ENHANCING TECHNOLOGICAL CAPABILITY IN SMALL MANUFACTURING SUPPLIERS:

Customer Influence and Supplier Action

by

Fiona M. Reed

A Doctoral Thesis
Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy of Loughborough University

May 2003

Abstract

This thesis investigates how small manufacturing firms gain awareness of future technological requirements, through a process described as "technology lookahead". This process is an important step towards developing technological capabilities which are appropriate to future market needs The research presented here is exploratory in nature, and follows a route of building and revising conceptual models or frameworks for understanding. A scoping study is used to identify two main themes for in-depth research.

The influence that customers have on technology lookahead is explored first, through case studies of two supplier development programmes While neither of the supplier development programmes are found to be very active in addressing technological issues, they appear to be successful in building up inter-firm relationships which enable the sharing of strategic technology information

Since there is a danger that over-reliance on customers for information can lead to short-term technology strategies, the second part of the research focuses instead on how small companies acquire information from sources outside the supply chain for technology lookahead The main finding from surveys and interviews is that while small manufacturers are active in information acquisition, they tend not to be conscious of seeking strategic technology information Although the process of technology lookahead is not recognised, it is likely that it occurs alongside activities with shorter-term goals, and is vulnerable to the same barriers as information acquisition. A particular problem is identified for small firms investigating unfamiliar technologies or markets, where they may not be able to find information or utilise the information that is available to them

The research calls for greater recognition of the process of technology lookahead, and suggests that it may be in the interests of large firms to support their suppliers in this activity - for the benefit of the whole supply chain

Acknowledgements

The research presented in this thesis was funded by the Engineering and Physical Sciences Research Council (EPSRC grant reference GR/M44699) under a PRIME Faraday Partnership research project entitled "Practice and procurement: alliances in the value chain" The research was completed during an EPSRC-funded secondment to Pera, and I would like to acknowledge Richard Grice at Pera for enabling me to do this.

I would particularly like to thank my supervisor, Dr. Kathryn Walsh, for her support, encouragement and advice throughout the research project and writing-up period Not only did she provide the inspiration to complete the thesis, but also helped in a practical way by allowing me time to work on the thesis alongside my other research commitments. I am also grateful to Dr. Victoria Hanna and Professor Richard Weston for their helpful comments and suggestions.

Without my family, none of this would have been possible. My mother, Meg Barrowman, deserves special thanks for the effort she put into proof-reading my thesis and for always being there for me. My father, Malcolm Reed, inspired me to start this endeavour in the first place. I would also like to thank my step-father, Eric Barrowman, for everything he has done for us and for just being Eric! Finally, I would like to thank my husband, Mark Bennett for helping me in more ways than I can count He has provided me with constant love and support, with endless cups of coffee, with practical advice and comments - and with the ultimate motivation to complete my thesis (in the form of our first child) I would therefore like to dedicate this work to all my family, and especially to my daughter Lucy Rhiannon Reed Bennett.

Publications

The following publications have arisen from the research presented in this thesis:

Refereed Journal Publications

Reed, F.M. and Walsh, K. (2000) 'Technology Acquisition and the Changing Face of Manufacturing Industry', *Industry and Higher Education,* **14,** (4), pp. 224-234. ISSN 0950-4222

Reed, F M and Walsh, K. (2002) 'Enhancing Technological Capability through Supplier Development· a study of the UK aerospace industry', *IEEE Transactions on Engineering Management*, **49,** (3), pp 231-242 ISSN 0018-9391

Refereed Conference Publications

Reed, F M and Walsh, K (2000) 'Technological Innovation within the Supply Chain', *Proceedings of the 2000 IEEE International Conference on Managing Innovation and Technology (ICMIT2000),* Vol. 1, pp. 485-490. 12-15 November 2000, Singapore ISBN 0-7803-6652-2 (IEEE Catalog number 00EX457)

Reed, F M , Walsh, K., and Grice, R. (2002) 'Information Acquisition for Technological Innovation and Technology Strategy in Small Firms', *Proceedings of the 2002 IEEE International Engineering Management Conference (IEMC 2002),* Vol. 1, pp. 137-142. 18-20 August 2002, St John's College, Cambridge, UK. ISBN 0-7803-7385-5 (IEEE Catalog number: 02CH37329)

Reed, F M , Walsh, K , and Grice, R. (2002) 'Supporting the Information Needs of Small Manufacturing Firms', *Proceedings of the 25th ISBA National Small Firms Policy & Research Conference (ISBA 2002),* Vol. 2, pp. 1392-1406. 13-15 November 2002, Brighton, UK ISBN 1-901177-08-4

“It is always wise to look ahead, but difficult to look farther than you can see ”

