3 showing the AS-IS study derived SIL constraints

Key - Author confidence: 'High* ' = Externally validated by interview; High = Corroboration across projects, no contradictory evidence; Medium = Evidenced through SVL by different methods; Low = Evidenced by one method only or contradictory evidence

Appendix location	Constraint	AS-IS Constraints	Author confidence
11.1.1, 11.1.19	29	Supplier having necessary skills to collaborate with design	High
11.1.1, 11.1.5, 11.1.16	30	An ability to communicate on expertise	High
11.1.2	31	The nature of the system – missile	High
11.1.3, 11.1.5	32	Design work practice – application of design rules undisciplined	High
11.1.3, 11.1.5, 11.1.9	33	Contact with supplier manufacturing process limited to date	Low
11.1.5	34	Need to know certain characteristics of supplier to get warm feeling	Low
11.1.5, 11.1.7	35	Supply issues handled by procurement	High
11.1.5, 11.1.9	36	No direction to involve suppliers in development work	High
11.1.5	37	Life cycle of product – development phases preclude SIL	Medium
11.1.5, 11.1.19	38	Getting suppliers interested	High
11.1.5	39	DFM (Assembly) requirements are project specific – carried by individuals	High
11.1.5	40	Suppliers unwilling to work with early info	Low
11.1.4	41	No belief that suppliers would voluntarily 'bare their chests' to problem solve	High*
11.1.6	42	Suppliers fail to understand the importance of reliability of systems	High
11.1.6	43	Known examples of spec grey areas	High
11.1.8	44	A reliable means of data exchange	High
11.1.5, 11.1.10	45	A convenient means of data exchange	High
11.1.5	46	Available internal resource to do modelling – development requirements	High
11.1.11	47	Living with the lot your left with – customer constraints	High
11.1.11, 11.1.12	48	Need for competitive tender	High
11.1.11, 11.1.12	49	Having to work with enforced supplier – suppliers changing due to decisions taken by other functions	High
11.1.13	50	Unit cost not total life cost	High
11.1.9, 11.1.15, 11.1.20	51	Separation of development and production (time (life cycle) and location)	High
11.1.6, 11.1.16	52	Ability to pass on all needed knowledge to supplier	High

Table 6-4 showing the workshop derived SIL constraints

Key - Author confidence: 'High* ' = Externally validated by interview; High = Corroboration across projects, no contradictory evidence; Medium = Evidenced through SVL by different methods; Low = Evidenced by one method only or contradictory evidence

Location	Constraint	Workshops constraints	Author confidence
11.2 11.1.15	53	Geography inhibits	High
11.2	54	'Cultural [33] differences' – this was specific to work practice – e. g., keeping a different working day	High
11.2, 11.1.5, 11.1.9	55	No incentive / direction to work with suppliers.	High
11.2	56	Need to be able to trust supplier	Low
11.2, 11.1.4	57	Not believing suppliers would bare their chests to problem solve, based on the premise that it didn't happen internally. Absent within, therefore absent without?	High

Table 6-5 showing the PIWG & IDT derived SIL constraints

Key - Author confidence: 'High* ' = Externally validated by interview; High = Corroboration across projects, no contradictory evidence; Medium = Evidenced through SVL by different methods; Low = Evidenced by one method only or contradictory evidence

Appendix location	Constraint	PIWG & IDT constraints	Author confidence
11.3	58	Fear of process change, bad experiences of previous process changes particularly the very high level of ongoing training required.	High*
11.3	59	Fear of technology change (based on past experience & knowledge of the current workforce) – 'culture shock' associated with moving to using a model as master for interaction between the parties.	Medium
11.3	60	Getting to grips with a common language.	Low
11.3, 11.1.3	61	Getting past fragile egos in design on the part of the OEM, empowering the supplier to ask questions, creating a questioning environment.	High

[33] 'Cultural' in this context was a term used by the OEM members of the team. NB- the OEM members appeared to have identified their own culture and what constituted a different culture in terms of work practice.

Table 6-6 showing comparison of research evidence and subsequent author confidence in case study findings in terms of SIL constraints

Constraint (Tables 6-3,6-4,6-5)	WORKSHOP	PIWG & IDT (SVL)	SVL	ASRAAM	STORM	RAPIER	SUPPLEMENTARY INTERVIEWS	ARCHIVE INFORMATION	AUTHOR CONFIDENCE
29	021097 PL 061098						CHAD-1 310797 (NIMROD), JIMS INTRO	080498	HIGH
30				PL 180598	PL 030698				HIGH
31	021097		130199	130199					HIGH
32	021097		PL	R970901			170398	DS01.0057, STATEMENT OF DESIGN INTENT, DESIGN ARCHIVE FOR PROENGINEER	HIGH
33			PL						LOW
34				R970901					LOW

Key: dates in WORKSHOP and PIWG columns relate to minutes (Gregory 1997 –1999)
Dates in other columns relate to published notes, reports, interview notes
PL relates to observations in a Personal Log
Descriptions in SUPPLEMENTARY INTERVIEWS and ARHIVE information columns relate to specific documents, data sources and meetings
Documents shown shaded are supplied in extract form in Appendix 11 (Confidential) as examples of the type of data source.

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Table 6-6 showing comparison of research evidence and subsequent author confidence in case study findings in terms of SIL constraints

Constraint (Tables 6-3,6-4,6-5)	WORKSHOP	PIWG & IDT (SVL)	SVL	ASRAAM	STORM	RAPIER	SUPPLEMENTARY INTERVIEWS	ARCHIVE INFORMATION	AUTHOR CONFIDENCE
35			PL	PL	PL 030698	PL 180298	PL	JIMS DOCUMENTATION , SAR (F46305)	HIGH
36			PL				PL		HIGH
37	021097		PL						MEDIUM
38				PL 180598			NIMROD 261198		HIGH
39	PL			PL			PL		HIGH
40	PL								LOW
41	PL						LOCKHEED 020698		HIGH*
42	PL						PL		HIGH
43	080498 031298	050898	PL 240399	PL180598, PL010997	PL 030698			080498	HIGH
44				R970901	PL 030698		MA&A EXEC		HIGH

Key: dates in WORKSHOP and PIWG columns relate to minutes (Gregory 1997 –1999)
Dates in other columns relate to published notes, reports, interview notes
PL relates to observations in a Personal Log
Descriptions in SUPPLEMENTARY INTERVIEWS and ARHIVE information columns relate to specific documents, data sources and meetings
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Table 6-6 showing comparison of research evidence and subsequent author confidence in case study findings in terms of SIL constraints

Constraint (Tables 6-3,6-4,6-5)	WORKSHOP	PIWG & IDT (SVL)	SVL	ASRAAM	STORM	RAPIER	SUPPLEMENTARY INTERVIEWS	ARCHIVE INFORMATION	AUTHOR CONFIDENCE
							MEETINGS 080699, 060899		
45			PL	R970901				080498 060798	HIGH
46			PL		PL 030698				HIGH
47						PL 180298	171297		HIGH
48	021097								HIGH
49	021097							120495	HIGH
50	291097					PL 180298			HIGH
51	021097			PL 010997, PL 060199, PL 130199					HIGH
52				PL			CHAD-1 310797 R970901	060798	HIGH
53	021097			PL 180598	PL 030698				HIGH

Key: dates in WORKSHOP and PIWG columns relate to minutes (Gregory 1997 –1999)
Dates in other columns relate to published notes, reports, interview notes
PL relates to observations in a Personal Log
Descriptions in SUPPLEMENTARY INTERVIEWS and ARHIVE information columns relate to specific documents, data sources and meetings
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Table 6-6 showing comparison of research evidence and subsequent author confidence in case study findings in terms of SIL constraints

Constraint (Tables 6-3,6-4,6-5)	WORKSHOP	PIWG & IDT (SVL)	SVL	ASRAAM	STORM	RAPIER	SUPPLEMENTARY INTERVIEWS	ARCHIVE INFORMATION	AUTHOR CONFIDENCE
54			PL	PL 180598	PL 030698			080498	HIGH
55			PL				PL		HIGH
56	PL								LOW
57	PL								LOW
58		270898	PL				171297 170798 (SCRIA)[34]		HIGH*
59		270898	PL						MEDIUM
60	PL								LOW
61		270898 031298 130199	PL	PL			171297		HIGH

[34] The SCRIA meeting described here took place at the DTI and was separate to the SCRIA event described and incorporated in the literature study. See Section 5.3.2.

Key: dates in WORKSHOP and PIWG columns relate to minutes (Gregory 1997 –1999)
Dates in other columns relate to published notes, reports, interview notes
PL relates to observations in a Personal Log
Descriptions in SUPPLEMENTARY INTERVIEWS and ARHIVE information columns relate to specific documents, data sources and meetings
Documents shown shaded are supplied in extract form in Appendix 11 (Confidential) as examples of the type of data source.

7 A Preliminary Design Ethos Framework

7.1 Introduction

This chapter describes the derivation of a preliminary design ethos framework based on the literature and case study findings. The decision rules for data selection in terms of natural groupings of constraints, rigorously defined examples in the literature and author confidence in the case study findings are described.

7.2 The preliminary framework

It would appear that design ethos is comprised of elements from both theories in use and theory espoused (See Figures 5-5 and 5-6). However, there is evidence to suggest that those issues that are industry specific are associated with the commercial imperative and problem solving ability of the company (See Section 5.6.2).

In the UK, where academic, professional and in-company learning is promoted for engineering staff, issues which comprise the mind's eye may well be harder to differentiate unless design discipline and product design tools differ massively across industrial sectors. A preliminary framework to describe design ethos based on the literature study and case study is described in Fig 7-1. This framework has been derived from Figures 5-5 and 5-6 and has three distinct levels:

- Past experience of problem solving, past experience of defining problems and the need for problem specific information and a shared technical language, hereafter referred to as problem solving - P.
- Managing fit for purpose, how the group manages business change and how it deals with other groups hereafter referred to as commercial imperative – CI.
- Visual culture issues – design representation, appreciation of design intent, managing internally and externally derived change, hereafter referred to as mind's eye – ME.

The first level deals with the group's collective past and present experience of problem solving and its desire for external communication to be problem specific – that is – to prevent problems or to solve known or perceived problems (Wheelwright and Clark 1994; Holt 1996; King and Majchrzak 1996). It also deals with the very real need for a shared technical language for the effective communication of knowledge both within and outside the group (Monczka et al. 1997).

The second level addresses how the group and the individuals therein manage business change; how the group deals with other groups; and, how the group manages the product's fit for purpose requirements (Holt 1996, Twiss 1992).

The third level addresses technical knowledge issues and is expected to be specific to the functions within the design community who are technically orientated. These are issues associated with a common appreciation of design intent (Henderson 1999; Ferguson 1992; Holt 1996). It also represents how the group or individuals therein, handle internally derived and externally derived technical change as well as their ability to use tools to facilitate this (Baba et al. 1996)

Past experience of problem solving
Past experience of defining problems – the need for problem specific information and a shared language

How one manages fit-for-purpose
How one manages business change
How one deals with other groups

Visual culture, design representation, appreciation of design intent, managing internally derived and externally derived technical change

Figure 7-1 illustrating a preliminary design ethos framework

This framework is used as grounding on which to explore the research questions. Eisenhardt (1989) states:

> A priori specification of constructs can also help to shape the initial design of theory- building research. Although this type of specification is not common in theory – building studies to date, it is valuable because it permits researchers to measure constructs more accurately.

7.3 Military characteristics

During the case study (AS-IS study, workshops, PIWG and IDT) a number of SIL constraints were defined by the military OEM which appeared to be anomalous to those found in the literature. By inspection, the author then grouped these constraints and assigned each group labels. Table 7-1 shows grouping of constraints; analysis in terms of existing literature and author confidence, and the subsequent allocation of group names. These groups are henceforth referred to as military characteristics, in as much as they are constraints identified in a military context. They may not be specific to military design. Further work is needed to understand the validity of these characteristics in a wider military context, and, to understand whether they are applicable to a wider body of industry. The military characteristics are the following:

- No now gain, no dictate
- But things will change
- Traitor tag
- Data exchange unreliable
- Something will be missed
- Too different to get accepted: broadcast the pain
- Fragile egos

No now gain, no dictate – refers to the problem of management buy-in at two levels. Firstly, it refers to an absence of clear instruction or the absence of instruction from superiors for whatever reason. Secondly it refers to the view that any saving made through SIL initiatives would be small in comparison to other expenditure in terms of time and cost. The implication being that SIL benefit would need to be significant in the grand scheme of the business to warrant serious attention. The author has linked the two points because the second point could very well be a cause of the first. This may very well underlie a superior's failure to give an instruction. Alternatively, the absence of a clear instruction – a mixed message – may be due to superiors wishing to keep their options open. Swink (2000) suggests that high levels of top management support are less important for new product design integration in high technology innovative environments, but the case study observations would suggest that it is important that there is buy-in from superiors within the design community.

But things will change – refers to the impact on SIL caused by the duration of the product development-manufacturing cycle. It reflects the likelihood of change during this cycle due to many separate influences.

Traitor tag – refers to the perception that by involving suppliers in the development stage, one could be seen as traitor-like. In this environment, there was available internal resource to support development requirements for parts; also, there was a realisation that DFM know-how was carried internally from project to project in the heads of individuals. The inclusion of external suppliers in these roles was seen as a problem.

Data exchange unreliable- refers to the inherent nature of data transfer. Unlike the literature which covers problems with CAD compatibility and the absence of standards (Spinardi 1996), it deals with delays in data exchange due to firewalls, hardware failure and the need to transport data between internal and externally approved PCs/workstations.

Something will be missed- refers to a perception that suppliers fail to understand the reliability requirements of systems. It refers to the view that suppliers had a different concept of excellence to themselves, which when taken to its worst case could eventually affect the product. This view was often illustrated with examples of poor performance on the part of the supplier.

A further point that emerged which this author also puts into this characteristic was that existing specifications often left grey areas that meant the communication of original design intent was impossible. Adequately describing the 'design envelope' was often a problem internally; there was no reason to think that it would be any better with external suppliers.

Too different to get accepted- broadcast the pain - refers to an inherent tendency to expect poor experiences of change processes based on previous change, whether supplier related or not. In addition there is a tendency to communicate this perception of bad experience. This may become a constraint to SIL where there is an absence of other information systems or mechanisms whereby factual experience about specific suppliers can be relayed.

Fragile egos- refers to a perception within the OEM design community, which was shared by the supplier, that designers generally did not appreciate their work being questioned. This was an obvious constraint for SIL as an open questioning environment was a pre-requisite.

Data analysis and derivation of military characteristics are shown in Table 7-1. This table shows how constraints are clustered into logical groups and compared with the literature evidence. Anomalous constraints are thereby identified and metaphorical names assigned.

These military characteristics are then compared with the preliminary design ethos framework which is shown in the context of organisational subculture in Figure 7-2. Military characteristics are further discussed in the context of a revised design ethos framework in Chapter 10.

7.4 Further discussion

Constraints indicated in the literature but not specifically noted in the case study were as follows:

Absence of a shared technology path – In the literature this refers mostly to product technology, materials processing and the fundamental materials research to support this. Although the ability of suppliers to maintain investment levels to maintain outsourced processes was an underlying concern, this appeared to be too remote a concern to warrant immediate attention. What was raised however, was a very real concern about common IT tools and the lack of visibility suppliers have of forward plans in this area. Examples of failure to do this would perhaps be incompatible PDM software, CAD hardware and software, document exchange and storage media.

Although the absence of a shared technology path was not picked up as a specific constraint to SIL, it was indicated as a possible cause of obsolescence problems for products that were later in their life cycle. The conclusion from this is that a common technology path is a sensible pre-requisite to SIL; however, its explicit absence did not appear to constrain participants in the case study.

Absence of computer integrated manufacture – Having had experience of attempting to implement this in-house with mixed results, a certain scepticism was evident among case study participants. The author on reflection did not consider there to be any specific evidence to suggest that the respondents considered an absence of CIM to be a significant constraint in working more closely with suppliers.

Absence of a documented CE process / rules of conduct - The author considered that the participants did not perceive the absence of any kind of written process to constrain SIL. The environment was one in which the overarching business process was one that allowed flexibility at the local level for controlled experimentation. Case study participants were therefore familiar with the development of processes. Following the successful completion of the pilot, existing design process documentation was up-issued to reflect the new way of working. Similarly, 'rules of conduct' for SIL were not made explicit during the pilot, but were developed informally in a team environment.

Supplier not involved in decision making / problem-solving – Not having worked closely with suppliers so early in design before, respondents did not indicate that this was a constraint. The participants in the AS-IS study gradually became convinced of the benefits of SIL, but this only became obvious very gradually. On the whole, staff outside the pilot did not see the fact that suppliers were not involved early in problem solving as a constraint to SIL itself.

7.5 Summary

This chapter has outlined a provisional design ethos framework. The framework is largely based on the work of Holt (1996) but is supplemented by the work of Henderson (1999), Ferguson (1992), King and Majchrzak (1996), Monczka et al. (1997), Wheelwright and Clark (1994), Baba et al. (1996) and Twiss (1992), together with the experience of the case study, see Tables 6-2, 6-3, 6-4.

Military SIL constraints identified in the case study are analysed against SIL constraints found in the literature (Table 7-1). From this analysis, a number of constraints are identified which may be specific to the military sector. A number of constraints identified in the literature but not observed in the case study are also described.

Design ethos, in the context of design subculture, is then compared with military characteristics developed, see Figure 7-2. SIL constraints are then carried forward for hypothesis formulation and quantitative data testing.