Sir Winston Churchill, 1952

Table of Contents

Location of Figures

Location of Tables

List of Abbreviations

ACR	Arms-length Contractual Relations
AES	Aero-Electronic Systems
AES-S1	Aero-Electronic Systems Supplier 1
AES-S2	Aero-Electronic Systems Supplier 2
AES-S3	Aero-Electronic Systems Supplier 3
AJV	Aero-Joint Venture (UK)
AJV-S1	Aero-Joint Venture (UK) Supplier 1
AJV-S2	Aero-Joint Venture (UK) Supplier 2
AJV-S3	Aero-Joint Venture (UK) Supplier 3
CAD	Computer-Aided Design
CBI	Confederation of British Industry
CBR	Centre for Business Research
CIPD	Chartered Institute of Personnel and Development
DTI	(UK) Department of Trade and Industry
EDI	Electronic Data Interchange
ESI	Early Supplier Involvement
FOAS	Future Offensive Air System
HEI	Higher Education Institute
HR	Human Resources
ICT	Information and Communication Technologies
LED	Light Emitting Diode
MBO	Management Buy-Out
MD	Managing Director
NPD	New Product Development
NTBF	New Technology Based Firm
OCR	Obligational Contractual Relations
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
ONS	Office for National Statistics
PCB	Printed Circuit Board
PLC	Public Limited Company
QCD	Quality Cost and Delivery
R&D	Research and Development

RTO	Research and Technology Organisation
SBAC	Society of British Aerospace Companies
SD	Supplier Development
SIC	Standard Industrial Classification
SME	Small to Medium-sized Enterprise
SMMT	Society of Motor Manufacturers and Traders
SPRU	Science Policy Research Unit

1. Introduction

Manufacturing industry in the United Kingdom is undergoing major change, shaped and pulled by both local and global forces Competition is now on a world-wide basis, and this has a profound effect on decisions concerning how and where products should be designed and manufactured Many companies have embraced the concept of "core competencies" (popularised by Hamel and Prahalad (Hamel and Prahalad, 1994)), concentrating all of their resources on those activities which provide them with an advantage over their competitors, while entrusting non-core activities to suppliers and sub-contractors Operations which are not central to the success of one firm may nonetheless provide a key input to the final product, and so every part of the supply network contributes to the competitiveness of a product to the end-user.

Increased outsourcing means that the role of firms within the supply network is changing. In technology-based industries such as aerospace and telecommunications, the large multinational companies - which were the original equipment manufacturers (OEMs) – are now focussing on systems integration as their core competence (Bertodo, 2002) Design and manufacture of sub-systems and sub-assemblies are increasingly being outsourced to their suppliers (Handfield et al , 1999). Clearly this demands new skills, expertise and technological capability from suppliers, who in the past may have only manufactured components.

The research presented in this thesis stems from a research agenda set by two major aerospace companies in the UK who have experienced difficulties in finding suppliers to meet their needs, particularly in terms of providing products with integrated mechanical and electronic functionality These companies have a particular interest in long-term supplier technological capability, and therefore the research aimed to investigate what is influencing suppliers in their technology innovation and lookahead (or awareness of future technology requirements and alternatives) The particular foci of this research are the smaller sub-assembly suppliers who face the greatest challenge in finding the resources to explore new technologies and develop their capabilities.

Specific technology challenges faced by suppliers include the drive to make products smaller, lighter and cheaper, but with greater functionality and higher performance and precision Often these requirements can only be met by the integration of different technologies into a single product (Kodama, 1992), for example by embedding electronics into a mechanical component or incorporating optical functions into an electronic sub-assembly While a firm may have expertise in one technology area, it may not have expertise in another area nor in the manufacturing process issues arising from the integration of different technologies Other technological challenges arise from the need for products with a better impact on the environment.

The new demands on suppliers are exacerbated by the rapidly changing technological environment. Novel product and process technologies are constantly appearing, and it can be difficult to predict in which it may be worth investing. Companies may need some form of "technology lookahead" – the ability to identify the important new technologies and to acquire or develop them at the right time. This was in the past much easier for the vertically integrated OEMs than it currently is for smaller suppliers This is because the former had a certain amount of "slack" in the system (in the form of employees with a broad range of technical expertise plus adequate financial resources for research and development) to maintain awareness and experiment with potential new technologies For small companies, it is much harder to devote resources to long-term, speculative projects at the same time as developing the next product and manufacturing the current one

It is however critical that small firms continue to update their skills and strengths if they are to avoid losing business to more innovative competitors. The increasing pace of change also manifests itself in competitive pressure to minimise time-to-market, requiring shorter product design cycles Simultaneously, product lifecycles are being compressed, which leaves less time to recoup investment and make a profit.

The financial pressures on small firms are not helped by the trend to rationalise the supply base The need for rationalisation arises partly from the drive to reduce the total cost of acquisition, partly from the need to eliminate duplication following mergers and acquisitions, and partly in order to be able to devote more resources to building partnerships with key suppliers. It is increasingly important for suppliers to be seen as providing good value for money, or they may lose their "preferred supplier" status. Increased global competition means that prices are under pressure from firms in lower-cost locations, and the demands of end-users for cost reductions also tend to be passed down through the supply chain. How much resource, therefore, can a small company afford to devote to technology lookahead?

The aim of this thesis is therefore:

- **to identify and evaluate mechanisms for maintaining and developing technological capability in small manufacturing suppliers.**

If suppliers in the UK are not technologically competitive, they will either inhibit the performance and success of the end product or system, or they will lose their position in the supply network. The focus of the thesis will be on smaller suppliers in particular, because they face the greatest challenge in developing technologically whilst overcoming resource limitations Small manufacturing suppliers are also of interest to "UK plc" because they provide around 10% of employment in the UK (Small Business Service, 2001).

There will also be a particular slant towards the needs of companies operating in mature industry sectors, where the issues concerning technology are rather different to those of new start-up companies in emerging industries. (For start-up firms, the challenges are often more to do with establishing a market and having the winning technology, rather than meeting the long-term technology needs of a mature market) The focus on mature industry sectors allows the opportunity to consider the development of technological capability in a relatively stable environment, where technological choices, such as integration of different technologies within a product, are not completely overshadowed by other considerations

The topic chosen belongs in the broad interdisciplinary research field of technology management, which boasts an ever-expanding number of academic journals drawing on contributions from economists, policy research, management schools, engineers and social scientists Within or related to the field of technology management, the research presented in this thesis links into the following research areas

- *innovation* - improvements in technological capability rely on innovation within individual firms i e the introduction of new products or processes
- *technology diffusion* - the adoption and spread of new technologies
- *new product development* - the processes by which new products are created (including decisions regarding which technologies to incorporate or use to manufacture the product)

- *concurrent engineering* – a method of developing products using interdisciplinary project teams to reduce development times, which may be extended to involve suppliers (early supplier involvement or "supplier-in-loop")
- *technology strategy and planning* – determines which technologies should be acquired or developed through which mechanisms (e g. internal research and development (R&D), firm acquisition or partnership)
- *technology forecasting, identification, assessment, selection, acquisition and exploitation* – specific technology management techniques relating to the previous point (e g. technology roadmapping)
- *R&D management* – the selection, execution and assessment of research projects and product and process development
- *metrics and evaluation* – the challenges associated with assessing success, whether in R&D projects or supplier performance
- *knowledge management* – issues concerning technological knowledge in both tacit and explicit forms, and how to codify, store and retrieve that knowledge
- *intellectual property (IP)* – how to protect and exploit technological innovation
- *co-operation, alliances, mergers and acquisitions* – accessing and exploiting new technology through relationships with other firms
- *management of people and change management* – how to work with employees to facilitate the growth and deployment of their technological knowledge and expertise, and to successfully introduce new technology into the firm

Although the research presented will touch upon many of these issues, certain areas have a particular relevance to the mechanisms of maintaining and developing technological capability in the manufacturing supply network These are:

- *innovation and technology diffusion*
- *(inter-organisational) concurrent engineering*
- *technology strategy and planning*
- *technology forecasting, identification, assessment, selection, acquisition and exploitation*

Topics directly concerning product development are not considered in great detail because this research focuses more on the underlying and enabling technologies rather than the complex technical and commercial issues surrounding new product development R&D management research would be pertinent were the primary interest in large companies, but the focus of the research is on smaller firms who may not have a dedicated R&D function

Outside the field of technology management, there are two other especially relevant research areas

- *strategic management* – looking at broader strategic issues beyond technology
- *supply chain management and supplier development* – examines the strategic use and management of suppliers, predominantly from a logistics perspective but sometimes relating to technology. It provides background context concerning processes for interaction between customers and suppliers

The next chapter will explore the literature in the areas highlighted, as well as some of the background issues concerning the relevance of this research, in order to place the work of this thesis in context. As will be explained in Chapter 3, the research followed a cyclical pattern, where literature, primary research and theorising continually re-shaped the form of this thesis The thesis is however written in a linear fashion, and the roadmap presented in Fig. 1.1 will help the reader to navigate the chapters