Table 7-1 showing data analysis and derivation of military characteristics

Constraint	Constraint description	Author confidence [Tables 6-2 & 6-6]	Constraint descriptions from literature [Table 5-3]	Academic rigour (L,T,I,C) [Table 5-3]	Anomalies between case study and literature ?	Author derived Military Characteristics
29	Supplier having necessary skills to collaborate with design	High	.6, 8	L		
30	An ability to communicate on expertise	High			Yes	
39	DFM (Assembly) requirements are project specific –	High			Yes	
	carried by individuals				Yes	Something will be
43	Known examples of 'grey areas'	High	13 perhaps	L,T, I	Perhaps	missed
52	Ability to pass on all needed knowledge to supplier	High				
42	Suppliers fail to understand the importance of reliability	High			Yes	

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
Author confidence: High* = Externally validated by interview; High = corroboration across projects, no contradictory evidence
Medium = evidenced through SVL by different methods, contradiction not internally valid; Low = evidenced by one method only, contradictory evidence

Table 7-1 showing data analysis and derivation of military characteristics

Constraint	Constraint description	Author confidence [Tables 6-2 & 6-6]	Constraint descriptions from literature [Table 5-3]	Academic rigour (L,T,I,C) [Table 5-3]	Anomalies between case study and literature ?	Author derived Military Characteristics
	of systems					
30	An ability to communicate on expertise	High				
61	Getting past fragile egos in design on the part of the OEM, empowering the supplier to ask questions, creating a questioning environment	High			Yes	Fragile egos
31	The nature of the system – missile	High	23	L,T, I		
32	Design work practice – application of design rules undisciplined	High	14	L,T, I		
33	Contact with supplier manufacturing process limited to date	Low	6	L		
34	Need to know certain characteristics of supplier to get warm feeling	Low	6	L		

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
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Table 7-1 showing data analysis and derivation of military characteristics

Constraint	Constraint description	Author confidence [Tables 6-2 & 6-6]	Constraint descriptions from literature [Table 5-3]	Academic rigour (L,T,I,C) [Table 5-3]	Anomalies between case study and literature ?	Author derived Military Characteristics
35	Supply issues handled by procurement	High	16 21, 27	C, L, I C L,T, I		
37 51 53	Life cycle of product – development phases preclude SIL Separation of development and production (time (life cycle) and location) Geography inhibits	Medium High High	24 (location)	L,T, I	Yes (time)	But things will change
38	Getting suppliers interested	High	1, 2, 17, 20, 28	L,T, I T L,T, I, C L,T, I, C		
40	Suppliers unwilling to work with early info	Low	23	L,T, I		

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
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Table 7-1 showing data analysis and derivation of military characteristics

Constraint	Constraint description	Author confidence [Tables 6-2 & 6-6]	Constraint descriptions from literature [Table 5-3]	Academic rigour (L,T,I,C) [Table 5-3]	Anomalies between case study and literature ?	Author derived Military Characteristics
41	No belief that suppliers would voluntarily 'bare their chests' to problem solve	High*	22	L, I		
57	Not believing suppliers would bare their chests to problem solve, based on the premise that it didn't happen internally. Absent within, therefore absent without?	Low				
44	A reliable means of data exchange	High	9 and 11 perhaps	C L,T	Perhaps	Data exchange unreliable
45	A convenient means of data exchange	High	13	L,T, I		
46	Available internal resource to do modelling – development requirements	High	18 perhaps	L, T	Perhaps	Traitor tag
47	Living with the lot your left with – customer constraints	High	3	C		
48	Need for competitive tender	High	21	C		
50	Unit cost not total life cost (assumes competitive tender					

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
Author confidence: High* = Externally validated by interview; High = corroboration across projects, no contradictory evidence
Medium = evidenced through SVL by different methods, contradiction not internally valid; Low = evidenced by one method only, contradictory evidence

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Table 7-1 showing data analysis and derivation of military characteristics

Constraint	Constraint description	Author confidence [Tables 6-2 & 6-6]	Constraint descriptions from literature [Table 5-3]	Academic rigour (L,T,I,C) [Table 5-3]	Anomalies between case study and literature ?	Author derived Military Characteristics
	does not include total life issues)					
49	Having to work with enforced supplier – suppliers changing due to decisions taken by other functions	High	5	L, I		
36 55	No direction to involve suppliers in development work No incentive / direction to work with suppliers	High High	20	L,T, I, C		
36 55	No direction to involve suppliers in development work No incentive / direction to work with suppliers	High High	20	L,T, I, C	Yes	No 'now' gain no dictate

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
Author confidence: High* = Externally validated by interview; High = corroboration across projects, no contradictory evidence
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54	'Cultural [35] differences' – this was specific to work practice – e. g., keeping a different working day	High	19	L,T, I		
56	Need to be able to trust supplier	Low	22	L, I		
58	Fear of process change, bad experiences of previous process changes particularly the very high level of ongoing training required.	High *			Yes	Too different to get accepted, broadcast the pain
59	Fear of technology change (based on past experience & knowledge of the current workforce) – 'culture shock'	Medium	15	I		

[35] 'Cultural' in this context was a term used by the OEM members of the team. NB- the OEM members appeared to have identified their own culture and what constituted a different culture in terms of work practice.

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
Author confidence: High* = Externally validated by interview; High = corroboration across projects, no contradictory evidence
Medium = evidenced through SVL by different methods, contradiction not internally valid; Low = evidenced by one method only, contradictory evidence

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Table 7-1 showing data analysis and derivation of military characteristics

	associated with moving to using a model as master for interaction between the parties.					
60	Getting to grips with a common language.	Low	8	L,T, I, C		

Key : Academic rigour : L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= some industry consensus
Author confidence: High* = Externally validated by interview; High = corroboration across projects, no contradictory evidence
Medium = evidenced through SVL by different methods, contradiction not internally valid; Low = evidenced by one method only, contradictory evidence

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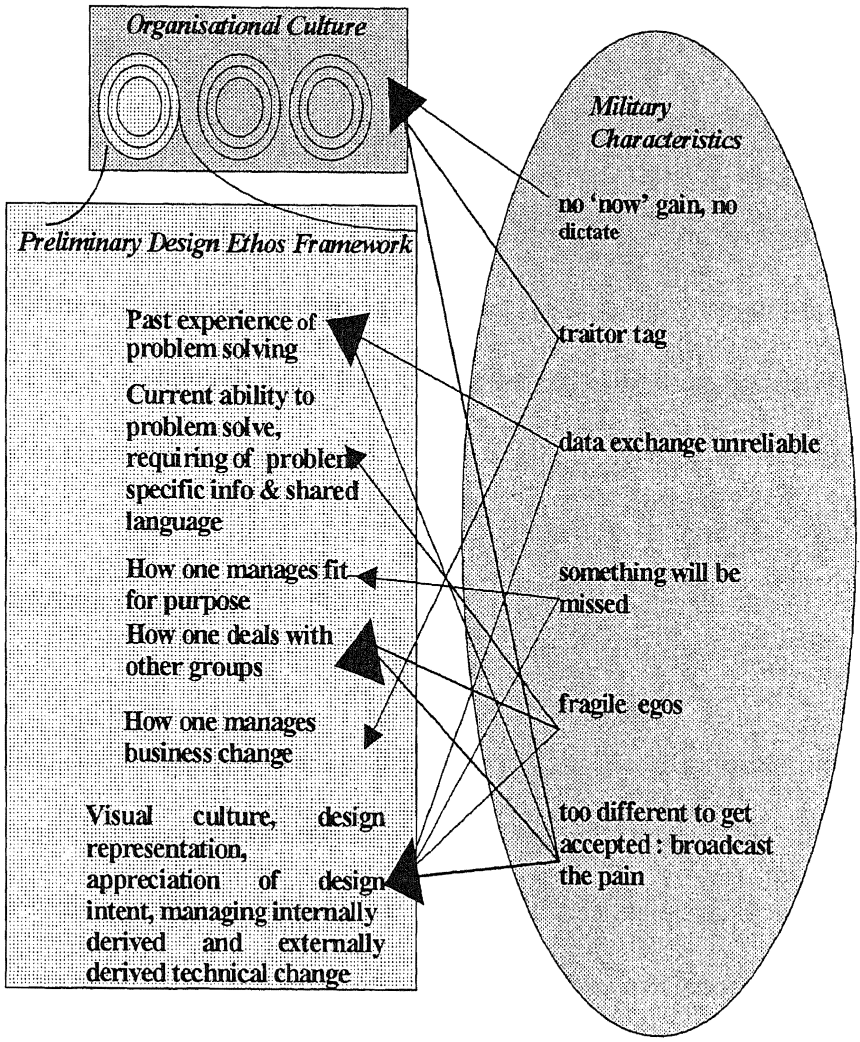

Figure 7-2 illustrating military characteristics and their relationship to the preliminary design ethos framework

8 Questionnaire Development

8.1 Introduction

This chapter describes the consolidation of the literature findings with regard to SIL constraints, the case study findings and the formulation of the questionnaire with regard to the research questions. The methodological construction of the questionnaire is described in chapter 4.

8.2 Questionnaire design

The questionnaire design is made up of five parts. These are consolidation of SIL constraints as identified in the literature, consolidation of constraints as identified in the case study, questionnaire piloting, questionnaire contextualisation and final questionnaire formulation. Figure 8-1 illustrates how one part leads to the next.

8.2.1 Question construction

Constraints from the literature and case study are summarised in Tables 5-3,6-3,6-4 and 6-5. The constraints identified could affect how OEMs work with suppliers. A questionnaire was designed incorporating these constraints for the purpose of testing whether responses from different industrial sectors differed.

The constraints as identified by both literature search and case study were first summarised and compared. Common constraints between the case study and literature were noted, and duplication acknowledged reducing the number of constraints accordingly. The author then considered each individual constraint in the context of each of the preliminary design ethos constructs.

8.2.1.1 Method

If the constraint was associated with past experience of problem solving, past experience of defining problems, a need for problem specific information, or issues associated with having a shared technical language, they were labelled 'problem related' issue – P.

If the constraint was associated with the product being/remaining fit for purpose, or how the group managed business change, or how the group dealt with other groups, it was labelled a 'commercial imperative' issue – CI.

If the constraint was associated with design representation, appreciation of design intent, or managing internally and externally derived change, it was labelled a 'minds eye' issue – ME.

A fourth category was thought necessary where the constraint appeared to not be associated with any of the constructs. The author calls this label 'O' and postulates that the constraint is associated with the company's organisational culture as opposed to any specific design subculture.

Questionnaire questions were then constructed which summarised the case study and literature derived constraints. Table 8-1 illustrates the relationship between constraints identified from the case study and literature and the questionnaire questions.

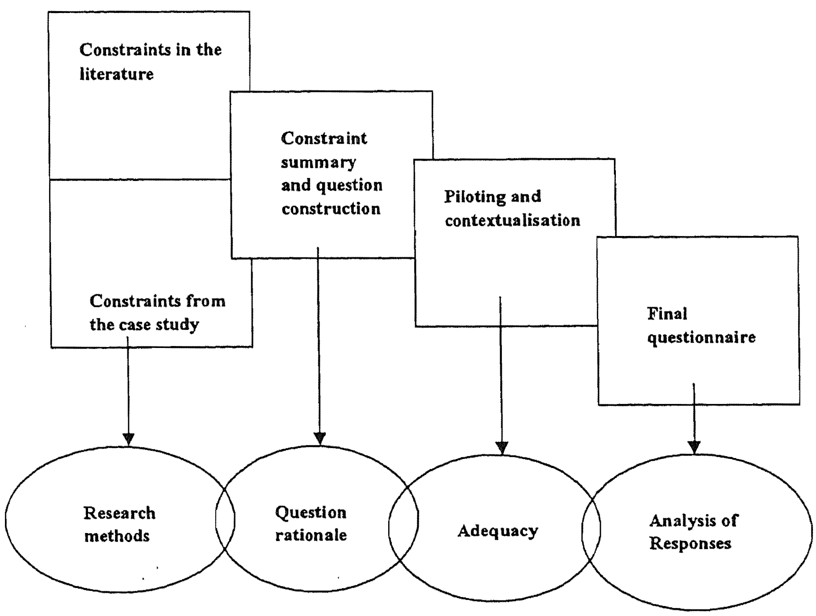

Figure 8-1 illustrating the process of questionnaire design

Table 8-1 showing the relationship between literature and case study constraints and questionnaire formulation

Key: L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= Some industry consensus

Constraint	Constraint description	Ethos constructs at play	Rigorous academic evidence	Supplementary case study evidence	Questions formulated
29	Supplier having necessary skills to collaborate with	ME			1
6	design		L		
33	Knowing/keeping abreast of supplier capabilities				
34	Contact with supplier manufacturing process limited				
	to date				
	Need to know certain characteristics of a supplier to				
	get warm feeling				
30	An ability to communicate on expertise			Yes	35
39	DFM (Assembly) requirements are project specific –			Yes	
43	carried by individuals			Yes	
13	Known examples of 'grey areas'		L,T, I	Perhaps	
52	Absence of open comms …	P,ME,CI			
60	Ability to pass on all needed knowledge to supplier		L,T, I		
8	Getting to grips with a common language.				
58	No common language			Yes	
	Fear of process change, bad experiences of previous				
	process changes particularly the very high level of				
42	ongoing training required	ME,CI		Yes	
31		ME,CI	L,T, I		
23	Suppliers fail to understand the importance of				15,19, 20, 28, 29,30
40	reliability of systems	O, ME	L,T, I		
23	The nature of the system – missile				
	Component complexity / frequently changing designs				
	/ ambiguous designs				
	Suppliers unwilling to work with early info	ME,CI		Yes	18, 34

Table 8-1 showing the relationship between literature and case study constraints and questionnaire formulation

Key: L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= Some industry consensus

Constraint	Constraint description	Ethos constructs at play	Rigorous academic evidence	Supplementary case study evidence	Questions formulated
30 61	Component complexity/ frequently changing designs / ambiguous designs An ability to communicate on expertise Getting past fragile egos in design on the part of the OEM, empowering the supplier to ask questions, creating a questioning environment				
32 14	Design work practice – application of design rules undisciplined Absence of design controls	P,ME,CI	L, T, I		35,11
35 16 21 27	Supply issues handled by procurement Discontinuities between internal functions within OEM/supplier Existing adversarial based procurement practice Absence of cross-functional teams/team skills	CI	L,T, C C L,T, I		2,6,9,10,31
37 51	Life cycle of product – development phases preclude SIL	P,CI		Yes (time)	23,24,25,21

Table 8-1 showing the relationship between literature and case study constraints and questionnaire formulation

Key: L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= Some industry consensus

Constraint	Constraint description	Ethos constructs at play	Rigorous academic evidence	Supplementary case study evidence	Questions formulated
53 24	Separation of development and production (time (life cycle) and location) Geography inhibits Appropriate co-location		L,T, I		
38 1 2 17 20 28	Getting suppliers interested Suitable metrics / acceptable to both sides Common objectives No existing long term relationship between the supplier and the buyer Absence of management support on both sides Absence of risk/reward (cost/benefit) to both sides, clear/some form of appropriate contract/ long term situation	CI, O	L,T, I L,T L,T, I, C L,T, I, C		7,,32,15,19, 33
41 57 22 56	No belief that suppliers would voluntarily 'bare their chests' to problem solve Not believing suppliers would bare their chests to problem solve, based on the premise that it didn't happen internally. Absent within, therefore absent	ME, CI ME,CI,P	L, I		18,26,27

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Table 8-1 showing the relationship between literature and case study constraints and questionnaire formulation

Key: L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= Some industry consensus

Constraint	Constraint description	Ethos constructs at play	Rigorous academic evidence	Supplementary case study evidence	Questions formulated
	without? Absence of trust / previous dealings Need to be able to trust supplier				
44 9 11	A reliable means of data exchange Problems of security of data transfer Fear of losing proprietary information	P,ME	 C L, T	Perhaps	13, 4
45 13	A convenient means of data exchange Absence of comms...	P,ME	 L, T, I		12
46 18	Available internal resource to do modelling – development requirements Not Invented Here syndrome	P,ME,CI	 L,T	Perhaps	3,16,17,18
47 3	Living with the lot your left with – customer constraints Client constrains	O	 C		8
48 50	Need for competitive tender Unit cost not total life cost (assumes competitive tender does not include total life issues)	CI			22

Table 8-1 showing the relationship between literature and case study constraints and questionnaire formulation

Key: L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= Some industry consensus

Constraint	Constraint description	Ethos constructs at play	Rigorous academic evidence	Supplementary case study evidence	Questions formulated
21	Existing adversarial based procurement practice		C		
49 5	Having to work with enforced supplier – suppliers changing due to decisions taken by other functions External forces – business need	CI	 L, I		6
36 55 20	No direction to involve suppliers in development work No incentive / direction to work with suppliers Absence of management support on both sides	O	 L,T, I, C		5
54 19	'Cultural [36] differences' – this was specific to work practice – e. g., keeping a different working day Common culture / will to change	ME,CI	 L,T, I		18

[36] 'Cultural' in this context was a term used by the OEM members of the team. NB- the OEM members appeared to have identified their own culture and what constituted a different culture in terms of work practice.

Table 8-1 showing the relationship between literature and case study constraints and questionnaire formulation

Key: L = Large scale research design, multiple authors, academic journals; T = Triangulation – multiple methods employed to reach conclusions
I = Insight into normally restricted areas, e. g., case studies written with industry and subsequently published in academic journals; C= Some industry consensus

Constraint	Constraint description	Ethos constructs at play	Rigorous academic evidence	Supplementary case study evidence	Questions formulated
59	Fear of technology change (based on past experience & knowledge of the current workforce) – 'culture shock' associated with moving to using a model as master for interaction between the parties.	ME,CI			14, 35
15	Component identity – how it is designed (2D.v.3D)		I		

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8.3 Deliberate design

8.3.1 Control variables

Participants were asked to indicate to which functional group they belonged and also whether they had belonged to other groups previously. This allowed the author to understand the wider skill mix within and across design communities.

8.3.2 Consideration of known differences – reliability test

Issue 8, – security considerations on the part of my customer - was known to be a constraint specific to the military sector and, as such, it was expected that the military sector would agree and the civil sector would disagree. A result that concurred with this expectation would give the author some confidence that the other cross-sectoral comparisons would be robust.

8.4 The final questionnaire

The final questionnaire is listed in Appendix 1. Analysis of responses can be found in Chapter 9.

8.5 Research hypothesis

By analysing the ethos constructs in terms of the SIL constraints, it was evident that in some cases all of the constructs of ethos manifested themselves in a particular constraint. Assuming that design ethos is influenced by the industry sector, and industry sectors are different in nature, then it should be possible to detect differences between the sectors in terms of what they view as SIL constraints. If this is the case, then it should then be possible to analyse such results in terms of ethos constructs. Table 8-3 shows the relationship of ethos constructs to questionnaire issues. In terms of research questions, and the formulation of suitable research hypotheses, Table 8-4 shows the relationship between the research questions, the experimental hypotheses and the null hypotheses.

Table 8-2 showing the relationship of ethos constructs to questionnaire issues (SIL constraints)

Design Ethos Constructs	Questionnaire issues
P	3,4,12,13,16,17,23,24,25,26,27,35
ME	1,3,4,11,12,13,14,16,17,18,20,26,27,28,29,30,34,35
CI	2,3,6,7,9,10,11,14,18,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35
O	5,8,15,19

Table 8-3 showing the relationship between the research question and

Table 8-3 showing the relationship between the research question and the experimental hypothesis

Research question	Working question	Experimental hypothesis	Null hypothesis
Does the ethos of a military design community differ from that of design communities in the civil sector?	Does the view of what constitutes SIL constraint in the military design community differ from that of a design community in the civil sector?	There is a difference in how the civil and military sectors consider (1-35) as a constraint to working with production suppliers during the development phase of components.	There is no difference in how the civil and military sectors consider (1-35) as a constraint to working with production suppliers during the development phase of components
	Reliability test	For question 8, true	For question 8, false
	Further analysis - Can any differences be attributed to ethos constructs?	Where the alternative hypothesis is true for questions 1-35, differences between sectors can be explained in terms of commercial imperative and problem solving issues alone.	Where the alternative hypothesis is true for questions 1-35, differences cannot all be explained in terms of commercial imperative alone and problem solving issues.

8.6 Statement of hypotheses

8.6.1 Experimental hypothesis 1

The industry sector has an effect on the views of SIL constraints (1-35), of design communities in that sector.

Reasoning: The view of what constrains SIL is dependent upon design ethos, which is made of three constructs – commercial imperative, mind's eye, and problem solving. A fourth construct - organisational factors is introduced to explain constraints that do not naturally fall within the original construct descriptions. The literature clearly differentiates the behaviours of personnel within specific industry sectors as to whether the industry is commercially or engineering-driven. It further suggests that differences between industry sectors appertain to such differences of behaviour. Therefore the null hypotheses for testing are:

> **H01** = There is no difference in how the civil and military sectors consider '**not knowing production-supplier capability**' as a constraint to working with production suppliers during the development phase of components.
>
> **H02** = There is no difference in how the civil and military sectors consider ' **a production-supplier's procurement status (vendor rating)**' as a constraint to working with production suppliers during the development phase of components.
>
> **H03** = There is no difference in how the civil and military sectors consider ' **available in-house production expertise**' as a constraint to working with production suppliers during the development phase of components.
>
> **H04** = There is no difference in how the civil and military sectors consider ' **restrictions on electronic communication**' as a constraint to working with production suppliers during the development phase of components.
>
> **H05** = There is no difference in how the civil and military sectors consider '**lack of management buy-in**' as a constraint to working with production suppliers during the development phase of components.
>
> **H06** = There is no difference in how the civil and military sectors consider '**the influence of other functional groups outside of my own**' as a constraint to working with production suppliers during the development phase of components.
>
> **H07** = There is no difference in how the civil and military sectors consider '**an absence of appropriate contracts**' as a constraint to working with production suppliers during the development phase of components.