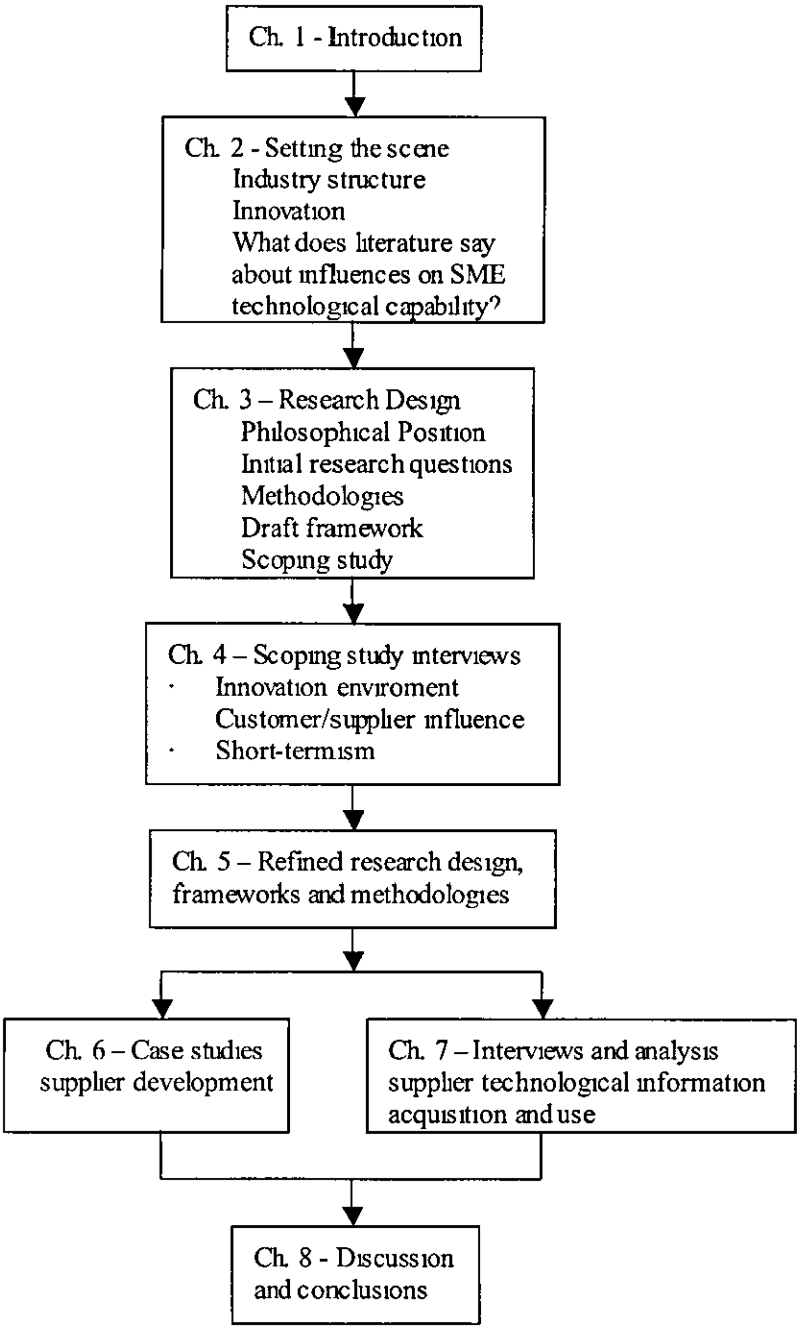


Figure 1.1 Roadmap of thesis chapters

2. Background and Literature

This chapter begins by considering the background context to this research, referring to relevant literature as appropriate. The focus is then on the "prior art" - how the existing literature tackles the issues of concern to this thesis, namely the influences on technological capability in small manufacturing suppliers The chapter concludes by identifying how this research will contribute to the literature

The literature review follows a series of questions which are intended to help the reader to understand the structure of the chapter The questions reveal the approach taken by the author in identifying relevant literature – since the research touches upon many different academic fields the literature review is by necessity selective rather than comprehensive

2.1. Background

This section explores in more detail the motivation for this research (which was introduced in Chapter 1). This involves considering why the technological capability of manufacturing suppliers might be of interest, and then examining the evidence for why the size of those suppliers (in terms of numbers of employees) might be relevant These factors are used to set the boundaries of the types of firms which are of interest to this study, in terms of their size and industry sector.

2.1.1. Why Does the Technological Capability of Manufacturing Suppliers Matter?

This question is considered in two parts – starting with technological capability and the importance of technological innovation, then looking at the increasing reliance on suppliers to provide this competitive edge

2 1.1 1 Importance of Technological Innovation in Giving a Competitive Edge

Technological innovation is widely recognised as being vital to the competitive success of individual companies and whole industry sectors (Porter, 1985). Without the introduction of new products, new processes or new technologies, firms are unlikely to survive. Innovation can create new possibilities, lower costs and improve the performance of existing products and services – all of which are key to winning and retaining customers (whether those customers are individuals, businesses or governments) Technological innovation has had a major global impact on all areas of business, perhaps most obviously through developments in information and communication technologies (ICT) This research, however, focuses more on innovation in the context of the "hard" technologies which contribute to the manufacture of a product The trend is for products to become smaller, lighter and cheaper, yet with increased functionality Technological innovation to meet these expectations demands greater integration of technologies (Kodama, 1992) - for example by embedding electronics within a component which has mechanical functionality This requires a broad range of skills and capabilities for design and manufacture

Innovation is defined here as the introduction of new products, services, manufacturing processes, business processes or organisational forms. An innovation may be new to a particular firm, new to a particular industry, or completely novel. Innovation may be incremental, or may involve radical step changes with "breakthrough" technology (Leifer et al., 2000). The innovation may also be "sustaining" (enhancing performance of existing products), or "disruptive" (providing a different set of attributes, often initially for a new market) (Bower and Christensen, 1995, Christensen, 1997).

The general understanding of the innovation process has changed over the past 50 years, and Rothwell (Rothwell, 1992) identified five different models which describe the conceptual evolution of technological innovation. Originally, innovation was seen as a linear process – the first generation model was that of "technology-push", whereby scientific discovery resulted eventually in a product to be marketed Then the effect of "market-pull" (also known as "need-pull") was recognised, resulting in a second linear model with customer requirements initiating the process. It was later understood that both of these processes work together, and the "coupling model" (the third generation model) became established. The fourth generation "integrated model" described innovation as a parallel process, with a high level of functional integration and concurrent engineering within companies. Subsequently the fifth generation model of innovation recognised the use of systems integration to make the innovation process faster and more efficient, and also highlighted the importance of inter-company networking

Although innovation is seen as the engine of economic growth, the evidence of its benefits for small firms is not clear-cut (Souder and Song, 1997). Freel (Freel, 2000) found that small innovating firms were no more profitable or productive than non-innovating small firms, nor more likely to have experienced growth in sales or employment figures. In the cases where the innovating firms had grown, however, they had grown significantly more than the non-innovating firms. Christensen et al. suggest that innovation in small firms is linked to their basic survival (Christensen et al., 1998), although this may be more evident in fast-changing industries than in other industries

There is clearly a need for further research to understand why small firms do not appear to accrue many of the benefits of innovation. The major concern in this study however is that technological innovation should take place at some level in the supply chain, which means that innovation involving supplier firms must be considered In fact there appears to be an increasing requirement for suppliers to add value to their products and services - which may make their part in technological innovation even more significant. The next section explores the reasons for increasing reliance on suppliers.

2 1 1 2 Increasing Reliance on Suppliers

The second reason why the technological capability of manufacturing suppliers might matter is because of increasing reliance on suppliers to take on more design and manufacture of sub-systems and sub-assemblies The reasons behind this are explored in this section

One factor has been the trend of focusing on core competencies, a concept popularised by Prahalad and Hamel (Prahalad and Hamel, 1990) Firms are encouraged to understand where their capabilities presently lie, and what they must do to build capabilities to exploit future opportunities Implicit in this approach is that it is not necessary to devote resources to non-core activities, and that these activities may be outsourced. This has meant a move away from vertical integrated companies (with design, development, manufacturing and assembly performed in-house) towards a supply network of many companies performing different functions.

As a result of outsourcing more activity, there is some evidence that large firms have been downsizing while more small firms are emerging to supply the products and services that were formerly provided in-house (Tether and Storey, 1998). The research identified a phenomenon during the 1980s where employment in a particular industry sector decreased, but the number of business units increased, contrary to the normal lifecycle pattern for an industry This phenomenon can be explained by a reduction in the number of large enterprises where employment is usually concentrated, alongside an increase in the number of micro and small enterprises.

This researcher has investigated whether the trend identified by Tether and Storey continued into the 1990s The evidence, presented in Appendix I, suggests that the trend did continue in the early 1990s but there was a reversal in the late 1990s. Nevertheless, in certain sectors such as aerospace there was an overall increase in the number of smaller firms and a decrease in the number of large firms with over 1000 employees. This does tend to confirm the increasing importance of small firms in high technology manufacturing, and therefore in technological innovation.

An alternative interpretation of the industry trend is that there may be an on-going cycle between vertical integration and outsourcing. Fine (Fine, 1999) uses the example of the personal computer industry, which had moved from vertical integration with companies such as IBM, to a modular structure It now appears to be moving back towards a vertically integrated structure, as Intel and Microsoft expand their activities to control more of the supply chain Whether outsourcing is a long-term industry trend, or reaching the turning point in its cycle, it still appears to have momentum in the relatively slow-moving aerospace sector. There remains a debate about what should be outsourced and what should be kept in-house. The make-or-buy decision is still an on-going research issue, due to concerns about outsourcing core competencies (Canez et al., 2000; Fine, 1999, Fine and Whitney, 1996; Sako, 1994). Chesbrough and Teece also warn of the dangers of outsourcing technologies which should be controlled in-house (Chesbrough and Teece, 1996). For each company it will be necessary to consider where their key skills and capabilities currently lie, and what will win orders in the future (Hill and Chambers, 1991). Systems integrators may consider that their market knowledge and project management are their key strengths, while expecting their suppliers to be the experts in enabling technologies

In addition to reliance on suppliers because of a strategy of outsourcing non-core activities, there has been a positive move towards partnership with suppliers This is due to popular recognition of the important role which supplier partnerships have played in Japanese automotive success (Clark, 1989) The partnership approach has been examined from a number of different angles in the literature. These include product development (Clark, 1989, Clark and Fujimoto, 1991; Wasti and Liker, 1999; Bidault et al., 1998b; Kamath and Liker, 1994), lean supply (Lamming, 1993; Bower and Keogh, 1997; Lamming, 1996, MacDuffie and Helper, 1997), network sourcing (Hines, 1994), total quality management (Tan et al., 1998), and business process reengineering beyond firm boundaries (Childe, 1998)

Dyer and Ouchi (Dyer and Ouchi, 1993) highlighted the advantages that Japanese-style partnerships bring in contrast with the traditional vertical integration of US auto-makers, including reduced cost of components, faster product development times and increasing market share Dyer and Ouchi exhorted US auto-makers to embrace the partnership concept, by outsourcing more, reducing the number of direct suppliers to reduce cost and improve quality, investing in the value chain; encouraging competition between suppliers by helping the weaker suppliers; and protecting investments by building trust with suppliers.

This description of Japanese-style partnerships (Dyer and Ouchi, 1993) suggests a positive impact on long-term technology capability in the value chain. When suppliers are in a long-term relationship with a buyer, this enables them to invest in new equipment and innovate to meet their customer's needs. They are involved early in the product design process and have extensive direct communication with product and process engineers Supplier engineers are able to work alongside engineers in the customer company, and also guest engineers from the customer company spend periods of time with suppliers to help them improve (These opportunities for informal communication have the potential to increase mutual awareness of future technological opportunities and requirements) Supplier innovation is encouraged by having to compete for contracts (which then typically endure for the lifecycle of a particular model). Sako considers the effect of the partnership approach on innovation (Sako, 1994), and concludes that supplier relationships may be structured either to enhance or discourage innovation Supplier innovation may be limited by hard bargaining with suppliers, which requires the buyer to keep tight control over product design specification and limits diffusion of technological information, and can leave small suppliers with little to invest. In contrast, relationships of trust and incentives to innovate will make suppliers better disposed to take risk (necessary for innovation)