H08 = There is no difference in how the civil and military sectors consider ‘ **security considerations on the part of my customer**’ as a constraint to working with production suppliers during the development phase of components.

H09 = There is no difference in how the civil and military sectors consider ‘ **outstanding issues from previous dealings**’ as a constraint to working with production suppliers during the development phase of components.

H010 = There is no difference in how the civil and military sectors consider ‘ **no clear choice of preferred production-supplier at the development stage**’ as a constraint to working with production suppliers during the development phase of components.

H011 = There is no difference in how the civil and military sectors consider ‘ **no existing process for working with production suppliers**’ as a constraint to working with production suppliers during the development phase of components.

H012 = There is no difference in how the civil and military sectors consider ‘ **the absence of a convenient means of sharing technical information** ’ as a constraint to working with production suppliers during the development phase of components.

H013 = There is no difference in how the civil and military sectors consider ‘ **the absence of a reliable means of sharing technical information**’ as a constraint to working with production suppliers during the development phase of components.

H014 = There is no difference in how the civil and military sectors consider ‘ **the change required in existing work practice**’ as a constraint to working with production suppliers during the development phase of components.

H015 = There is no difference in how the civil and military sectors consider ‘ **production-suppliers’ unwillingness to share process know-how pre-contract**’ as a constraint to working with production suppliers during the development phase of components.

H016 = There is no difference in how the civil and military sectors consider ‘ **available in-house support for early design**

realisation e. g., rapid prototyping' as a constraint to working with production suppliers during the development phase of components.

H017 = There is no difference in how the civil and military sectors consider ' **a fear of losing core skills to outside the company**' as a constraint to working with production suppliers during the development phase of components.

H018 = There is no difference in how the civil and military sectors consider ' **cultural differences e. g., language, aptitude, business ethics**' as a constraint to working with production suppliers during the development phase of components.

H019 = There is no difference in how the civil and military sectors consider ' **production-suppliers unwillingness to participate in design proving**' as a constraint to working with production suppliers during the development phase of components.

H020 = There is no difference in how the civil and military sectors consider ' **inadequate skills amongst production-suppliers**' as a constraint to working with production suppliers during the development phase of components.

H021 = There is no difference in how the civil and military sectors consider ' **production suppliers generally not available when needed**' as a constraint to working with production suppliers during the development phase of components.

H022 = There is no difference in how the civil and military sectors consider ' **the requirement for three quotes from suppliers**' as a constraint to working with production suppliers during the development phase of components.

H023 = There is no difference in how the civil and military sectors consider ' **our rigid milestones**' as a constraint to working with production suppliers during the development phase of components.

H024 = There is no difference in how the civil and military sectors consider ' **our inappropriate milestones**' as a constraint to working with production suppliers during the development phase of components.

H025 = There is no difference in how the civil and military sectors consider ' **the segregation of development and production work**' as a constraint to working with production suppliers during the development phase of components.

H026 = There is no difference in how the civil and military sectors consider ' **the segregation of development and production work**' as a constraint to working with production suppliers during the development phase of components.

H027 = There is no difference in how the civil and military sectors consider '**the negative experience of colleagues**' as a constraint to working with production suppliers during the development phase of components.

H028 = There is no difference in how the civil and military sectors consider '**the type of component/system being developed**' as a constraint to working with production suppliers during the development phase of components.

H029 = There is no difference in how the civil and military sectors consider '**the complexity of the components being developed**' as a constraint to working with production suppliers during the development phase of components.

H030 = There is no difference in how the civil and military sectors consider '**technically 'out of step' production suppliers**' as a constraint to working with production suppliers during the development phase of components.

H031 = There is no difference in how the civil and military sectors consider '**imposed/enforced suppliers**' as a constraint to working with production suppliers during the development phase of components.

H032 = There is no difference in how the civil and military sectors consider '**this company's existing poor relationship with production suppliers (some/all)**' as a constraint to working with production suppliers during the development phase of components.

H033 = There is no difference in how the civil and military sectors consider '**this company's existing cosy relationship with production suppliers**' as a constraint to working with production suppliers during the development phase of components.

H034 = There is no difference in how the civil and military sectors consider '**production suppliers' inability to work with 'early' (incomplete, changing) design information**' as a constraint to working with production suppliers during the development phase of components.

H035 = There is no difference in how the civil and military sectors consider '**the existing process for working with a production supplier**' as a constraint to working with production suppliers during the development phase of components.

8.6.2 Experimental hypothesis 2

Where alternate hypothesis 1 is true for questions 1-35, differences between sectors can be explained in terms of commercial imperative and problem solving alone.

Reasoning: The literature has suggested that those issues that are industry specific are associated with the commercial imperative and problem solving ability of the company alone. In the UK, where academic, professional and in-company learning is promoted for engineering staff, issues which comprise the mind's eye may well be harder to differentiate. The purpose of research hypothesis 2 is to test the design ethos constructs of CI, P, ME and O and to decide whether there is any evidence to support the preliminary design ethos framework. Special attention is paid to differences between sectors and their relationship to the mind's eye construct.

H0ethosvariation = Where the alternate hypothesis is true for questions 1-35, differences cannot all be explained in terms of commercial imperative and problem solving issues.

8.7 Summary

This chapter has summarised the SIL constraints found in the literature and the case study and has described the process by which those constraints were aligned with the constructs of ethos. It has also described how those constructs were then compiled into questionnaire issues. In aligning the ethos constructs with the SIL constraints, a number of anomalies were discovered which have been labelled organisational 'O' constraints as opposed to design subculture derived constraints and these anomalies will be discussed in the context of the findings in later chapters.

This chapter has also described the incorporation of a questionnaire reliability test using issue 8 – security considerations on the part of my customer.

Finally this chapter describes the formulation and statement of experimental and null hypotheses in terms of the independent variable – the industry sector, and the dependent variable – the view of what is a SIL constraint, and possible intervening variables in the form of design ethos constructs.

9 Quantitative Questionnaire analysis

9.1 Introduction

Chapter 3 describes design ethos, for purpose of this thesis, as:

> The characteristic manner or approach to constraints on SIL working displayed by personnel involved in the design of new products

This chapter explores constraints on SIL working as perceived by two separate design communities and describes differences and similarities between sectors based on the statistical analyses of questionnaire responses. Conclusions are then drawn as to whether design ethos varies between the military and civil sectors.

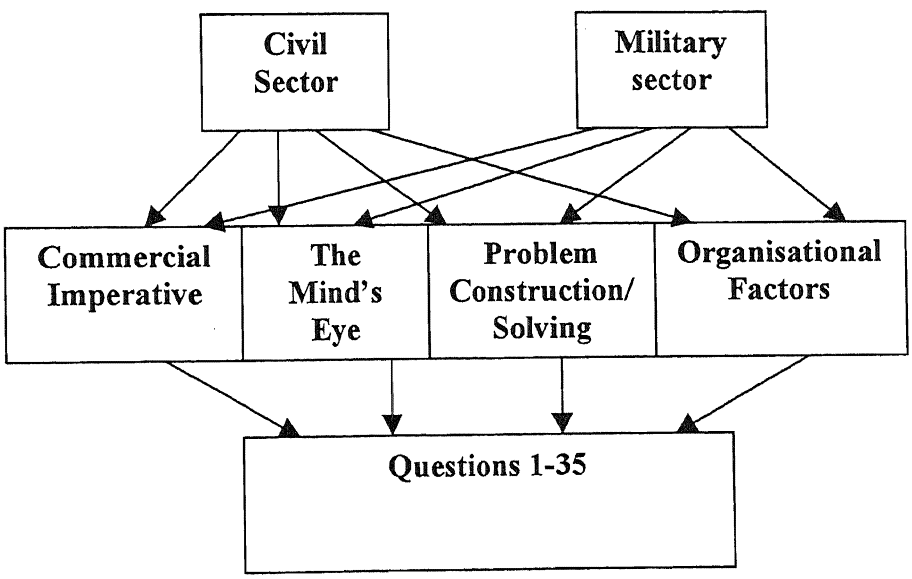

Figure 9-1 illustrating the structure of the data problem

9.2 Data description

Both samples were drawn from design communities at large OEMs. A detailed overview of the distribution method and sampling is given in chapter 4. Distribution of questionnaires within each sector was to design-related, supplier–facing personnel. All of the companies had experience of concurrent engineering internally and showed an interest in the factors that influenced SIL.

Based on the common approach to targeting participants it is assumed that the two sample populations were similar. However, in order to control for the possibility of a disproportionate level of any function in each sector, participants were asked to state their current and previous functional experience so that cross tabulation could be undertaken.

Table 9-1 showing the sample size achieved and the estimated population

Company	Estimate of population**	Number Sent Out	Number back	Sample
MBD (Stevenage & Lostock)	250	32	18	17
BAe (Chadderton, Warton, Farnborough, Brough)	1000	25*	24	24
Lockheed Martin (Plymouth)	10	10	6	6
GKN WHL (Yeovil)	250	10	9	9
Ford (Dunton, Dagenham, Bridgend)	1000	45	45	43
Vauxhall (Luton)	50	20	13	12
Total	2560	142	115	111

Key * 25 hard copies sent out; however, distributed internally on company network by email.
** Population refers to design- related, supplier- facing personnel

Oppenheim states that sample accuracy is more appropriate than its size. This is particularly important when attempting to interpret differences between groups as is the aim of this research. The literature and case study had led the author to believe that military responses to the Likert scale would be in the 1-2 (strongly agree / agree) region for all of the questions, and that questions derived specifically from the military case study may draw differing responses from the civil sector. The preliminary study had in effect reduced the prospective distribution of responses already. Therefore a smaller sample size than usually required would suffice. If we assume that ninety five per cent of the sample population is expected to give this particular answer for each issue, (De Vaus 1996) shows that sample sizes as low as seventy six can produce a sampling error as low as five per cent in the population. Therefore the sample responding in a certain way will reflect the population plus or minus 5%. The total sample size was one hundred and eleven (fifty-six in one, and fifty-five in the other). This led the author to believe that the results would conform to this assumption of population validity.

9.2.1 Research questions, hypotheses and test methods

Table 8-3 shows the relationship of the research questions to the experimental hypotheses. Table 9-2 shows the research hypotheses with the associated test method.

9.3 Data preparation

All questionnaire data were input to SPSS version 9 and this software was used for subsequent analysis.

Table 9-2 showing the research hypotheses and the test method

Experimental hypothesis	Null hypothesis	Test Method
There is a difference in how the civil and military sectors consider (1-35) as a constraint to working with production suppliers during the development phase of components.	There is no difference in how the civil and military sectors consider (1-35) as a constraint to working with production suppliers during the development phase of components	Descriptive statistics Significance testing between sectors Kolmogorov-Smirnov, Mann-Whitney, Chi-sqd testing
Where the alternative hypothesis is true for questions 1-35, differences between sectors can be explained in terms of commercial imperative and problem solving issues.	Where the alternative hypothesis is true for questions 1-35, differences cannot be explained in terms of commercial imperative and problem solving.	Factor analysis- rotation Analysis of factor clusters in terms of design ethos constructs : Commercial Imperative, Problem solving, Mind's Eye and Organisational factors

9.3.1 Cleaning the data set

Missing data in specific cases were dealt with via pairwise deletion. Cases from inappropriate candidates were removed from the sample by listwise deletion. Listwise deletion involves the deletion of the questionnaire from the analysis. Pairwise deletion involves the temporary deletion of cases from the analysis, for those questions that had no entries. The rest of the cases, and answered questions therein were used in the analysis.

Alternative approaches were considered for dealing with missing data. These were: a sample mean approach, a group means approach and a regression analysis, however, given the total number of questions lost to the analysis, the benefits and problems that these individual methods themselves create, it was deemed appropriate to use pairwise deletion. The use of this method is considered later in the context of data impact.

9.4 Initial analysis

Figure 9-2 illustrates the analysis roadmap and shows the information obtained from each test.

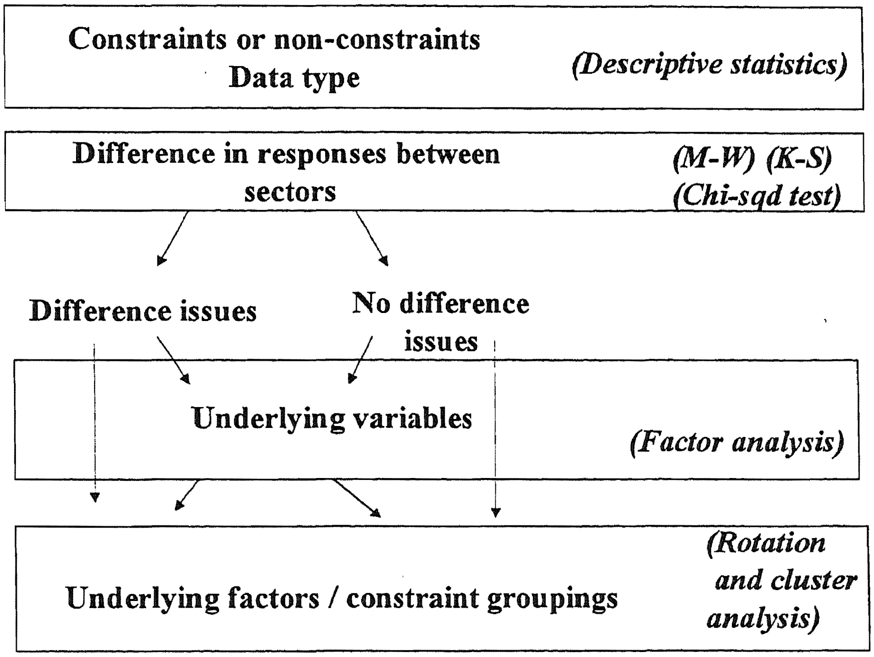

Figure 9-2 illustrating the analysis roadmap and the information obtained

9.4.1 Descriptive statistics

In order to build up a picture of what the sample looked like in both sectors, and to confirm that the constraints were indeed corroborated, the mean responses were analysed for each question. For the military sector, the mean value varied from 2.07 to 3.05. For the civil sector, the mean value varied from 2.07 to 3.48. For the civil sector the SD ranged from .85 to 1.37, for the military sector it ranged from .89 to 1.21. See Table 9-3. The author's expectation, based on the literature, was that responses would be in the 1 to 2 range for all constraints. The descriptive statistics now indicated that there was some tendency towards disagreement and statistics now indicated that there was some tendency towards disagreement and possible subtle differences between the sectors in the area of what constituted a constraint, which deserved further exploration.

Table 9-3 showing comparison of descriptive statistics

Variable	N		Min		Max		Sum		Mean		Std. Deviation	
	Mil	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**
Q1	56	55	1	1	5	4	116	114	2.07	2.07	.89	.94
Q2	56	55	1	1	5	5	153	154	2.73	2.8	1.05	1.08
Q3	56	55	1	1	5	5	143	136	2.55	2.47	1.16	.98
Q4	56	55	1	1	4	5	145	144	2.59	2.62	.99	1.37
Q5	56	54	1	1	4	5	131	118	2.34	2.19	1.15	1.07
Q6	56	55	1	1	5	4	130	144	2.32	2.62	.94	.85
Q7	56	55	1	1	4	5	132	147	2.36	2.67	.96	1.14
Q8	56	55	1	1	5	5	147	164	2.63	2.98	1.02	.97
Q9	56	55	1	1	4	4	142	135	2.54	2.45	1.03	1.02

Table 9-3 showing comparison of descriptive statistics

Variable	N		Min		Max		Sum		Mean		Std. Deviation	
	Mil	Civil	Mil	Civil	Mil	Civil	Mil	Civil	Mil	Civil	Mil	Civil
Q10	56	55	1	1	5	5	133	121	2.37	2.20	1.05	1.13
Q11	56	55	1	1	5	5	163	150	2.91	2.73	1.05	1.16
Q12	56	55	1	1	5	5	143	134	2.55	2.44	.91	1.05
Q13	56	55	1	1	5	5	141	137	2.52	2.49	1.01	1.20
Q14	56	55	1	1	5	5	136	153	2.43	2.78	.93	.92
Q15	56	55	1	1	5	5	142	153	2.54	2.78	.95	1.10
Q16	56	55	1	1	5	5	137	150	2.45	2.73	1.13	1.27
Q17	55	34	1	1	4	5	168	112	3.05	3.29	.99	1.09
Q18	56	34	1	1	5	5	148	98	2.64	2.88	1.10	1.25
Q19	56	54	1	1	4	5	145	147	2.59	2.72	1.07	1.22
Q20	56	54	1	1	5	5	148	124	2.64	2.30	1.21	1.16

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Table 9-3 showing comparison of descriptive statistics

Variable	N		Min		Max		Sum		Mean		Std. Deviation	
	Mil	Civil	Mil	Civil	Mil	Civil	Mil	Civil	Mil	Civil	Mil	Civil
Q21	55	54	1	1	5	5	146	131	2.65	2.43	1.00	1.13
Q22	56	54	1	1	5	5	164	167	2.93	3.09	1.11	1.19
Q23	56	54	1	1	5	5	151	188	2.70	3.48	1.08	1.00
Q24	56	54	1	1	5	5	145	164	2.59	3.04	1.04	1.10
Q25	56	54	1	1	4	5	149	158	2.66	2.93	1.07	1.03
Q26	56	54	1	1	5	5	166	152	2.96	2.81	1.06	1.12
Q27	56	54	1	1	5	5	165	157	2.95	2.91	1.05	1.05
Q28	56	54	1	1	4	4	156	150	2.79	2.78	1.00	1.00
Q29	56	54	1	1	5	5	149	150	2.66	2.78	1.07	1.11
Q30	55	54	1	1	5	4	141	134	2.56	2.48	1.07	1.00
Q31	56	54	1	1	4	4	119	121	2.13	2.24	.90	.87

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Table 9-3 showing comparison of descriptive statistics

Variable	N		Min		Max		Sum		Mean		Std. Deviation	
	Mil	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**	**Mil**	**Civil**
Q32	56	34	1	1	4	4	144	89	2.57	2.62	.97	.92
Q33	55	34	1	1	4	5	158	94	2.87	2.76	1.00	1.05
Q34	55	54	1	1	5	5	137	136	2.49	2.52	1.09	1.22
Q35	55	23	1	1	4	5	147	65	2.67	2.83	.90	1.34
Valid N (listwise)	53	22										

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9.5 Control variables

It was necessary to consider what other possible causal factors existed which may have affected views on constraint in each sector. One possible factor that needed consideration was the cross-functional make-up of each sample, and how this differed between the samples from each industrial sector.

9.5.1 Current functional experience

Table 9-4 shows the profile of respondents in each sector. The profile indicates that the sample taken varies by more than 10 per cent in three areas. These are manufacturing, component engineering and procurement/purchasing. The military sector sample has relatively high procurement functional experience, while the civil sample has low functional experience of procurement. Similarly, within the samples, there is low functional experience of component engineering in the military sector sample while there is relatively high functional experience of component engineering in the civil sector sample. The difference in manufacturing experience indicated that the profile of participants was perhaps skewed towards early life of products in the military sector.

In order to decide whether this may have significantly influenced the outcome of the comparison between sectors, thereby making the outcomes unreliable, it was necessary to understand the influence on specific issues of the functions in question. A cross tabulation of issues 6,7,10 and 20 (constraints that showed priority differences across sectors) was conducted against function to understand whether the response varied significantly due to the function's influence. By inspection, see Appendix 2, the high incidence of procurement/purchasing staff in the military design community sample appeared to have influenced the distribution. Further sampling to negate this effect was outside the scope of the research; however, the functional expertise profiles of questionnaire participants is carried forward for further discussion in Chapter 10.

Table 9-4 showing a comparison of the current functional profiles of respondents within the military and civil sectors

Function	Civil %	Mil %	Note
Business Project Management	1.8	8.9	
Component Engineering	18.2	1.8	Possible cause for concern
Design Engineering	30.9	26.8*	
Design Project Management	5.5	12.5	
Manufacturing	23.6	5.4	Possible cause for concern
Other	5.5	14.3	
Production Engineering	7.3	3.6	
Procurement/ Purchasing	1.8	19.6	Possible cause for concern
Quality	5.5	7.1	
TOTAL	100	100	

Key: * incorporates functional group DE/PP

9.5.2 Previous functional experience

Based on a cross tabulation exercise there appeared to be a wider range of functional experience in the civil sector sample than in the military sector. Also, in the military sector, the description of functional experience within the 'other' category is perhaps skewed towards the early life of products as opposed to later life as in the civil sector. This may be corroborated by the higher proportion of respondents in the civil sector who considered themselves as having manufacturing experience. It should be noted, however, that previous functional experience could have been in the participant's current or previous employment. The previous functional expertise profiles are carried forward for discussion in chapter 10.

In the civil sector, the descriptions within the 'other' category also suggest a wider experience outside of the automotive industry e. g. , Facilities, Consultancy, unlike the descriptions given in the 'other' category in the military sector which suggest the same industry sector. However, without further detailed description of these roles, it is impossible to make inference comparing the type of experience between the sectors. These particular distributions are omitted from Appendix 3 for reasons of clarity.

9.6 Inferential statistics

9.6.1 Inspection of the distributions

By combining Likert answers 1+2, and 4+5, the results were analysed in terms of the majority responses to each issue within each sector. See Table 9-7. Agreement (1+2) and disagreement (4+5) is decided based on over 50% of the participants having indicated this.

By this method it appeared that there was consensus between the sectors on the majority of variables; however, a number indicated disagreement.

Responses to issues were summated to explore which issues were considered to be strong constraints and which issues were least constraining. After correcting for missing data the issues could be scaled as to which were strong constraints and which were least constraints. Tables 9-5 and 9-6 show the top five issues considered to be constraints and the bottom five, by inference, considered least constraints.

9.6.1.1 Strong constraints

Table 9-5 showing top five constraints in each sector

Military Constraint	% in agreement	Civil Constraint	% in agreement
1	89%	1	78%
31	71%	5	69%
6	70%	10	76%
5	59%	31	67%
7	63%	20	69%

Issues 1, 5 and 31 were considered top constraints by both sectors. These were related to not knowing production supplier capability, lack of management buy-in and imposed/enforced production-suppliers . Issues that varied between sectors were 6,7,10 and 20. These related to the influence of other functional groups, an absence of appropriate contracts , no clear choice of preferred production supplier at the development stage, and inadequate skills amongst production-suppliers.

9.6.1.2 Least constraints

Table 9-6 showing least constraints in each sector

Military least constraints	% in agreement	Civil least constraints	% in agreement
17	44%	23	56%
26	39%	17	53%
27	39%	22	41%
22	36%	24	35%
11	39%	8	38%

Issue 22 – the requirement for three quotes from suppliers was considered to be a low constraint in both sectors, while issue 17 – a fear of losing core skills to outside the company, was considered a non-constraint. This issue was the only one identified by both sectors to be a non-constraint. This result is discussed later. The civil sector also appeared to view rigid milestones and inappropriate project milestones as a low constraint. The military sector appeared to view no existing process for working with production-suppliers, previous negative experience of colleagues and the negative experience of colleagues as low constraints.

The answer to issue 8 – security considerations on the part of my customer, was anticipated in the civil sector, although the split of answers between agree and disagree did suggest some other factor, e. g., an alternative interpretation of the question. Nonetheless, the indication by a large number of participants that this was not a constraint gives some confidence as to the reliability of the instrument.

9.6.2 Analysis of the distributions

Initial analysis of the samples' histograms suggested that there was some variation in the responses to each of the variables between sectors and that in some cases responses did not appear to follow the normal distribution around the Likert '2'. Kolmogorov-Smirnov, Mann-Whitney and Chi sqd tests were used to explore responses. If the tests showed significant difference in each of the variables across sectors in shape, location or comparison of categories, then this might indicate more fundamental differences between the sectors.

Frequency plots for each issue in each sector were reviewed. To enable chi-sqd testing, categories were combined where the number of responses in each category was five or less and to ensure that fewer than twenty percent of the categories had a frequency less than five. See Section 9.6.3 for weaknesses of this particular method. For consistency, the same method was conducted for corresponding issues in each sample. For example, disagree and strongly disagree were combined as were agree and strongly agree. Siegal and Castellan (1988) state:

> The combining of categories must be done judiciously. That is, the results of the statistical test may not be interpretable if the combining of the categories has been capricious. The categories that are combined must have some common property of mutual identity if interpretation of the outcome of the test after combining of rows and columns is to be meaningful.

Table 9-7 showing the degree of consensus between sectors by inspection

Question number	Constraint description	MIL agree	MIL (3)	MIL Disagree	CIVIL agree	CIVIL (3)	CIVIL Disagree	Consensus
1	Not knowing production-supplier capability	50	0	6	43	5	7	Sector consent - agree
2	A production-supplier's procurement status	29	12	15	27	14	14	Sector consent - agree
3	Available in-house production expertise	34	4	18	34	12	9	Sector consent - agree
4	Restrictions on electronic communication	33	8	15	34	3	18	Sector consent - agree
5	Lack of management buy-in	33	10	13	37	9	8	Sector consent - agree
6	The influence of other functional groups outside of my own (e.g., visibility of required information)	39	9	8	28	17	10	Sector consent - agree
7	An absence of appropriate contracts	35	12	9	26	15	14	Sector consent - agree
8	Security considerations on the part of my customer	30	12	14	21	13	21	Mil agree, civil split
9	Outstanding issues from previous dealings	34	7	15	33	10	12	Sector consent - agree
10	No clear choice of preferred production-supplier at the development stage	39	6	11	42	2	11	Sector consent - agree
11	No existing process for working with production suppliers	24	10	22	27	11	17	Sector consent - agree
12	The absence of a convenient means of sharing technical information	35	11	10	35	8	12	Sector consent - agree
13	The absence of a reliable means of sharing technical information	35	8	13	35	8	12	Sector consent - agree
14	The change required in existing work practice/design process	32	17	7	25	16	14	Sector consent - agree
15	Production-suppliers' unwillingness to share process know-how pre-contract	31	15	10	25	11	19	Sector consent - agree

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Table 9-7 showing the degree of consensus between sectors by inspection

Question number	Constraint description	MIL agree	MIL (3)	MIL Disagree	CIVIL agree	CIVIL (3)	CIVIL Disagree	Consensus
16	Available in-house support for early design realisation e.g., rapid prototyping	36	5	15	29	6	20	Sector consent - agree
17	A fear of losing core skills to outside the company	5	13	24	9	7	18	Sector consent - disagree
18	Cultural differences e.g., language, aptitude, business ethics	32	6	18	16	12	14	Sector consent - agree
19	Production-suppliers' unwillingness to participate in design proving / testing	32	7	17	30	4	20	Sector consent - agree
20	Inadequate skills amongst production-suppliers	30	7	19	37	4	13	Sector consent - agree
21	Production-suppliers, generally not available (when needed)	27	15	13	36	5	13	Sector consent - agree
22	The requirement for three quotes from a supplier	21	15	20	17	15	22	Mil agree, civil disagree
23	Our rigid milestones	31	8	17	10	9	35	Mil agree, civil disagree
24	Our inappropriate milestones	31	11	14	18	17	19	Mil agree, civil disagree
25	The segregation of development and production work	32	5	19	21	13	20	Sector consent - agree
26	Previous negative experience of working directly with production-suppliers	19	15	22	26	10	18	Mil disagree, civil agree
27	The negative experience of colleagues	24	10	22	24	13	17	Sector consent - agree
28	The type of component / system being developed	24	16	17	26	10	18	Sector consent - agree
29	The complexity of components being developed	31	8	17	29	4	21	Sector consent - agree
30	Technically 'out of step' production-suppliers	21	10	14	34	7	13	Sector consent - agree
31	Imposed / enforced production-suppliers	40	11	5	36	13	5	Sector consent - agree
32	This company's existing poor relationship with	29	15	12	17	10	7	Sector consent - agree

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Table 9-7 showing the degree of consensus between sectors by inspection

Question number	Constraint description	MIL agree	MIL (3)	MIL Disagree	CIVIL agree	CIVIL (3)	CIVIL Disagree	Consensus
	production-suppliers (some/all)							
33	This company's existing cosy relationship with production-suppliers (some/all)	**23**	**12**	**20**	**17**	**8**	**9**	Sector consent - agree
34	Production-suppliers' inability to work with 'early' (incomplete, changing) design information	**34**	**7**	**14**	**33**	**4**	**17**	Sector consent - agree
35	The existing process for working with a production-supplier	**30**	**11**	**14**	**10**	**4**	**9**	Sector consent - agree

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The 'don't know' category was only combined with other categories where absolutely necessary. Where this did take place for a variable across both sectors, note was taken so that results could be reviewed for the effects of such a combination. Where such results were uncorroborated, these differences between sectors are considered to be weak, whereas corroborated results are considered to be strong.

The chi-sqd test[37] showed that nine out of thirty five variables showed significant difference in response between sectors, seven at the 0.01 level and 2 at the 0.05 level.

Kolmogorov-Smirnov testing showed only one difference between the sectors (23). This test compares cumulative distribution functions for two groups to detect differences in shapes and location. Mann-Whitney tests indicated four differences (6,14,23,24), indicating that for these variables, the two sampled populations are not equivalent in location. The difference in results between the two tests may be explained in terms of sample size. Siegel states that there is evidence to indicate that whereas for very small samples the Kolmogorov-Smirnov test is slightly more efficient than the Mann-Whitney test, for large samples (>40) the converse holds. Sample size here is >40, therefore both sets of results are carried forward for interpretation.

Table 9-8 summarizing the inferential statistics

Key: ** Chi-sqd difference (p<0.05)
*** KS- difference in shape or location (p<0.05)
**** M-W difference in location (p<0.05)

Variable	Chi-Sq	Asymp. Sig.	K-S Z	Asymp. Sig.	M-W U	Asymp. Sig.
Q1	12.302	.002 **	.585	.884	1529	.941
Q2	.530	.767	.197	1.00	1492.5	.767
Q3	2.336	.311	.831	.494	1514.5	.873
Q4	.190	.663	.679	.746	1484.5	.729
Q5	3.705	.295	.503	.962	1405.5	.508
Q6	10.890	.004 **	.987	.284	1226.0	.045 ****
Q7	6.282	.099	.802	.541	1303.0	.145
Q8	6.379	.041 **	.811	.527	1238.5	.061
Q9	2.823	.420	.262	1.00	1480.5	.709
Q10	5.318	.070	.590	.877	1355.0	.237
Q11	1.622	.444	.441	.990	1390.5	.357
Q12	1.222	.543	.674	.754	1419.0	.436
Q13	3.337	.343	.393	.998	1475.0	.682
Q14	8.728	.013 **	.682	.740	1232.5	.055 ****[38]
Q15	11.480	.009 **	.879	.422	1338.0	.212
Q16	3.373	.185	.609	.852	1357.5	.259
Q17	1.208	.547	.427	.993	814.5	.281
Q18	1.503	.472	.464	.983	852.0	.382
Q19	.099	.952	.350	1.00	1434.5	.624
Q20	5.156	.076	.784	.571	1268.5	.128
Q21	182.543	.000 **	.917	.369	1268.5	.167
Q22	1.240	.744	.316	1.00	1391.0	.455
Q23	34.573	.000 **	1.932	.001 ***	914.0	.000 ****
Q24	10.825	.004 **	1.155	.139	1167.0	.032 ****
Q25	7.347	.007 **	.957	.319	1301.0	.182
Q26	5.083	.079	.746	.635	1376.5	.399
Q27	2.038	.361	.409	.996	1469.0	.787
Q28	2.726	.256	.371	.999	1496.0	.920
Q29	.060	.807	.447	.988	1429.5	.598
Q30	1.807	.613	.344	1.00	1424.0	.694
Q31	1.370	.504	.340	1.00	1393.0	.446
Q32	.120	.942	.169	1.00	926.5	.823
Q33	1.505	.471	.453	.986	863.5	.526
Q34	1.652	.438	.315	1.00	1477.0	.959
Q35	1.136	.286	.729	.663	592.0	.639

[37] Testing was conducted using the military sector as the expected statistic and the civil sector as the observed. Subsequent reversal of these categories in line with the civil sector perhaps representing a benchmark, made no difference to the result

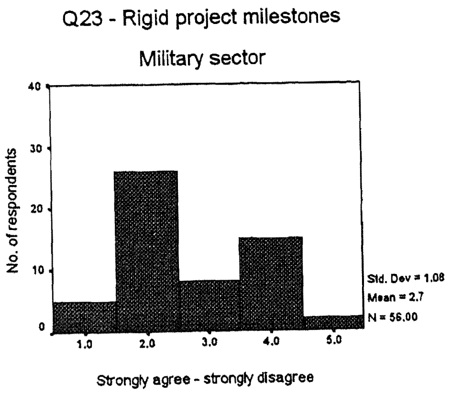
[38] Borderline

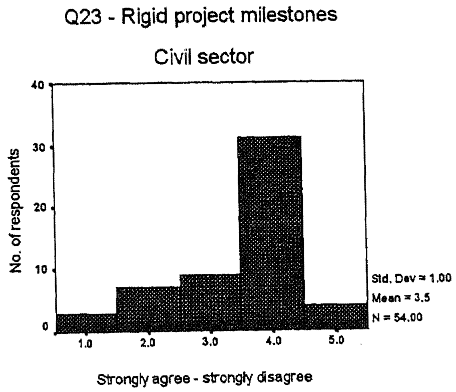
Table 9-9 showing issues with significant differences between sectors

Variable	Difference test	Design Ethos Construct	N (civil)	N (military)
23	** *** ****	CI,P	54	56
24	** ****	CI,P	54	56
6	** ****	CI	55	56
14	** ****	ME,CI	55	56
15	**	ME,O	55	56
1	**	ME	55	56
21	**	CI	54	55
25	**	CI	54	56
8	**	O	55	56

Key: ** Chi-sqd difference (p<0.05)
*** KS- difference in shape or location (p<0.05)
**** M-W difference in location (p<0.05)

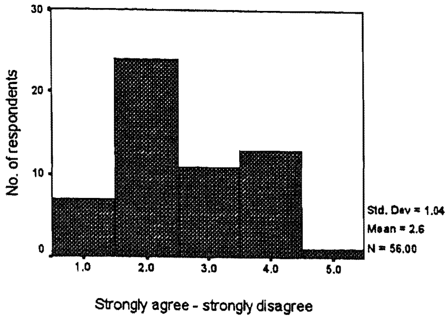
Distributions that yielded differences are displayed below in order of initial confidence as per Table 9-9. These differences are discussed further in 9.6.3 and in Chapter 10.





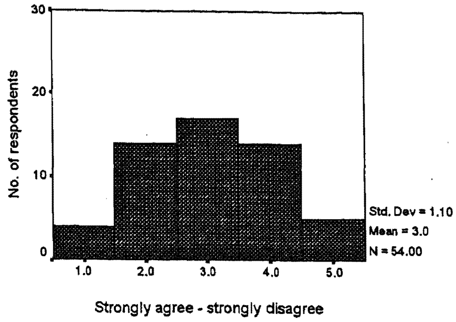
Q24 - Inappropriate project milestones

Military sector



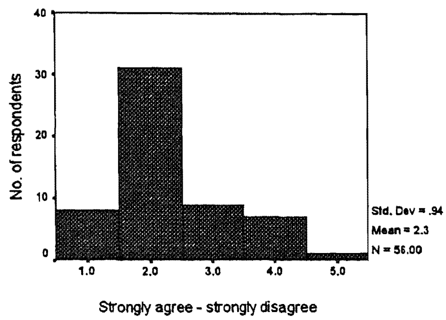
Q24 - Inappropriate project milestones

Civil sector



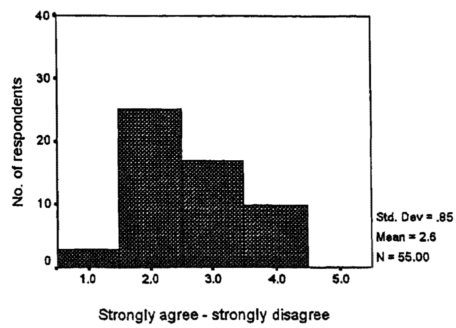
Q6 - The influence of other functional groups...

Military sector



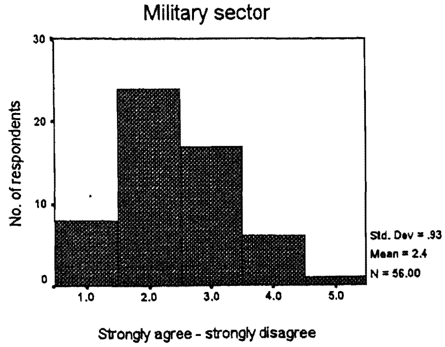
Q6 - The influence of other functional groups ...

Civil sector



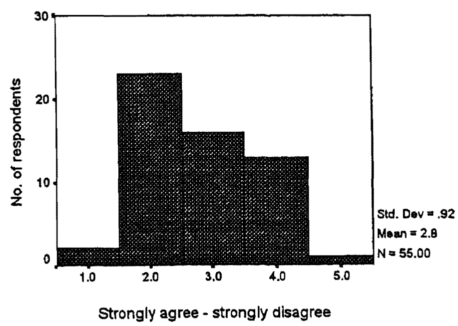
Q14 - The change required...