There has been some misunderstanding of the Japanese partnership model by those seeking to emulate it. Partnerships in Japan itself are changing, and Japanese suppliers now have to be more technologically independent (Lamming et al., 1999). Partnership in Japan was traditionally characterised by a single customer dominating the relationship with the supplier, and by the customer helping the supplier with product and process technologies Suppliers are now expected to be much more independent, to undertake R&D and prototyping, and to work with a number of different customers (Lamming et al, 1999) Japanese firms are also now rationalising their supplier base, and those suppliers who do not develop their technology independently are at risk. Kamath and Liker (Kamath and Liker, 1994) emphasised the fact that only certain first-tier suppliers enjoy close relationships with their Japanese partners. With over a hundred first-tier suppliers, Japanese auto-makers limit partnership to around a dozen suppliers with "*outstanding technology, sophisticated management and global reach*" Partners have responsibility for developing entire sub-systems on their own, but other suppliers will have lesser roles. "Mature" suppliers undertake complex assembly to customer specifications, while "child" suppliers undertake only simple assembly, following customer specified design requirements. "Contractual" suppliers provide commodity or standard parts, either from their catalogue or from detailed customer blueprints

Most companies will (at least informally) classify their suppliers according to the nature of the relationship they have with them. In the academic literature, a number of formal categories are proposed. For example, Sako distinguishes between arms-length contractual relations (ACR) and obligational contractual relations (OCR) exhibited amongst both British and Japanese firms (Sako, 1992). The ACR model allows both buyer and supplier to remain independent of each other, and relies on trust that both parties will meet the terms of their written agreements. The OCR model permits greater reliance on the other party, and "goodwill trust" is a prerequisite to this type of relationship The OCR model may be more appropriate for a strategic supplier than the ACR model, since it is characterised by mutual long-term commitment

From the perspective of technology development and future capability, strategic suppliers are likely to be those referred to as black box suppliers by Clark and Fujimoto (Clark and Fujimoto, 1991), rather than those who supply proprietary parts or detail-controlled parts Hines (Hines, 1994) differentiates between sub-contractors who make parts to order, and common suppliers who provide off-the-shelf, standardised components – again, the strategic relationship is usually with the sub-contractor rather than the common supplier. Kaufman et al (Kaufman et al., 2000) describe a typology of small and medium sized manufacturing suppliers looking at the dimensions of technology and collaboration, sub-divided into high and low categories (see Table 2 1) The four types of firms proposed are commodity suppliers, collaboration specialists, technology specialists and problem-solving suppliers. The technology specialists and problem-solving suppliers are likely to be the most critical in terms of their technological contribution to the end product, and therefore exemplify why the technological capability of suppliers is seen as important in this research.

Table 2.1 Typology of small and medium-sized manufacturing suppliers (Kaufman et al., 2000)

		Collaboration	
		Low	High
Technology	Low	**Commodity Supplier** • Spot market supplier • Low cost, low price priorities • Little or no differentiation	**Collaboration Specialist** • Detail-controlled parts supplier • Uses a closed network in each industry • Can be in many industries to maintain customer product information
	High	**Technology Specialist** • Proprietary parts supplier • Innovation in product technology used to produce high barriers to entry • First mover advantages • Uses design capabilities for competitive advantage	**Problem-solving Supplier** • Black box supplier • High differentiation • Cost less important • Small runs, high process and labour flexibility

2.1.2. Why is the Size of a Firm an Issue when Thinking about Technological Capability?

The previous section discussed why technological innovation is important and why there may be increasing reliance on suppliers to provide this technological edge. The size of those suppliers will vary according to their role and industry sector – for example in the automotive sector small firms are usually further down the supply chain Hines (Hines, 1994) describes the tiering of automotive suppliers as a pyramid (see Fig 2 1), with the average company size increasing towards the top of the pyramid, and number of suppliers at each level following an inverse relationship. In Kaufman's (Kaufman et al , 2000) sample, described at the end of the previous section, problem-solving suppliers tended to be larger than the other types of suppliers, with an average of 260 employees (average number of employees ın collaboratıon specıalist firms – 150; technology specıalısts – 44, commodıty supplıers – 28) Accordıng to Rothwell and Dodgson (Rothwell and Dodgson, 1991), thıs may be because problem-solvers need to retaın a greater breadth of technıcal personnel ın order both to ınteract with their customers and to keep abreast of the latest technologıcal developments. The technology specıalısts (companıes whıch may have key technologıcal capabılıtıes) tend however to be smaller companies, reflectıng theır more narrow focus There has been recognıtıon of the ımportance of small hıgh-tech firms ın recent years (e.g. (Storey and Tether, 1998a; Oakey and During, 1998)) The need to maintaın and develop technological capabılıtıes ıs crucıal regardless of firm sıze, and ıs necessary for less advanced small companıes as well as technology specıalısts