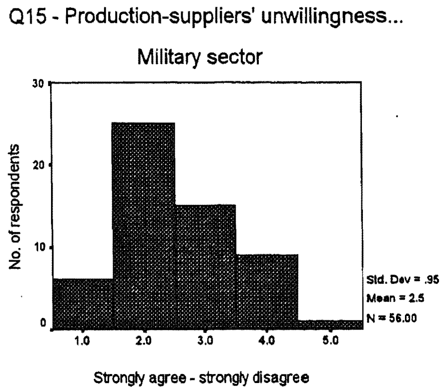
Military sector

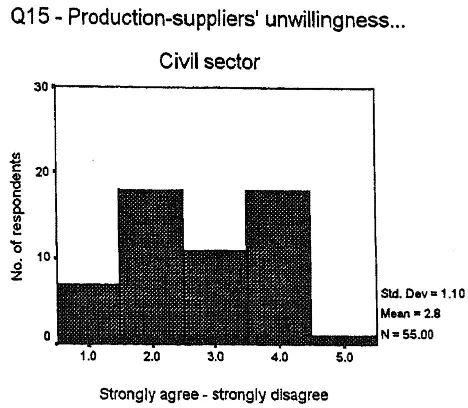


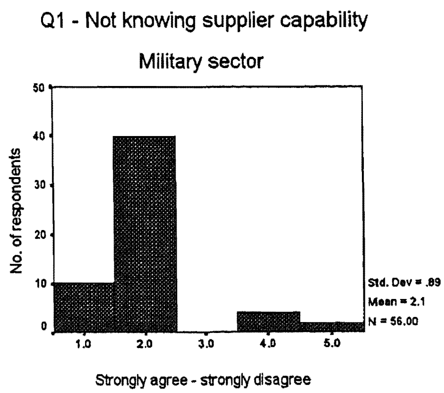
Q14 - The change required...

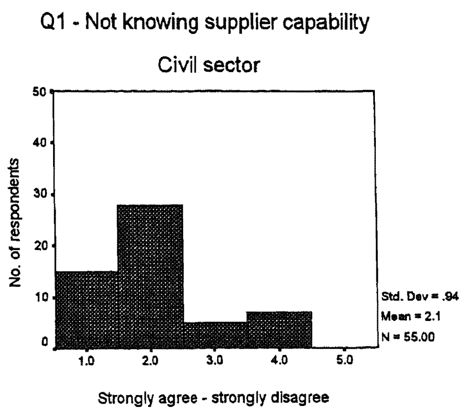
Civil sector

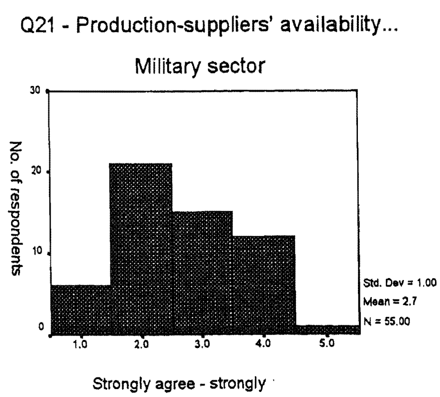


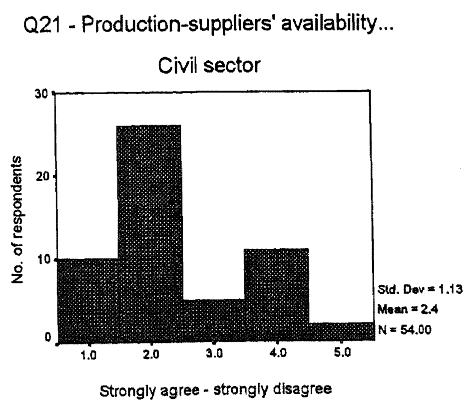

Q15 - Production-suppliers' unwillingness...
Military sector
No. of respondents
0
10
20
30
1.0
2.0
3.0
4.0
5.0
Std. Dev = .95
Mean = 2.5
N = 56.00
Strongly agree - strongly disagree


Q15 - Production-suppliers' unwillingness...
Civil sector
No. of respondents
0
10
20
30
1.0
2.0
3.0
4.0
5.0
Std. Dev = 1.10
Mean = 2.8
N = 55.00
Strongly agree - strongly disagree


Q1 - Not knowing supplier capability
Military sector
No. of respondents
0
10
20
30
40
50
1.0
2.0
3.0
4.0
5.0
Std. Dev = .89
Mean = 2.1
N = 56.00
Strongly agree - strongly disagree

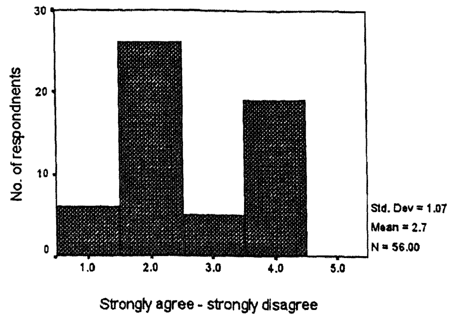

Q1 - Not knowing supplier capability
Civil sector
No. of respondents
0
10
20
30
40
50
1.0
2.0
3.0
4.0
5.0
Std. Dev = .94
Mean = 2.1
N = 55.00
Strongly agree - strongly disagree


Q21 - Production-suppliers' availability...
Military sector
No. of respondents
0
10
20
30
1.0
2.0
3.0
4.0
5.0
Std. Dev = 1.00
Mean = 2.7
N = 55.00
Strongly agree - strongly


Q21 - Production-suppliers' availability...
Civil sector
No. of respondents
0
10
20
30
1.0
2.0
3.0
4.0
5.0
Std. Dev = 1.13
Mean = 2.4
N = 54.00
Strongly agree - strongly disagree

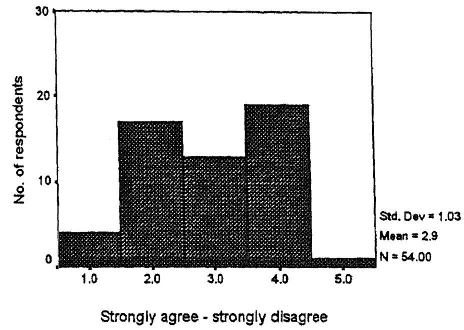
Q25 - Segregating development and production...

Military sector



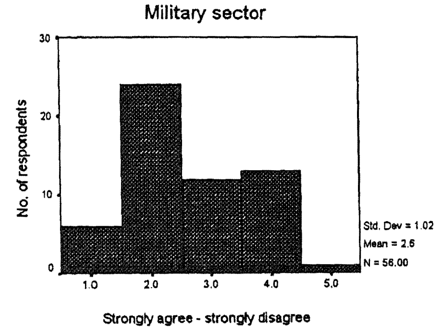
Q25 - Segregating development and production...

Civil sector



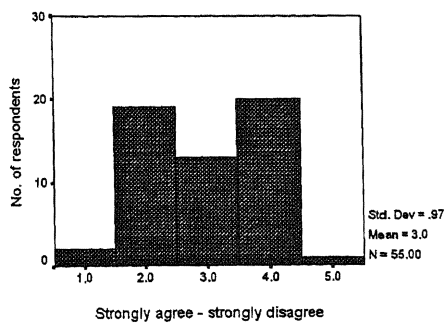
Q8 - Security considerations of my customer

Military sector



Q8 - Security considerations of my customer

Civil sector



9.6.3 Test method considerations

A chi-sqd test was used to define association between distributions however, some pairwise deletion had taken place in the data cleaning exercise and there was some likelihood that some differences could been missed. Missing data were most associated with issues 17,18,33, and 35. None of these issues showed significant difference at the 0.01 or 0.05 level and none were indicated as having any significant difference by the other test methods.

Of the nine variables identified, four were indicated as being significantly different by other test methods. Of the five remaining variables, three responses from the civil sector (8,15,25) exhibited by inspection pronounced bimodal behaviour that might indicate evidence of sector difference.

The five variables were then reviewed as to whether the combining of 'don't know' category with other categories had influenced the outcome. Of the five variables (21,1,25,15,8), only variables 21 and 25 had been determined through the incorporation of the 'don't know' category. As such, the author considers that there is weak evidence for variables 21 and 25, despite bimodal indications from the civil sector on variable 25. Table 9-10 indicates the authors confidence in the differences found between sectors. These differences are carried forward for further discussion in Chapter 10.

The comparison on variable rankings and differences between the sectors are discussed in Chapter 10.

Table 9-10 showing differences between sectors with author confidence

Key: shading indicates variable deleted due to weakness of test method

Variable	Description	Confidence	Reason
23	Our rigid milestones	Very high	K-S test, M-W test, Chi-sqd test
24	Our inappropriate milestones	Very high	M-W test, Chi-sqd test
6	The influence of other functional groups outside of my own (e.g., visibility of required information)	Very high	M-W test, Chi-sqd test
14	The change required in existing work practice / design process	Very high	M-W test, Chi-sqd test
15	Production-suppliers' unwillingness to share process know-how pre-contract	Low	Chi-sqd test (single test evidence)
1	Not knowing production-supplier capability	Low	Chi-sqd test (single test evidence)
8	Security considerations on the part of my customer	Low	Chi-sqd test (single test evidence)
21	Production-suppliers generally not available (when needed)	Low	Test method weakness (combination of categories)
25	The segregation of development and production work	Low	Test method weakness (combination of categories)

9.7 Exploratory factor analysis

Traditionally, factor analysis has been used to explore the possible underlying structure in a set of interrelated variables without imposing any preconceived structure on the outcome (Child 1990). This aim was conducive with an exploration of constraints and as such a factor analysis was undertaken to understand whether a small number of common issues could account for a pattern of correlation in issues 1-35. Factor analysis tells the author whether responses to particular issues covary because they have underlying factors in common and allows insight into whether patterns of response emerge. Although most kinds of distribution can be used in factor analysis, one needs to be cautious concerning skewed , truncated or multi-modal distributions. Visual inspection had shown some variables had a tendency towards being bi-modal. Factor analysis was therefore undertaken in the knowledge that the technique had weaknesses for these type of data. Communality of variables prior to factor analysis would need to be explored.

Once underlying factors and their loaded variables had been identified – be it tentatively - an analysis could be undertaken to compare the individual factors with the preliminary constructs of ethos. The author was particularly interested in whether a pattern would emerge to reflect the ethos constructs of CI, P, ME and O – that is – whether a priori constructs were evident.

Finally, by knowing which particular issues had shown significantly different responses between sectors, conclusions could be drawn as to the viability of the ethos constructs and as to whether, if valid, they could be used to predict sector specific constraints. The following sections describe data preparation, factor analysis and rotation in more detail.

9.7.1 Communality testing

A Kaiser-Meyer-Olkin (KMO) test was first conducted to see whether all 35 variables would be appropriate for factor testing. The KMO test evaluates a group of variables with regard to their communality. The KMO statistic (KMOs) ranges from zero to one. If this statistic yields a value higher than 0.5 then the correlations on the whole [of the variables in question] are sufficiently high to make factor analysis possible (De Vaus 1996). A value of 0.7 and above is ideal, 0.5 – 0.7 is acceptable with caution and below 0.5 indicates that the group of variables is inappropriate for factor analysis.

Initial analysis of all thirty- five variables yielded an unsatisfactory KMOs. Variables with low communality (that contributed least to the variance in the sample) were removed one by one and the KMOs recalculated [a method advised by De Vaus 1996: 263]. Thirty-five variables were reduced to twenty - five by this method: – KMO = 0.666. See Table 9-11.

A subsequent factor analysis yielded nine factors with eigenvalues greater than one. The eigenvalue is a measure that attaches to factors and indicates the amount of variance in the pool of original variables that the factor explains. The higher the value, the more variance it explains. These nine factors were carried forward for further analysis.

9.7.2 Factor analysis and rotation

Using nine factors, a rotation exercise was undertaken to see how the constraint variables loaded on each factor. See Appendix 4. Using Varimax[39] rotation a number of variables loaded on more than one factor, so, for clarity of interpretation, variables were only included on the factors for which they loaded most highly. Table 9-12 shows the rotated component matrix.

Table 9-13 shows the results of the factor analysis in terms of factors defined, the loaded variables as defined by factor rotation and the name assigned to the factor. These factor descriptions are henceforth referred to as underlying constraint groupings. In line with the author's preliminary definition of design ethos[40], Table 9-13 also provides a new list of highly tentative ethos constructs in line with the factor analysis results.

Calculating the factor scores showed the respective factor ratings. Factor scores were calculated by adding together the scores of the variables that loaded most highly on each factor. Kline (1997) has shown this method to correlate highly, in most cases, with more elaborate procedures. See Table 9-13. For purposes of this research, the factor score (although only defined in an exploratory context) could subsequently be developed as a 'constraint index' allowing practitioners to allocate resource accordingly. For example, factors 1, 2 and 4 have the highest factor scores and may require greater practitioner effort.

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[39] Rotated factors are uncorrelated and the communalities and the ability to reproduce the original correlation matrix are identical to, and therefore subject to, the same limitations of the data structure in the original factor analysis. See section 9.7.

[40] Design Ethos - The characteristic manner or approach to constraints on SIL working displayed by a design community.

Table 9-11 showing Factor Analysis using a Kaiser-Meyer-Olkin Measure of Sampling to define whether there is a significant relationship between variables[41]

(Key: () indicates the Extraction Value)

Test	Runs										
	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1
	Q2	Q2	Q2	Q2	Q2	Q2	Q2	Q2	Q2	Q2	Q2
	Q3	Q3	Q3	(.531)							
	Q4	Q4	Q4	Q4	Q4	Q4	Q4	Q4	Q4	Q4	Q4
	Q5	Q5	Q5	Q5	Q5	Q5	Q5	Q5	Q5	Q5	Q5
	Q6	Q6	Q6	Q6	Q6	Q6	Q6	Q6	Q6	Q6	Q6
	Q7	Q7	Q7	Q7	Q7	Q7	(.614)				
	Q8	Q8	Q8	Q8	Q8	Q8	Q8	Q8	Q8	Q8	Q8
	Q9	Q9	Q9	Q9	Q9	Q9	Q9	Q9	Q9	Q9	Q9
	Q10	Q10	Q10	Q10	Q10	Q10	Q10	Q10	Q10	Q10	Q10
	Q11	Q11	Q11	Q11	Q11	(.572)					
	Q12	Q12	Q12	Q12	Q12	Q12	Q12	Q12	Q12	Q12	Q12
	Q13	Q13	Q13	Q13	Q13	Q13	Q13	Q13	Q13	Q13	Q13
	Q14	Q14	Q14	Q14	Q14	Q14	Q14	Q14	Q14	Q14	Q14
	Q15	Q15	Q15	Q15	Q15	Q15	Q15	Q15	(.664)		
	Q16	Q16	(.514)								
	Q17	Q17	Q17	Q17	Q17	Q17	Q17	Q17	Q17	Q17	Q17
	Q18	Q18	Q18	Q18	Q18	Q18	Q18	Q18	Q18	Q18	Q18
	Q19	Q19	Q19	Q19	Q19	Q19	Q19	Q19	Q19	Q19	Q19

[41] Extraction method: Principal Component Analysis – variables with the lowest communality are systematically removed. KMO then indicates whether there is a relationship between the remaining variables

Test	Runs										
	Q20	Q20	Q20	Q20	Q20	Q20	Q20	Q20	Q20	Q20	Q20
	Q21	Q21	Q21	Q21	Q21	Q21	Q21	Q21	Q21	Q21	Q21
	Q22	Q22	Q22	Q22	Q22	Q22	Q22	(.648)			
	Q23	Q23	Q23	Q23	Q23	Q23	Q23	Q23	Q23	Q23	Q23
	Q24	Q24	Q24	Q24	Q24	Q24	Q24	Q24	Q24	Q24	Q24
	Q25	Q25	Q25	Q25	Q25	Q25	Q25	Q25	Q25	(.566)	
	Q26	Q26	Q26	Q26	Q26	Q26	Q26	Q26	Q26	Q26	Q26
	Q27	Q27	Q27	Q27	Q27	Q27	Q27	Q27	Q27	Q27	Q27
	Q28	Q28	Q28	Q28	Q28	Q28	Q28	Q28	Q28	Q28	Q28
	Q29	Q29	Q29	Q29	Q29	Q29	Q29	Q29	Q29	Q29	Q29
	Q30	Q30	Q30	Q30	Q30	Q30	Q30	Q30	Q30	Q30	Q30
	Q31	Q31	Q31	Q31	Q31	Q31	Q31	Q31	Q31	(.519)	
	Q32	Q32	Q32	Q32	(.576)						
	Q33	Q33	Q33	Q33	Q33	Q33	Q33	Q33	Q33	Q33	Q33
	Q34	(.491)									
	Q35	Q35	Q35	Q35	Q35	Q35	Q35	Q35	Q35	Q35	Q35
KMO[42]	.464	.600	.592	.588	.644	.629	.644	.642	.644	.645	.666 [43]

[42] Kaiser-Meyer-Olkin measure of sampling

[43] 0.7 = ideal

Table 9-12 showing Rotated Component Matrix

(Extraction method: Principal Component Analysis)
(Rotation method: Varimax with Kaiser Normalization[44])
(Key: *= Variable with highest loading on factor)

	Component								
	F1	F2	F3	F4	F5	F6	F7	F8	F9
Q1	.318		.317					.710*	
Q2								.656*	
Q4		.577*		.439					
Q5			.578*						
Q6						.798*			
Q8	.323								.745*
Q9				.782*					
Q10						.388		.656*	
Q12		.869*							
Q13		.865*							
Q14						.728*			
Q17									.699*
Q18		.503*				.335	.344		.327
Q19	.720*								
Q20	.811*								
Q21	.749*								
Q23							.821*		
Q24							.819*		
Q26	.431			.664*					
Q27			.467	.593*					
Q28					.870*				
Q29					.907*				
Q30	.737*								
Q33			.703*						
Q35			.657*				.337		
Factor Score[45]	3.017	2.799	1.938	2.478	1.777	1.526	1.64	2.022	1.444
% of variance explained[46]	20.906	8.952	7.474	6.904	6.553	6.072	5.013	4.959	4.645
% of variance explained[47]	11.910	9.372	8.338	7.987	7.141	6.816	6.775	6.689	6.450

44 Rotation converged in 15 iterations
45 Factor score calculated using Kline's method (Kline 1997)
46 Extraction Sums of Squared Loadings
47 Rotation Sums of Squared Loadings

Table 9-13 showing the results of the factor analysis

Factor (factor score)	Loaded variables	Underlying constraint grouping	Tentative revised design ethos construct
1 (3.017)	19 Production-suppliers' unwillingness to participate in design proving / testing 20 Inadequate skills amongst production-suppliers ***(Important constraint in civil sector)*** 21 Production-suppliers, generally not available (when needed) 30 Technically 'out of step' production-suppliers	Suppliers' aptitude, skill level, contracts	Exhibiting NIH
2 (2.799)	4 Restrictions on electronic communication 12 The absence of a convenient means of sharing technical information 13 The absence of a reliable means of sharing technical information 18 Cultural differences e.g., language, aptitude, business ethics	Problems with data / information exchange mechanisms	Tool impaired
3 (1.938)	33 This company's existing cosy relationship with production-suppliers (some/all) 35 The existing process for working with a production-supplier 5 Lack of management buy-in ***(Important constraint in both sectors)***	Existing processes, relationships. Management support	Process critical
4 (2.478)	9 Outstanding issues from previous dealings 26 Previous negative experience of working directly with production-suppliers ***(Low constraint in military sector)*** 27 The negative experience of colleagues ***(Low constraint in military sector)***	Supplier history	Legacy aware
5 (1.777)	28 The type of component / system being developed 29 The complexity of components being developed	Technological view of the product	Technology esteemed
6 (1.526)	6 The influence of other functional groups outside of my own (e.g., visibility of required information) ***(Important constraint in both sectors,) (significant difference between sectors)*** 14 The change required in existing work practice/design process , ***(significant difference between sectors)***	External influences on the process	Change influenced
7 (1.64)	23 Our rigid milestones ***(Low constraint in civil sector) (Significant difference between sectors)*** 24 Our inappropriate milestones ***(Low constraint in civil sector) (Significant difference between sectors)***	Existing design milestones	Milestone restricted

Factor (factor score)	Loaded variables	Underlying constraint grouping	Tentative revised design ethos construct
8 (2.022)	1 Not knowing production-supplier capability ***(Important constraint in both sectors) (Significant difference between sectors)*** 2 A production-supplier's procurement status 10 No existing process for working with production suppliers ***(Low constraint in military sector)***	Visibility of supplier capability – procurement status	Later life cycle excluded
9 (1.444)	8 Security considerations on the part of my customer ***(Low constraint in civil sector) , (significant difference between sectors)*** 17 A fear of losing core skills to outside the company ***(non-constraint in both sectors)***	Continuity of service (skill, data security)	Security centred

9.8 Cluster analysis

Child (1990) states that factor analysis often precedes cluster analysis. The author takes this to mean that factor analysis defines salient variables that can then be further analysed in terms of the systematic way in which people have responded. Cluster analysis is less sensitive to distribution type; however its outcome is considered tenuous, merely serving to broadly confirm the grouping of issues (Child 1990). This is because it is reliant upon subjective judgement [e.g., choice of cluster number] and much less on statistical analysis than factor analysis.

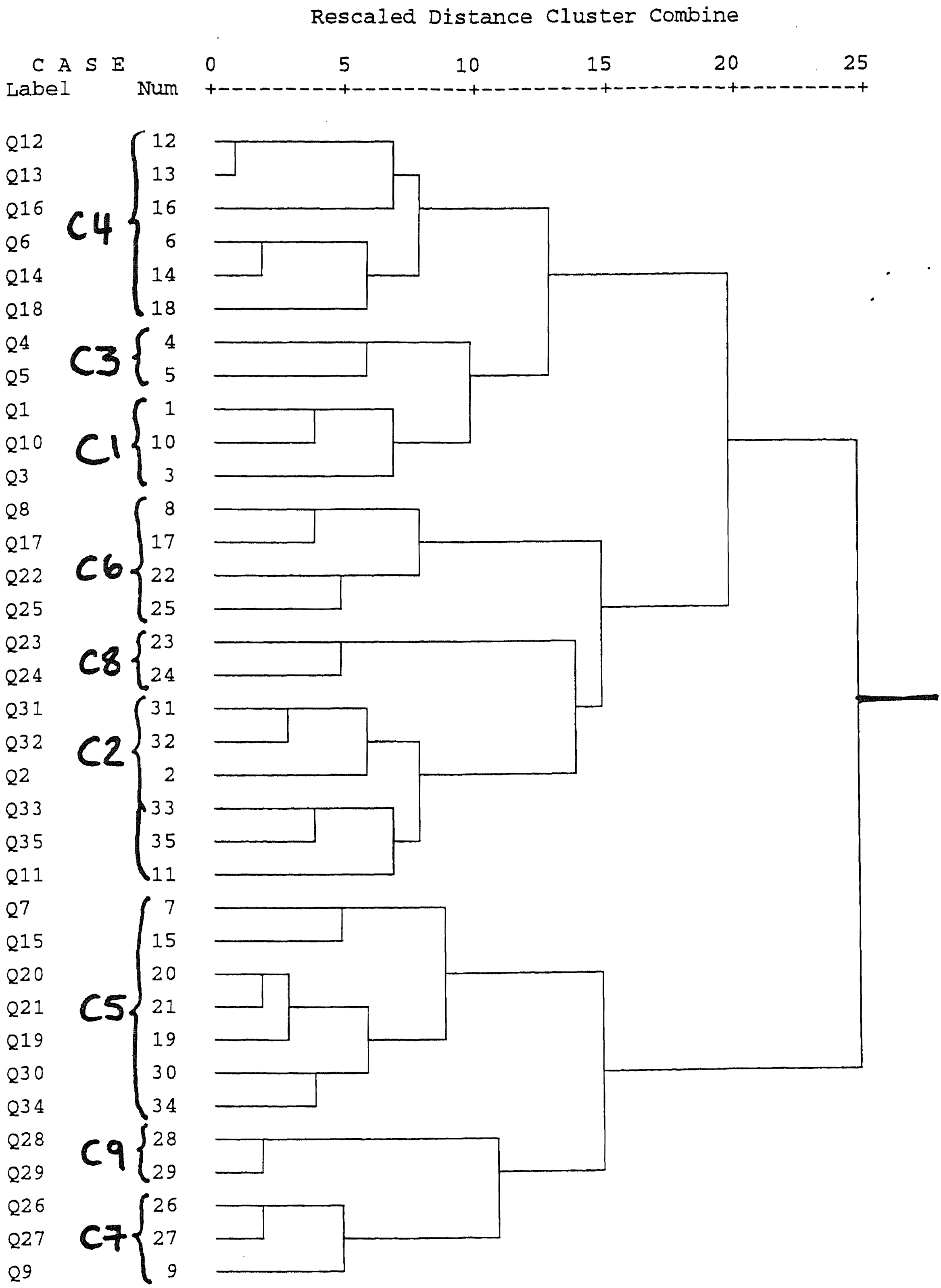
However, if we conduct a cluster analysis on all the variables and then use a techniques such as Ward's Linkage[48] to independently determine an appropriate number of clusters, the method provides the author with some confidence as to the robustness of the developed factors.

Hierarchical cluster analysis was conducted to further investigate the grouping of constraints. Initially, an arbitrary ten clusters were investigated. Ward's Linkage indicated[49] three major clusters however a number of smaller clusters were apparent. Nine clusters were chosen to provide a comparison for the factor analysis. The factor and cluster analysis largely concurred although a number of discrepancies were apparent. See Table 9-14 with dendogram.

Table 9-14 showing comparison of factors with cluster analysis

Cluster	Factor	Underlying constraint grouping
1	F8	Visibility of supplier capability – procurement status
2	F3	Existing processes, relationships, management support
3	F2, F3	Problems with data / information exchange mechanisms Existing processes, relationships, management support
4	F2	Problems with data / information exchange mechanisms
5	F1	Suppliers' aptitude, skill level, contracts
6	F9	Continuity of service (skill, data security)
7	F4	Supplier history
8	F7	Existing design milestones
9	F5	Technological view of the product
?	F6	External influences (on the process)

[48] Ward's Linkage determines cluster membership by calculating the total sum of squared deviations from the mean of the cluster. The criterion for fusion is that it should produce the smallest possible increase in the error sum of squares. In effect the group which sees the smallest increase in variance with the introduction of the case/variable will receive it.
[49] For a good cluster solution, one observes a sudden jump in the distance coefficient as one reads down the table (Agglomeration Schedule – Appendix 5). The stage before the sudden change



Dendogram illustrating Hierarchical Cluster Analysis
(Using Ward's Method)

The absence of corroboration for factor 6 (F6) and the manifestation of variables from factors 2 and 3 (F2 and F3) in different clusters may be due to either the format of the data used in the factor analysis or the sensitivity of cluster analysis to systematic responses from participants. Unfortunately further analysis was outside the scope of the research. The original factors (F1-F9) are carried forward for analysis in terms of design ethos.

9.9 Validity of ethos constructs

Factors and their loaded issues were subsequently reviewed to reflect their association with preliminary design ethos constructs. Table 9-15 shows the relationship of factors to the preliminary design ethos constructs.

Table 9-15 showing factors with their preliminary design ethos constructs and sector differences

Factor grouping	Underlying constraint grouping	Preliminary constructs of ethos	Differences between sectors
19,20,21,30	Suppliers' aptitude, skill level, contracts	O,ME,CI,	No
4,12,13,18	Problems with data / information exchange mechanisms	ME,P,CI	No
5,33,35	Existing processes, relationships, management support	O,ME,CI,P	No
9,26,27	Supplier history	CI, P,ME	No
28,29	Technological view of the product.	ME,CI	No
6,14	External influences on the process	CI,ME	Yes (Very high confidence)
23,24	Existing design milestones	P,CI	Yes (Very high confidence)

indicates the optimal stopping point for merging clsuters. In this instance a number of jumps were apparent.

Factor grouping	Underlying constraint grouping	Preliminary constructs of ethos	Differences between sectors
1,2,10	Visibility of production supplier capability – procurement status	ME,CI	Yes (High confidence)
8,17	Continuity of service (skill, data, security)	O,ME,P	Yes (High confidence)

This led to the conclusion that although the literature and case study had suggested preliminary design ethos constructs to be CI, P, ME, and O, when tested statistically, preliminary design ethos constructs alone were inappropriate for predicting SIL constraint or sector differences. No pattern of issues emerged, and the new factors were associated with a combination of the old constructs. The statistical analysis suggested that underlying issues of constraint would be better described differently as:

1. Suppliers' aptitude, skill level, contracts
2. Problems with data / information exchange mechanisms
3. Existing processes, relationships, management support
4. Supplier history
5. Technological view of the product
6. External influences on the process
7. Existing design milestones
8. Visibility of supplier capability – procurement status
9. Continuity of service (skill, data security)

A number of tentative design ethos constructs are proposed in line with these constraint groupings. These are illustrated in Figure 9-3.

9.10 Results in terms of experimental hypothesis 1

The industry sector has an effect on the views of SIL constraints (1-35), of design communities in that sector.

The responses of industrial sectors to specific issues were tested using a chi-sqd test. The value of chi-sqd was found to be significant at the 0.01 level for variables 23,21,1,4,6,25,15 and significant at the 0.05 level for 14 and 8. Kolmogorov-Smirnov testing confirmed differences in shape and location for variable 23. Mann-Whitney tests confirmed differences in location for variables 6, 14, 23, 24. Variables 21 and 25 were subsequently dropped due to weakness of the Chi-sqd test method for these variables.

Because of this, it was concluded that the proportion of participants responding in a similar way to these variables varied significantly between sectors. Therefore, H023, H01, H024, H06, H015, H014, H08 at the 0.05 level are not supported and the experimental hypothesis is supported. The significance of these findings for practitioners is discussed in chapter 10.

9.11 Results in terms of experimental hypothesis 2

> Where alternate hypothesis 1 is true for questions 1-35, differences between sectors can be explained in terms of commercial imperative and problem solving alone.
>
> **H0ethosvariation** = Where the alternate hypothesis is true for questions 1-35, differences cannot all be explained in terms of commercial imperative and problem solving issues.

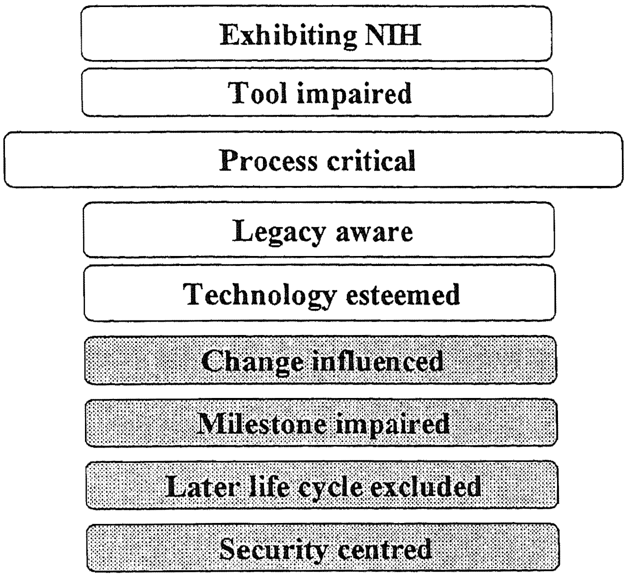


Figure 9-3 illustrating a revised design ethos framework

Key: shading indicates sector differences. NB there is high author confidence in there being differences between the sectors in 'Change influenced' and 'Milestone impaired' and low confidence in 'Later life cycle excluded' and 'Security centred'.

An exploratory factor analysis and cluster analysis was carried out on SIL issues across the sectors. The cluster analysis largely confirmed the factor analysis, although further work on a larger scale would be recommended to confirm the factors deduced.

Empirically, it would appear that the factors identified did not fit directly with the preliminary design ethos constructs. Therefore, grouping of issues to concur with the preliminary constructs was not supported suggesting that a more appropriate and complex definition of design ethos constructs in the context of SIL should be developed.

Where the results of difference testing and factor analysis were compared, it appeared that sector differences could be associated with all preliminary constructs of ethos (CI, P, ME and O) as opposed to just CI and P. See Table 9-15. This does not support the literature findings. It would appear that mind's eye and organisational issues also play a part in the differences between sectors. Empirically therefore, the experimental hypothesis 2 is rejected and the null hypothesis is accepted.

The significance of these findings for practitioners is discussed in chapter 10.

9.12 Conclusion

In conclusion, many of the SIL constraints tested do not show significant difference between sectors indicating that sectors largely face the same issues when attempting to implement SIL. This has important implications for cross-sectoral learning and is discussed in this context in Chapter 10.

There is however some evidence to suggest significant difference between sectors in 8 out of 35 of the SIL constraints ($p<0.05$). Based on the framework proposed, these issues are not solely associated with the constructs of commercial imperative and problem solving as the literature would suggest but are associated with wider proposed constructs. This finding is carried forward for discussion in

Chapter 10. Based on the findings from the factor analysis, a more appropriate framework for design ethos in a SIL context is proposed. See Figure 9-3.

The influence of functional experience on a pre-disposition to SIL working cannot however be discounted. Functional organisation within companies is largely driven by business targets, and as such, military companies may well skill people differently to civil companies. The original framework for design ethos does however, go some way towards accommodating this in the form of how certain functional roles could view the commercial imperative and how functional groups construct and solve problems based on the explicit and tacit knowledge gained over time. The discontinuity between the samples in terms of functional experience cannot be discounted as a causal factor in the research outcome. For this reason, further work is needed to understand the differences between the procurement role in the military sector and the component engineering role in the civil sector; however, this is outside the scope of this research in terms of funding and access. The possibility remains that there is a likelihood that the two sectors simply have different skill mixes for their personnel who are employed in a design-related, supplier-facing role. Alternatively, the two functional descriptions may well share some characteristics in different industry sectors.

A reliability test across sectors using issue 8 yielded a positive result. The responses to issue 8 were anticipated, although a split of answers in the civil sector did suggest some other factor, e. g. an alternative interpretation of the question. Nonetheless, the indication by a large number of participants that this was not a constraint gave some confidence as to the reliability of the instrument.

9.13 Summary

This chapter has explored constraints on SIL working as perceived by two separate design communities. It describes differences and similarities between sectors based on the statistical analysis of questionnaire responses.

Statistical data are summarised in Appendices 2-5 and Tables 9-1, 9-3 – 9-14. This chapter concludes that different sectors are largely constrained by the same issues when implementing SIL however, there is some evidence to suggest significant variation between sectors in eight out of thirty five of the constraints tested, a summary of which can be found in Table 9-10.

Furthermore, underlying groupings of constraint are identified (Tables 9-11 and 9-13) which can be described in terms of a characteristic manner and approach. This is tentatively interpreted as evidence of design ethos. A revised design ethos framework is provided in Figure 9-3.

10 Conclusion and discussion

10.1 Introduction

This chapter concludes the thesis with a summary of the findings and implications for practitioners. Research methods and conclusions are critically analysed for rigour and alternative explanation. Limitations of the study and areas requiring further research are clearly stated. Finally, the contribution to knowledge is outlined.

The research findings fall into four categories. These categories are the following:

- The determinants of good SIL practice based on an extensive literature study;
- The characterisation of a military design community based largely on an in-depth case study;
- Possible differences between military and civil design communities based on a statistical analysis of what each community views to be SIL constraints; and,
- Implications for practitioners based on the previous outcomes.

The author postulated, design communities in the military and civil sectors have associated with them different design ethos. The research evidence supports this. The author suggests that this difference needs to be acknowledged when attempting to implement SIL. This difference may also have wider significance for change managers who are attempting to implement change programmes with design communities in the military and civil sectors.

10.2 The research methodology : its value in exploring SIL

The mixed-method employed (literature study, case study and questionnaire) allowed the author to acquire and test complementary data on SIL issues. The exploration of ethos in the design context required qualitative information on SIL constraint. The comparison of sectors required quantitative analysis. Although each method was inherently susceptible to problems of internal and external validity, in combination, they provided the research with the qualitative and quantitative information required. Further, each method compensated for the weaknesses of the previous method. For instance, the questionnaire remedied the literature's weakness in cross sector comparisons. The case study gave enormous insight into one company but required supplementary knowledge from the literature to understand whether the observed constraints were revelatory.

In this instance the qualitative data sources (case study and literature) informed the questionnaire. The addition of a comments-box on the questionnaire supplemented the quantitative results and served to elucidate the supplier-working experience in qualitative terms.

The action research approach in the case study, combined with the comments received from the questionnaire provided significant insight for the author beyond that available from the current literature. This was used to interpret the factor analysis and formulate the revised design ethos framework.

Further, a number of constraints identified through the military case study were shown to be equally applicable in the civil sector. These case-derived constraints provided new knowledge outside of that currently reported in the literature. This suggests that a number of issues may find wider applicability in other sectors.

In summary, the mixed method employed proved entirely appropriate for research of this type.

10.3 Determinants of good SIL practice

Based on the literature survey, determinants of good SIL practice are restated in Table 10-1 (Table 5-2 repeated). Table 10-1 is a summary of all determinants identified from the literature. It is a broad description embracing issues identified in academic and non-academic literature.

These determinants of good SIL are later discussed in the context of implications for practitioners.

Table 10-1 showing determinants of good SIL

Determinants of good SIL
• Agreed metrics, objectives, rules of conduct, risks and rewards • Shared technology path and knowledge of technical capabilities • Compatible IT (design to manufacture) • Open, frequent communications • Efficient delivery system, secure data transfer • A long term relationship, previous relationship, trust, non-adversarial based procurement approach • Individual control of proprietary information • Formal plan and structure, management support, clear roles and responsibilities, stability of staff, no discontinuities between internal departments – all bought in • Design control, common 2D/3D capability, common understanding of the complex nature of the design, the design's fluid nature and the ambiguity of the design process and work practice, supplier involved in decision making • A common technical language • Overcome NIH, willing to change/evolve culture to incorporate other work methods • Appropriate co-location • No client constraints • Business need, e. g. restructure, down size, cost and time savings required

10.4 The character of a military design community

Constraints to SIL are those issues identified in the literature and case study that prevent SIL or make SIL very difficult. By comparing the constraints to SIL identified in the literature and those observed during the case study it was possible to identify which constraints were common. Constraints identified during the case study that were absent from the literature survey were grouped by the author into common areas. These areas are henceforth termed 'military characteristics', and serve to provide insight into a military design ethos. These characteristics are outlined in Figure 10-1. Chapter 7 describes their derivation. These characteristics are later interpreted in the context of differences between sectors and in terms of external validity with other companies in the defence sector.