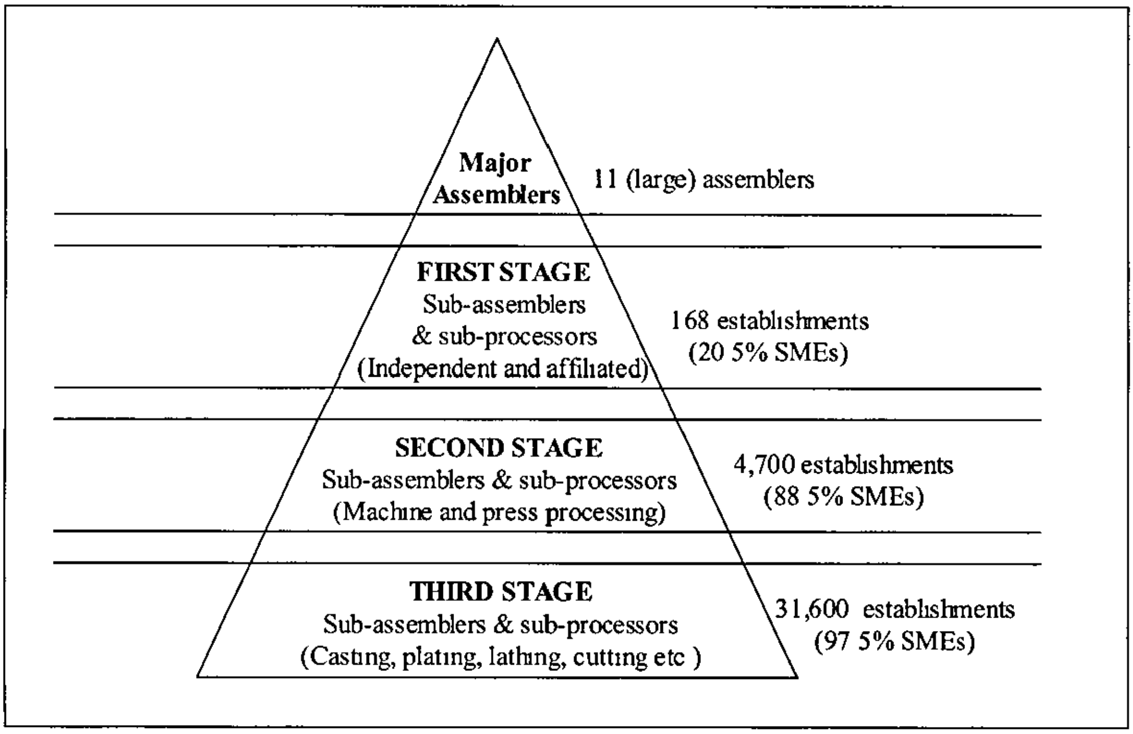


Figure 2.1 Tiering of suppliers in Japan's automotive industry (Hines, 1994) N.B. SME = small to medium sized enterprise

One reason for lookıng at small firms ıs that this researcher ıs ınterested ın mature ındustry sectors such as aerospace where most companıes would be classıfied as small and medıum enterprıses (SMEs) wıth under 250 employees. In the UK there are approxımately 700 companıes wıth 1 or more employees currently lısted under the Standard Industrıal Classıficatıon code (1992) 35 3 (whıch is the manufacture of aircraft and spacecraft), accordıng to the FAME (Fınancıal Analysıs Made Easy) database from Bureau Van Dıjk Of these firms, almost 89% have less than 250 employees and only 5% have over 1000 employees

In manufacturing in general, something of the order of 98% of all companies (with at least one employee) have less than 250 employees (and in fact 91% have fewer than 50 employees). SMEs account for 53% of employment in the manufacturing sector, and 34% of turnover (Small Business Service, 2001). Since small firms dominate manufacturing in terms of their sheer numbers, their technological capability will impact upon the competitiveness of the supply chains in which they operate

So far in this chapter the arguments have pointed towards the increasing requirement for small manufacturing suppliers to engage in technological innovation, with the underlying implication that this may be challenging for them. Many would in fact argue that small companies are much more innovative than large companies and that outsourcing more design and manufacture to suppliers should therefore have a positive impact on the technological capability of the supply network. This section explores the role of small firms in innovation in order to understand this issue better. There is an extensive literature addressing aspects of this question – predominantly from economists, policy researchers and management researchers Various studies have compared the relative importance of large and small firms in innovation, using different measures of innovation Others have taken a more qualitative approach, examining the respective characteristics of large and small firms and the differences in their innovation styles The following sections review these issues

2 1 2 1 Relative Importance of Large v Small Firms in Innovation

The relative importance of large firms and small firms in innovation has been widely debated in recent decades. The popular interest in this question stems from the link between innovation and economic growth – particularly employment growth. In order to support the companies who are most innovative, and therefore most likely to stimulate growth, policymakers need to know where innovation occurs. Is it in the R&D departments of large corporations, or in firms which are small and dynamic? The evidence in the literature appears, at first glance, to be mixed In the case of technological innovation, for example, sometimes the small firms appear to have the technological skills and expertise, while the large firms have resource and infrastructure e g sales channels (Lawton Smith et al, 1991) In other cases, small firms are very reliant on external knowledge sources for their technological expertise and although they are seen as good incremental innovators, it is the large firms which produce radical innovation (Sugasawa and Liyanage, 1999).

In fact the dichotomy over whether innovation belongs to small or large firms can be dated back to the economist Schumpeter Schumpeter's early work drew attention to the role of the small entrepreneur in undertaking radical innovation – from which new industries emerge (Schumpeter, 1934). His later work (Schumpeter, 1942) instead emphasised innovation in large R&D intensive firms, where market dominance permits risk-taking. It was the latter view that prevailed and dominated public policy in Europe for many years