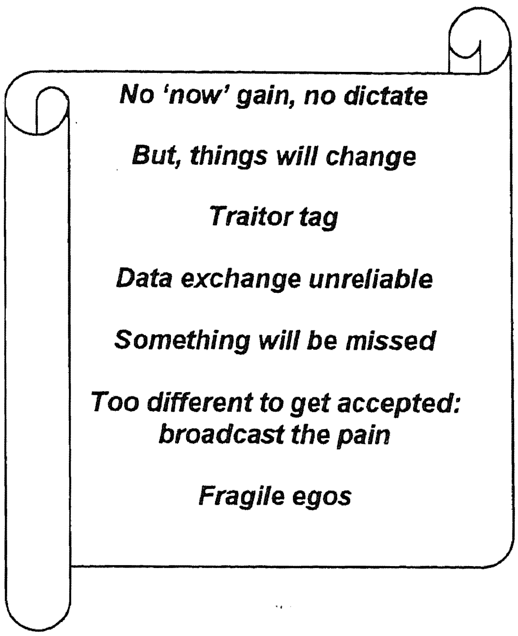


Figure 10-1 illustrating case study derived military characteristics

10.4.1 The revised design ethos framework - critical evaluation

Statistical testing of questionnaire responses suggested the preliminary design ethos constructs of problem solving[50], mind's eye[51], commercial imperative[52] and organisational factors, were inappropriate in the context of predicting key factors that affected SIL implementation. This decision was heavily based on how the original constructs of ethos were assigned to each constraint. A revised design ethos framework is therefore proposed. See Figure 9-3.

[50] Problem Solving - Past experience of problem solving, past experience of defining problems and the need for problem specific information and a shared technical language.
[51] Mind's Eye - Visual culture issues – design representation, appreciation of design intent, managing internally and externally derived change.

Based on the high response to the questionnaire and the fact that thirty- four of the thirty-five issues were identified as constraints by both sectors, the author believes that the revised design ethos framework describes the underlying factors that dictate constraint when implementing SIL in the two sectors.

10.4.2 Evaluation of the military character against the revised design ethos framework

The characterisation of the military design community was based on an in-depth case study with one OEM and addressed how that company interfaced with its suppliers mostly, but not exclusively, in a mechanical design context. This characterisation is now analysed with respect to the revised design ethos framework to see whether the new constructs of design ethos are recognisable. Analysis has been conducted by combining Figure 10-1 and Figure 9-3. Figure 10-2 illustrates the results of this analysis.

The conclusion from this exercise was that the characterisation of the military design community showed a high degree of conformance with the new design ethos constructs.

A number of the characteristics observed related to the constraint grouping – **existing processes, skills and relationships**. This related to the design ethos

[52] Commercial Imperative - Managing fit for purpose, how the group manages business change and how it deals with other groups

construct – **process critical**. The matching of the design community character in this way allows those tasked with implementing SIL to focus effort in this area.

The characteristics which may be subject to sectoral difference are – **'broadcast the pain', 'something will be missed' and 'but things will change'**. These relate to the design ethos constructs of – **change influenced, milestone impaired, later life cycle excluded and security centred**. Implications for practitioners are considered later.

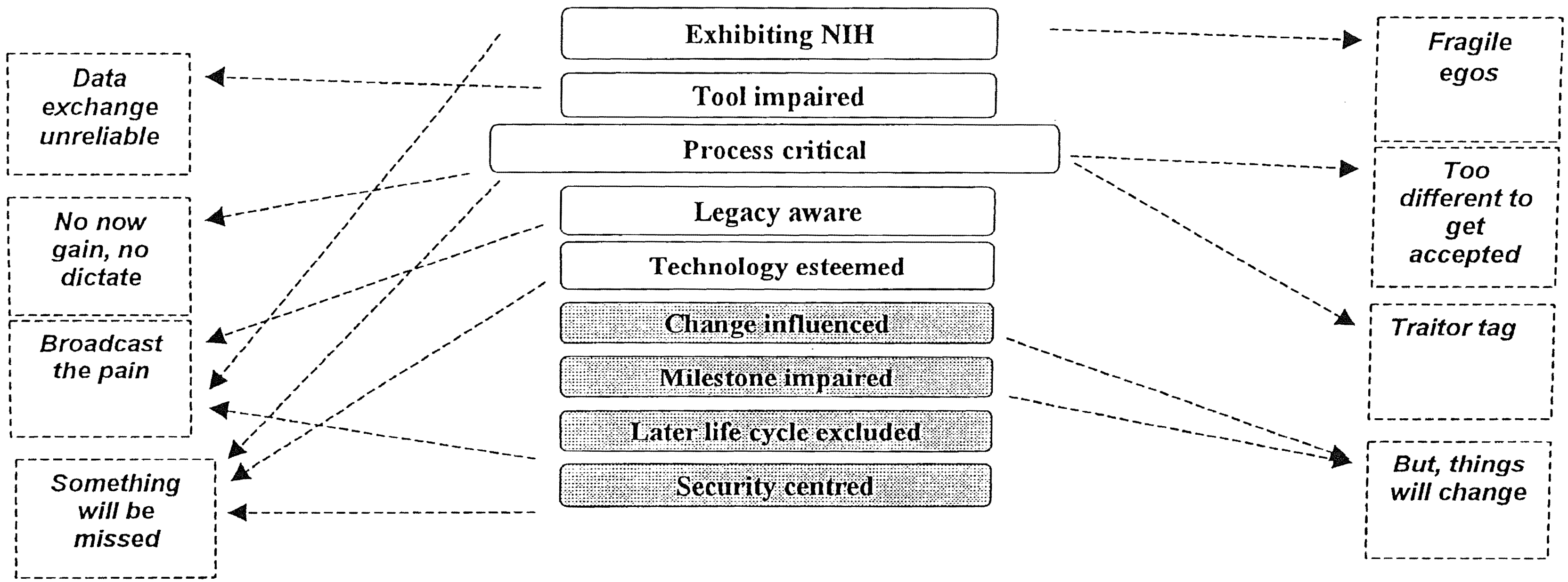


Figure 10-2 illustrating the evaluation of the military characterization

Key: shading indicates sector differences.

10.5 Towards an implementation model

Common important constraints for both sectors related to not knowing production supplier capability, lack of management buy-in and imposed/enforced production-suppliers. These constraints, which are taken directly from the research questionnaire, are now described:

Not knowing supplier capability is an issue currently enjoying industrial interest and is manifested in the following subject areas: supplier development, capability assessment and extranet development using electronic data interchange in a business to business (B2B) environment (Mecham 2000). This finding serves to reiterate the importance of this issue for future ongoing research. Differences between sectors, and their relevance, are discussed later.

Lack of management buy-in may be dependent upon the level of management that is seen as being bought into the process. A recent article by Swink (2000) suggests that high levels of top management support are less important for new product design integration in high technology innovative environments. The case study observations would suggest that it is important that there is buy-in from superiors within the design community. This is an important finding and adds to the body of existing knowledge.

Enforced / imposed production suppliers remains an important constraint to both sectors implying the need for some degree of history and therefore trust with a supplier. This is consistent with the case study; however, the circumstance under which a supplier is enforced deserves clarification. Suppliers may be imposed by other functions or by external clients. These two aspects of SIL constraint are discussed later.

Interestingly, **the requirement for three quotes** was considered a weak constraint in both sectors. This suggests a general OEM view that competition remains an important part of a customer-supplier relationship even in a close working environment. This finding reinforces the view that some form of competition is considered essential in all supplier transactions independent of supplier status. The implication of competition serves many purposes, even if one particular supplier is favoured prior to the process. Apart from satisfying any legal competition requirements, going through the 'three quote' process to find either a single source or select dual sources can provide backup resource, avoid complacency on the part of single source suppliers and protects a buyer when the rate of technological change is uncertain or unpredictable (Dowlatshahi 1999). There may be an assumption that commercial competition would always be a pre-requisite to such a relationship and therefore is not considered an important constraint, more a forgone conclusion. This finding could well have been contradicted had supplier's views been included in the questionnaire.

A fear of losing core skills to outside the company, was indicated to not be a constraint in either sector. This was an interesting finding as the case study and more recently the literature (McIvor and McHugh 2000) had led the author to expect this to be a constraint in both sectors.

The prospect of SIL representing some kind of a threat did not appear to be an issue for the majority of participants. This may have been for a number of reasons:

- A belief that SIL would only be initiated for non-core skills
- An acceptance that core skills would perhaps be lost, but participants felt helpless to affect this and so did not feel constrained in how they worked closely with suppliers.
- 'Core skills' may have different interpretations; however, this was not indicated in pilot testing.
- This particular constraint from the literature may well be invalid in these sectors, or with this unit of analysis i.e., UK – based. Companies in the aerospace defence and automotive sectors may be different in viewing this issue this way.

This finding was inconsistent with the existing literature but adds to the body of knowledge in that it may well be revelatory reflecting the particular business dynamics of the companies in question.

10.6 Sector differences

Using Chi-sqd, Kolmogorov-Smirnov and Mann-Whitney tests, views on SIL constraint were compared between the civil and military sectors. Statistically significant differences between sectors related to: rigid and inappropriate project milestones; not knowing supplier capability; the influence of other functional groups; the change required to existing processes; suppliers unwilling to share process knowledge; and security considerations on the part of the customer.

The difference in the issue of **rigid and inappropriate milestones** is perhaps rooted in the fundamental differences between design processes and market lead-time requirements between the sectors. It would seem that in the civil sector milestone issues are not seen as a constraint to working closely with suppliers. This may be because of there being established processes for this way of working or that rigid milestones were some how considered irrelevant to this type of interaction.

In the military sector rigid and inappropriate milestones are seen as a constraint. This may be for a number of reasons. In the military sector, there was very little evidence of early design milestones at the component level accommodating supplier involvement. Design milestones were set early in projects and design and manufacture were clearly differentiated. The involvement of suppliers in design build teams is a relatively recent initiative in the military sector. Suppliers were invited to be involved early to contribute financial forecasts, provide production knowledge and insight into potential show stoppers.

Not knowing production supplier capability was indicated as an important constraint in both sectors, but drew significantly different (chi-sqd only) responses from both sectors, indicating that the two sectors viewed the issue differently. This may have been because the sectors required a different level of supplier capability, or perceived visibility of that capability, or access to the information, in a different way. The author however retains low confidence in this difference due to only one test method having indicated this. If this difference is real, it is however an important finding and requires further investigation to verify and understand the sector difference. It could perhaps have implications for existing researchers attempting to move best practice between sectors.

A higher proportion of participants in the military sector than in the civil sector believed - **The influence of other functional groups outside of my own** – to be a constraint. This may reflect some kind of underlying factor such as the civil sector's wider / longer experience of integrated design teams (IDTs). If IDTs are successful and all functions that are usually an encumbrance are bought-in to the process, then a team approach should preside. This being the case, one might expect functions within a design community to have perceived their own status in

SIL decisions to be equal to that of the others. This would have led participants to respond that they did not feel that other functional groups constrained SIL.

This was not evidenced by the results. The civil sector also indicated that 'other functional groups' were still a constraint. Supplementary comments made with questionnaire responses re-enforced this view. Procurement and finance functions were singled out for particular criticism. This perhaps suggests that IDTs are perhaps not working effectively, functions external to the IDTs retain influence, or that some other factors are at play. The stronger response from the military sector perhaps indicates that this is a larger constraint in this sector than in the civil sector.

The change required in existing work practice showed significant difference largely due to there being a higher proportion in disagreement in the civil sector than in the military sector. This would suggest that the civil sector was perhaps more familiar with changes to working practice.

Production-suppliers' unwilling to share process know-how pre-contract showed significant difference between sectors largely due to there being a higher proportion in disagreement in the civil sector than in the military sector. This is perhaps due to the weaker position of suppliers in an increasing competitive civil market and OEMs' willingness to change suppliers for commercial reasons alone.

Also, experimentation with facilitating commercial contracts such as Ford's use of Early Supplier Involvement agreements (Ford 1997) may have to some degree negated this issue as a constraint. Early supplier involvement agreements in the Ford context have the purpose of identifying two or more suppliers to work with program teams to develop design intent. The agreements clearly set out the commitment and exit criteria for both parties. Under such agreements, confidentiality is implied in line with existing guidelines between the two companies. Such contracts are relatively new to the military sector, e.g., BAe's collaboration agreement, where the parties agree to royalty free use of existing intellectual property of the parties necessary for the purpose of preparing proposals for the MOD (BAe 1998).

10.7 Discussion

In order to understand these sector differences in context, it is necessary to explore whether these issues in isolation explain the lethargy to embrace SIL in the military sector or whether there are other explanations for why certain businesses are slower than others to embrace certain paradigms. This section discusses other possible causes for differences between sectors.

Hierarchy of officialdom - The author has proposed the idea of design ethos as an explanation for the lethargy to embrace SIL in the military sector. If we consider a large defence company as a bureaucracy, another explanation might be that proffered by Belbin (1996). Belbin believes that inertness [not unlike lethargy to embrace new paradigms] lies in 'the number of tiers that characterise the hierarchy of officialdom'. He equates this to the Field Marshall Haig phenomenon. Plainly, initiatives are planned at the top, tactics and instructions are passed down, but eventually peter out usually at great cost and by implication little benefit. If this were the case, then how is it that other large companies spawn, are quick to embrace, and have success with initiatives like SIL? Some authors have attempted to come up with factors that differentiate success and failure. Monczka et al. (1997) identify, among other factors, the following:

- A high level of management support for the integration effort in both the buying company and supplier's organisation'; and,
- A high degree of clarity in both the buying company and the supplier's organisation regarding the roles and responsibilities of each organisations personnel in the project'.

These factors in combination directly oppose a 'hierarchy of officialdom' implying a need for clear instruction at a high level combined with the effective dissemination of support for SIL at lower levels.

A practical case of this is reported by Lei et al. (1999) within a large company in the oil industry. It describes how in combination with an emphasis on core competency and development of new strategy, a new CEO acted to eliminate layers of management that were considered to have choked decision making and strangled initiative. The findings of Liker et al. (1999) are perhaps further evidence that 'tall hierarchies' impact design – manufacturing integration.

Hierarchies of officialdom may explain some lethargy to embrace SIL; however, one could argue that large OEMs in either sector may be bureaucratic, nonetheless differences remain.

Business urgency - Another possible explanation for this lethargy is business urgency. By this the author refers to the urgency with which a customer requires to see improvement and thus the reverence given to the issue by academics, consultants and by businesses themselves. To illustrate this, the following quote was taken from a questionnaire participant in the military sector:

> Have the process, know what needs to be done, problem is the business readily resources recovery activities but not preventative. Current example to highlight the point, prevention based resource vs recovery ratio is 1:26. Will be on an uphill battle until the penny finally drops.

If customers where to require closer working in set time scales in the military supply chain then the priority to introduce SIL would change. Similarly, the adoption or trial of a new business practice may also be based on its relevance to 'in vogue' subjects elsewhere, e.g., professional organisations such as IEEE, IMechEng or CIPS, and trade organisations like SBAC and IFPMM.

It can however be argued that companies in both civil and military sectors are subject to these influences, and that this in isolation does not explain the differences described in this research.

Differences in business dynamic and business archetype - Based on this research, the author believes that the ethos' of design communities can be differentiated and that once understood can be used positively to support the introduction of new business practice independent of business urgency. It is also the author's view that the design ethos of a design community is symptomatic of a company's business dynamic and business archetype. Business dynamic [the author's description] can be characterised by a company's relationship maturity with its suppliers (Macbeth and Ferguson 1994) and its business archetype which can be described as lean, self-empowered or project orientated (Tranfield 1999a). Business dynamic and business archetype also determine the attitudes and interests of the group. For example, a project orientated group with a partnering type relationship with its suppliers may readily accept a supplier joining its design group. Conversely, a lean orientated group that has adversarial relationships with suppliers may not be accepting of the same change.

During the case study the project team were assessed as being of a transitional business dynamic and of a business archetype that was split between self-empowered and project-orientated. Table 10-2 compares the civil and military sectors.

Table 10-2 showing a comparison of sector characteristics

Sector	Business dynamic	Business archetype
Military (aerospace defence)	Transitional	Self-empowered / project-orientated
Civil (automotive)	Adversarial-transitional-partnering	Project orientated ->Lean

One could ask:

If two companies, one from either sector, had the same business archetype and business dynamic, would they share the same ethos?

This research suggests that ethos, while unarguably affected by both dynamic (relationship maturity with suppliers) and archetype (lean, self-empowered, project-orientated) is also affected by legacy issues (processes, skills, resource), current customer constraints and the proximate change required of individuals and of the group, in this case the design community.

Differences found between sectors are in the areas of: external influences on process; existing design milestones; visibility of supplier capability; and continuity of service. In moving from one business state (archetype and dynamic) to another, the view of suppliers and visibility of supplier capability may well be affected, but differences in design milestones and continuity of service issues remain, because of the fundamental differences between customers and the type of product being produced.

In conclusion, business dynamic and business archetype may affect the ethos exhibited, but will not affect there being a difference in ethos between the sectors.

10.8 Implications for practitioners

The research has implications for practitioners. In particular the determinants of good SIL, the differences and similarities between the sectors, and the framework for design ethos.

Determinants of good SIL were derived from the literature. See Table 10-1. When considering involving suppliers in design processes, companies should consider these issues early. This will allow the task to be scoped and the SIL route to be considered as a viable management option.

Many aspects of the business will be affected. Ragatz et al. (1997) describe these types of issues as being managerial or environmental. They found that where SIL had been successful, specific management and environmental issues were found to differentiate the most and least successful efforts. These issues were then prioritised. By mapping the author's SIL determinants to the work of Ragatz et al., practitioners are provided with a prioritised list of SIL determinants that can be used to scope the SIL task. See Table 10-3.

Not knowing supplier capability and the influence of other functional groups remain important constraints in each sector as well as showing significant differences in response between the sectors. The author however has more confidence in the latter constraint than the former because of confirmatory statistical testing.

The differences between the sectors suggests that cross sectoral learning may be inappropriate and that research effort is needed to understand the issues at play in each sector as well as validate the differences found especially in the area of 'not knowing supplier capability'. See Figure 10-3 and Table 10-4.

Design communities nonetheless require knowledge of supplier capability. This might be achieved by direct contact with suppliers and their capabilities and also through appropriate information systems. The assessment of supplier capability is an area that will require input from the entire design community and should not be limited to isolated functions.

Knowledge of supplier capability requires a mechanism for communicating supplier capability data. It infers that the OEM wishes to understand the suppliers capability in terms of processing knowledge, as well as how a supplier can

Table 10-3 showing prioritized list of SIL determinants

Supplier involved in decision making, design control, common 2D/3D capability, common understanding of the complex nature of the design, the design's fluid nature and the ambiguity of the design process and work practice
Business need, e. g. restructure, down size, cost and time savings required
Formal plan and structure, management support, clear roles and responsibilities, stability of staff, no discontinuities between internal departments – all bought in
Open, frequent communications
Efficient delivery system, secure data transfer
A common technical language
Overcome NIH, willing to change/evolve culture to incorporate other work methods
A long term relationship, previous relationship, trust, non-adversarial based procurement Approach
No client constraints
Compatible IT (design to manufacture)
Appropriate co-location
Shared technology path and knowledge of technical capabilities
Agreed metrics, objectives, rules of conduct, risks and reward
Individual control of proprietary information

contribute to close working. This last point is a mind's eye issue because it is expectant of an ability to interpret design intent, understand design representation and manage change.

Possible sectoral differences in this area are important. If the differences are real and are associated with the effective communication of supplier capability information within the OEM or the accurate capture of supplier process capability, best practice can be sought. However, if the difference is due to the mind's eye issues, this is potentially a more difficult task because of the origins of mind's eye issues, See Figure 5-6. e.g. , requiring a common education in terms of engineering values.

The ability to communicate design intent and manage internally and externally derived change will no doubt become a differentiator in any competitive market. This is even more concerning when one considers the variety introduced into an already complex activity when companies expand on a global stage. Every effort should therefore be made to achieve best practice within one's own sector in terms of training design community personnel and suppliers and also in the adoption of appropriate standards.

The similarities between the sectors suggest that cross sectoral learning may be appropriate in the sense that sharing of best practice may be benficial. Once more, where constraints are considered highly important across sectors there may be a need for basic research to solve the widely perceived problem. See Figure 10-3 and Table 10-4.

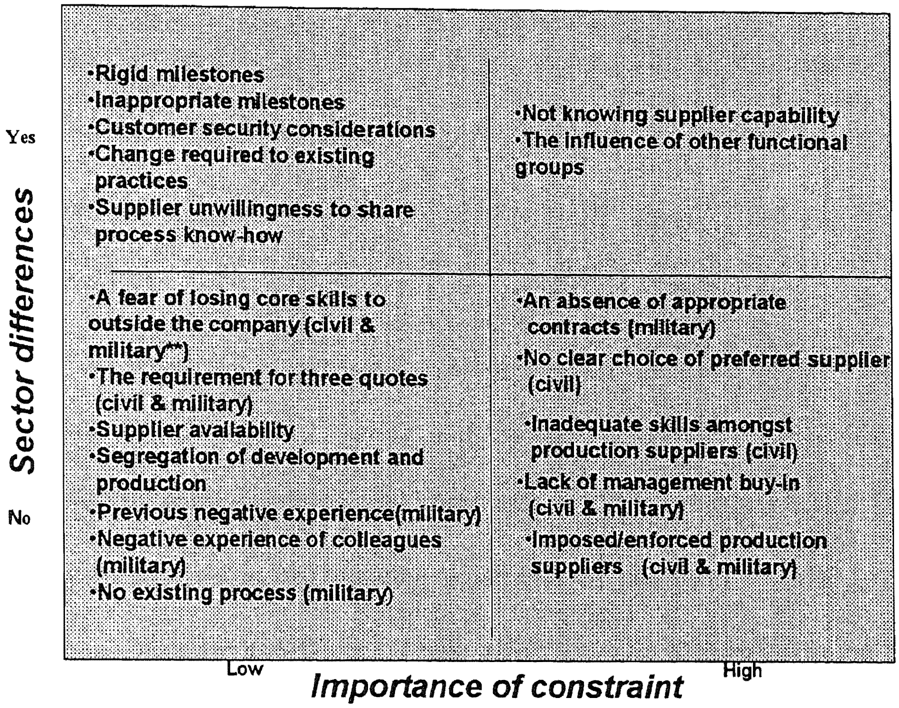


Figure 10-3 illustrating a roadmap for targeted research

Key : ** indicates issue is not a constraint

Table 10-4 showing implementation tasks

Model category	Implication	Practitioner tasks
Sector differences Important constraint	Different issues for each sector. Cross sectoral learning inappropriate	Understand issues and requirements within each sector. Look for / develop best practice within sectors
Sector differences Unimportant constraint	Different issues for each sector. Cross sectoral learning inappropriate	Understand issues and requirements within each sector. Look for / develop best practice that suits
No sector differences Unimportant constraint	Same issues in each sector.	Cross sectoral learning where appropriate
No sector differences Important constraint	Same issues in each sector. Cross sectoral learning appropriate	Very important for fundamental research. Cross sectoral learning where appropriate

The military sector sees the influence of other functional groups and an absence of appropriate contracts to be major constraints although this may have been overcome to some degree in the civil sector. Alternatively, through experience, other issues in the civil sector may have simply taken precedence. The civil sector, however, listed 'no clear choice of preferred production supplier at the development stage' and 'inadequate skills amongst production-suppliers' as top constraints.

This author considers these findings to be time-line dependent. She believes that the civil sector has moved through contract issues and problems with functional groups only to find more pressing problems in the form of timely supplier selection and supplier capability. These issues are still constraints in both sectors however, indicating that although the civil sector may be further ahead in dealing with these problems they are by no means resolved. Particular problems remain with functions that remain external to IDTs.

> Designer demanding to use an unsuitable component or supplier. Designs left or delayed until too late before making appropriate selections [civil sector quote]

> Generally working with suppliers although creates problems the biggest problems/constraints are internal – Finance & Purchasing Departments who have little or no concept of being at the sharp end of both production and maintenance day to day hour to hour needs. This can mean the supplier is working on good will and trust that an order number for the work will be forthcoming [military sector quote]

> Buyer placing orders (long term) with suppliers without consulting engineering and then leaving us to engineer it.
>
> Buyer too close to supplier and sympathises with them.
>
> Buyer will not talk to us. [civil sector quote]

Lack of management buy-in and enforced production suppliers remain important constraints in both sectors. These items need to be prioritised as fundamental issues in both sectors and are candidates for further research

The design community needs to feel comfortable that management has bought in to its SIL efforts. The literature would suggest that this needs to be clearly demonstrated and that no scope should be left for mixed messages. For example, a powerful manager who espouses a positive company position on SIL, but is then observed taking action which opposes it, e.g., advocating internal suppliers as opposed to external, or obviating agreements with SIL suppliers, will be a major constraining influence on personnel.

The prospect of enforced/imposed suppliers remaining a source of constraint is very real. This can be dealt with at two levels. Where suppliers of a particular commodity are likely to be enforced/imposed on a design community, for reasons of political offset or work- share, this should be made clear to the design community and to the supplier. In this instance, SIL is perhaps inappropriate.

Cost based supplier selection is no longer an appropriate practice in isolation and this research has shown examples where this has become a source of resentment between functions within a company – primarily between procurement and design.

> … Purchasing will sometimes switch to another supplier late in the programme to one who cannot supply to the design as released – we wonder why ? This makes relationships with this size of company quite difficult. [civil sector quote]

> The main problem with the way manufacturers were chosen on [named project] was the early choices were driven by cost, not good. The later choices were driven by work-share even worse. Engineering took a back seat and logic did not apply. [military sector quote]

> … Customer expectations of the way we should work constrain the ways suppliers approach MOD contracts.[military sector quote]

Supplier selection must address the total value of a supplier to the company. No single function has the skill or company insight to decide this. Where suppliers are forced onto a design community for commercial reasons, when consensus is that another supplier is more suitable, personnel should be equipped to make the case in each area. Sophisticated supplier selection and supplier development systems are now in development. Too often these systems are 'owned' by single functions. Such decisions are necessarily multi-functional. Therefore, all functions in the design community should be able to contribute to the decision based on their own experience of particular suppliers. Perceptions of 'enforced/imposed' suppliers will only be laid to rest when this happens.

Imposed / enforced production-suppliers may well be insurmountable if suppliers are required by clients. However, if suppliers are imposed on a design community by external functions then steps can be taken to reach consensus on the decision. For example, supplier selection processes that include cross-functional views may well quell the notion of internally imposed suppliers. Such a forum will allow the total cost of a supply decision to be debated as opposed to piece part costs alone. Where it is necessary to impose a supplier for other reasons, those reasons can be shared, so preventing internal notions of cronyism.

10.8.1 Sector differences in terms of mind's eye issues

Differences between sectors are describable in terms of problem solving, commercial imperative, mind's eye, and organisational factors. The literature had suggested that differences would only be related to problem solving and commercial imperative. Difference in organisational factors is not surprising, however, the difference in mind's eye issues is. This implies that within this unit of analysis (design communities in UK-located, OEMs serving the military and civil sectors) mind's eye issues are inconsistent. One would have expected mind's eye issues to be consistent because of common academic and professional training and equitable access to IT tools. Possible reasons for difference in mind's eye issues are:

- The increasingly international skill mix due to company collaboration, joint venture and a widening client base. This may have introduced alternative approaches to communicating design intent, by introducing new TFGs and norms.
- Individual company support for in-house and off-site training programmes may have introduced disparity that manifests itself in differences in the ability to communicate design intent and manage change effectively.
- Progress with the adoption of standards in design practice in certain sectors, particularly for 3D design. This may have reduced the scope for variety in communicating and interpreting design intent in particular sectors by standardising the design approach.
- Fundamental differences in CI issues may influence the importance bestowed on ME issues in each sector. For instance, a company striving for engineering excellence as opposed to designing to cost may well put less emphasis on an ability to communicate design intent, while emphasising designer freedom in the interest of engineering excellence.

These reasons, in isolation or in combination will affect the expectation on supplier capability and the degree to which current work practice will need to change to accommodate SIL.

This conclusion has possible implications for how managers in different sectors choose and train their engineers, as well as how IT systems and standards are adopted in support of cross company working.

10.8.2 SIL showstoppers

The design ethos framework combined with the sector difference analysis suggests that there are differences between sectors in the areas of continuity of service; existing design milestones; visibility of supplier capability – procurement status and external influences on the process. The author suggests that while the first two factors may be showstoppers for SIL, the latter two can be addressed through cross sectoral learning and academic and professional training throughout the supply chain.

The author further suggests that continuity of service and existing design milestones such as defined product introduction cycles and data security requirements must be questioned in the light of changing technology and the cost and innovation advantages that can be achieved through SIL. For instance, in the military sector, the MOD has recently reviewed its own product introduction milestones. Why then, should rigid and inappropriate milestones further down the supply chain remain a constraint to supplier interface efficiencies? Surely, these constraints should be open to review. The civil sector considers rigid and inappropriate milestones a low constraint. This is perhaps a key area where the military sector would really benefit from cross sectoral learning.

10.8.3 The new design ethos framework as a SIL tool

The literature has described the idea of defining the ethos of a group by the characterisation of observable behaviour. It is this concept that the author borrows to discuss the possible application of the design ethos framework.

The underlying constraint groupings and design ethos framework could be used to develop focused workshops to facilitate SIL implementation across a company. Unless otherwise indicated, workshops could be aligned with generic constraint groupings. See Tables 9-10 and 9-12. Each workshop would be structured to generate key actions that need to be taken to overcome constraints to SIL. Alternatively, each construct of ethos could become a workshop theme. The aim of each workshop would be to table the AS-IS position and to conduct a gap analysis and action plan to move the company towards stated goals. In combination with Figure 10.3 and Table 10-3, efforts could then be focussed on cross-sectoral learning or fundamental research. As a set of tools they could be used to identify where and in what direction resource is required.

For example, based on the existing characterisation, subsequent SIL implementation at MBD will need to focus effort on addressing issues associated with existing processes, skills and relationships where design ethos is process critical. See Figure 10-2.

This set of tools complements the outcomes of the AEROEXTN programme which were a Decision Support Tool (DST) for supplier involvement in concurrent engineering with a design community (Fan et al. 1999a), a SIL implementation rule base (Philpott 2000) and a pilot demonstrator of SIL for the industrial collaborators (Philpott et al. 1998; Philpott et al. 1999; Gregory et al. 1998; Hamblin et al 1999; Hamblin et al. 2000; Fan et al. 1999b; 1999c).

10.9 Limitations of the study

External validity - Statistical difference between sectors was measured in terms of distribution of responses. Difference was measured at the 0.05 level. This means that for each issue of difference there is a ninety-five percent confidence level that wider population would behave in the same way. One point that remains is how well the collaborators were representative of military and civil companies. The military collaborators were all aerospace - defence OEMs and the civil companies were both OEMs from the automotive sector. Despite the confidence level in the differences found, it is impossible to say whether these differences were specific to aerospace-defence and automotive, or whether they are symptomatic of differences between any military and any civil company. Despite this concern, the mixed method employed to define questionnaire issues, which drew upon cross sectoral experience in the literature, led the author to believe that the revised design ethos framework has some validity in other industrial sectors; however, the empirical differences between sectors requires further validation.

A further limitation in terms of the quantitative analysis is the nature of the data. Non-parametric testing was used to explore differences between sectors due to initial testing indicating non-homogeneity of variance and bi-modal tendency for some variables. In order to improve the power-efficiency of these tests, in comparison to parametric tests, larger samples would be required which were outside the scope of the research.

Factor and cluster analyses were used to define the design ethos framework. Due to the nature of the data, both tests had weaknesses that may have manifested themselves in the slight discrepancies in outcome. Any subsequent work should investigate whether variables 4 and 35 (non-equal variances across sectors) and variable 8 (bi-modal tendency) adversely affected the factor / cluster formations and whether differences between sectors were missed due to *Type II* [53] errors.

The differences between sectors were defined using a combination of tests. Where difference results were corroborated by multiple tests, the author has a high confidence. Where differences were indicated by single tests the author has low confidence in that constraint differing across sectors due to the likelihood of *Type I* errors[54]. The inadequacy of the chi-sqd test in deciphering sector differences in variables 25 and 21 and the impact of segregation of development and production especially in terms of time, requires further investigation.

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[53] Variability in scores prevented the techniques showing statistical difference or that the tests used were not sufficiently precise and sensitive to show up subtle differences.

The effect of sample profile - Cross tabulation of current and previous functional experience with the major differences between sectors showed disparity in three areas. A high proportion of participants in the military sector considered themselves to have procurement experience, while this was low in the civil sector. Similarly, a high proportion of the civil sector considered themselves to have component engineering experience; whereas, this was low in the military sector. The effect of this disparity requires further investigation. Possible causes of the disparity are:

- The possibility that the questionnaire simply did not reach equivalent proportions of procurement and component engineering staff in each sector, even though this was not the case for the other functional descriptions.
- Engineering driven companies may deliberately skill design related and supplier facing people differently to cost-driven companies. Alternatively the two functional descriptions may well be one and the same.
- The two roles may well be evolutionary in that component engineering in the civil sector is evolving into a procurement role. Alternatively, procurement in the military sector is evolving into a component engineering role.

What is interesting about the disparity is the fact that the sample profile of design – related; supplier-facing personnel is different in each sector. This difference between the samples requires research to determine:

- Whether it is a real difference or an accidental consequence of the research method
- How each function is skilled in each sector
- What the effect is on design community ethos of different skills in these functions

[54] One in 20 event occurred and the results don't actually differ.

Disparity between the two samples in terms of manufacturing experience appears supported by the theory that the military sample appears skewed towards the early life of products. See Section 9.5.2.

Independent of whether these findings are real or accidental, discontinuity between the samples in terms of functional experience cannot be discounted as a causal factor in the research outcome.

Information on duration of CE experience was not collected. The problem with the collection of this information was that large companies rarely effectively share experience, so one project group indicating experience may not indicate that that the experience was shared throughout the company. This is corroborated by the current level of research effort in the area of knowledge management that is attempting to remedy the situation. Therefore the case study did not measure the group's communal experience of SIL merely confirmed knowledge of CE techniques and an interest in extending this to suppliers. The questionnaire did not gather data on the sample in this area relying more on available company literature and individual examples as evidence of CE experience. While a more explicit description of duration of experience may have been useful to the research, an effective way of measuring this was considered an impossible task.

Holt (1996) believes engineering ethos stems from academe, employment experience, and shared interests and attitudes of engineers as an identifiable group. This author concurs with this view but in doing so also considers that 'design ethos' of a design community also includes members who are not professional engineers and people whose professions are immature. For example, professional qualifications for procurement and purchasing staff are relatively young.

If we are to cultivate a positive SIL ethos, then attention should be paid to academic background, industrial experience and shared interests and attitudes of the design community. Using the same argument as Holt, the identifiable group then becomes the design community. For purpose of this research, academic background, industrial experience, and, shared interests and attitudes of the design community become the variables of influence. The questionnaire attempted to address industrial experience in the form of current and previous functional experience as well as shared views of SIL constraint. It failed to control for academic background. Subsequent research should perhaps address this.

Business environments naturally evolve. It is impossible to control for all variables in such an environment. This author has attempted to control for the issues that the literature has indicated important. There is a possibility that unforeseen variables could be influencing the research outcomes.

The process - The allocation of original design ethos constructs (CI, ME, P, O) to SIL constraints required that preliminary ethos constructs be matched to constraint descriptions. Judgement of this kind is subjective and there is therefore a possibility of loss of meaning due to the translation. Subsequent translation of the case study and literature derived constraints into questionnaire issues also relied heavily on formulation of a representative question from a group of issues.

It is possible that certain nuances of constraint may have been lost during the formulation of questionnaire issues; however, questionnaire respondents were given the opportunity to comment or elaborate on issues. The participants' additional comments gave the author confidence that the constraints originally captured did reflect the current situation, in that a number of the comments made provided further example and elaboration to existing points. See Appendix 9. These comments also gave the author further insight into the business dynamic and business archetypes of each of the companies, aiding in the interpretation of the results.

The allocation of descriptions to the factor groupings again required formulation of common themes. Other interpretation may be possible and can only really be explored with further validation of the underlying constraint groupings and revised design ethos framework. Unfortunately, this is outside the scope of this research.

Tool validation - The research is limited in that the underlying constraint groupings (Table 9-13) and revised design ethos framework (Figure 9-3) requires further validation as a tool to aid SIL implementation. Unfortunately this was outside the scope of the research in terms of time and cost. However, the author continues to enjoy the interest of the collaborators in her work and there could be future opportunities for validation of the framework as a tool.

10.10 Contribution to knowledge

The contribution to knowledge that this thesis provides is the insight it offers into the issues associated with implementing concurrent engineering with external suppliers, and the identification of sector-specific issues as well as those which will benefit from cross sectoral learning.

The mixed-method employed provides triangulation of findings. The case study, although subject to initial confidentiality restrictions, is believed to be revelatory in its insight into a military design community's difficulties with the SIL concept. The thesis itself provides a cross-sectoral comparison of constraints to SIL, largely corroborating the existing literature but also identifying anomalies that may be specific to the aerospace-defence and automotive sectors. It compares SIL priorities in both sectors as well as exploring areas of fundamental difference.

The thesis explores the concept of design ethos in a SIL context from philosophical and practical standpoints and proposes that design ethos can be both observed and characterised and is fundamentally different across sectors. Further, it proposes that such characterisation is essential for practitioners in understanding the practicalities of SIL implementation and possibly other change programmes in design communities.

This work provides SIL practitioners with frameworks for the assessment of SIL aptitude and the focussing of SIL resource for maximum benefit. It is of value to military and civil OEMs for purpose of change management, also to their suppliers in understanding the different needs of military and civil customers when working in a concurrent engineering manner.

10.11 Issues for further study

Based on the evaluation of findings and limitations of this study, issues for further study would appear to be:

- The validation of the ethos framework in a wider selection of military and civil companies, i.e., armaments/ submarine in the military sector, non-automotive in the civil sector. The further development of the design ethos framework as a tool for SIL implementation.

- The effect of skill mix on successful SIL. Team characterisation by assessment of business dynamic, business archetype and mix of characters.
- Effectively communicating management buy-in in the civil and military sectors
- Design community supplier interfaces - Procurement or Component Engineering? Conduct an investigation into the appropriate skill mix for personnel in company-interface roles.
- Creating a suitable design ethos – Inter-company team players by design? Understanding the requirements in terms of education, experience, and professional training.
- Sectoral differences in mind's eye issues – Equipping design communities with best practice in the area of communicating design intent and managing internally and externally derived technical change.
- Investigation into the feasibility of applying the design ethos framework as defined in terms of SIL, as a generic framework for 'third party' involvement in design. Third party in this instance may refer to collaborative OEMs, JV partners or sister- design- communities in merger environments.