The link between small firms and innovation was renewed with the publication of the Science Policy Research Unit (SPRU) innovations database and subsequent analysis by Pavitt et al of the size distribution of innovating firms in the UK (Pavitt et al., 1987) Small firms were found to contribute a disproportionate number of innovations in comparison with their share of employment and R&D expenditure, and their innovative contribution was found to have increased between the late 1950s and early 1980s A study in the US also confirmed the important contribution of small firms in innovation (Acs and Audretsch, 1990) Previously, innovation had been measured by inputs such as R&D expenditure, which is positively related to firm size, and "intermediate" outputs such as patenting activity, neither of which are seen as reliable indicators (Acs and Audretsch, 1993, Pavitt, 1988). The SPRU database was instead based on innovation counting, using significant technical innovations (between 1945 and 1983) identified by industry experts The results, however, have not been without controversy. Tether et al. (Tether et al , 1997) re-evaluated the evidence concerning the size classification of firms and found that the shape of the curve of innovation intensity against firm size in the manufacturing sector was j-shaped - rather than having the u-shape described by Pavitt et al. This means that smaller enterprises introduce a share of innovations commensurate with their share of employment, and medium sized companies introduce proportionally less – whilst the largest enterprises are responsible for a higher proportion of innovations relative to their share of employment. Tether also questioned the value of the innovations introduced by different sized firms, suggesting that the value increases with size of firm, although not proportionately (Tether, 1998).

The difficulty in finding suitable metrics for innovation continues to hamper research in this area Measuring expenditure on R&D favours large firms, because small firm R&D is often informal, sporadic, and spread across different functions, which makes it difficult to assess (Roper, 1999) (Kleinknecht and Reijnen, 1991). Innovation counting appears fairer to small firms, but the use of experts to identify innovations has not been repeated on a large scale since the SPRU database (which only extends to 1983) Acs and Audretsch (Acs and Audretsch, 1993) based innovation counts on numbers of new products mentioned in trade journals, but this may not be a reliable measure (Vandijk et al , 1997; Brouwer, 1998; Menkveld and Thurik, 1999).

One alternative is to ask individual firms to identify the number of new products (or processes) they have introduced in a period of time. A number of innovation surveys in the UK have used this type of subjective measure (e g. (Cosh and Hughes, 2000; Marsh, 1996; Craggs and Jones, 1998)) These survey results consistently suggest that the larger a firm, the more likely it is to produce at least one innovation in the sample period, and this relationship is also true for novel innovations (not only new to themselves but to their industry) (Cosh and Hughes, 2000). Leaving aside the question as to whether small firms may be less likely to complete such surveys, this method of counting innovations does not distinguish between a large firm adding one new product to a range of hundreds, and a small firm with only one product which manages to introduce five new products (see Freel for an alternative measure using innovation rates (Freel, 2000)), although most observers would hold that the small firm in this example was more innovative than the large firm Another problem with taking the survey results at face value is that although the percentage of large firms that innovate may be higher than the percentage of small firms, there are of course many more small firms than large firms. This means that the overall contribution of innovations by small firms may be more significant than might be inferred from the surveys

The literature examining the relative importance of small firms in innovation is not at all conclusive in pointing to either large or small firms as the main source of innovation. Instead it is clear that both large and small firms contribute to innovation, and this is now examined in the context of the complementary characteristics of large and small firms.

2 1 2 2 Complementary Roles

Instead of contending that either large or small firms were more important in innovation, Rothwell emphasised the dynamic complementarities that exist between large and small firms in innovation (Rothwell, 1983). The characteristics of both large and small firms give them complementary advantages and disadvantages. These advantages are summarised in Table 2.2 (taken from (Rothwell and Dodgson, 1991)). Small firms have behavioural advantages over large companies because of their responsiveness, lack of bureaucracy in decision-making and ease of internal communication Large firms, however, have material advantages - such as the ability to fund R&D and technical specialists, ease of access to external specialist networks and the possibility of spreading risk across a portfolio of projects (Rothwell and Dodgson, 1991) SMEs can therefore contribute more in terms of innovation where entry costs are low and where factors other than product price are important (Rothwell and Dodgson, 1993)

The lack of formality and bureaucracy in small firms influences their approach to new product development compared with large firms (O'Shea and McBain, 1999). Large firm structures, however, make it much easier for them to work with governments than it is for small firms (Carayannis and Roy, 2000) Ussman et al. (Ussman et al, 2001) identified particular barriers to innovation that small Portuguese firms face. These include cultural barriers, in that these firms tend to resist change, and innovation is perceived as an unnecessary risk when competitors are not innovating. Also, the low sales volumes of the small firms make it difficult to recoup the costs of innovation. Barriers were also seen in the lack of information concerning European innovation programmes, and the difficulty in accessing funding institutions due to bureaucracy.

Nooteboom observed that small firm reliance on tacit knowledge provided them with both advantage and disadvantage in innovation - advantage in that it is difficult for competitors to copy their unique skills, but disadvantage in that it is necessary to be aware of how things are currently done in order to understand the potential benefits of a new technology Small firms perform less R&D than large firms, but when they do, it is more intensive and more productive. In comparison with large firms, small companies are less likely to filter out the more risky ventures. This is due to lack of bureaucracy, lack of vested interests in maintaining existing product lines and a poor understanding of risks This can either make them very successful or cause them to fail dramatically (Nooteboom, 1994)

The distinction between small and large firm characteristics is not always clear-cut – for example Ettlinger (Ettlinger, 1997) notes that the assumption that small firms cannot afford capital-intensive equipment is not always true. The suggestion is that technology transfer programmes have been quite successful in helping high tech small firms invest in

Table 2.2 Advantages and disadvantages of small and large firms in innovation (Rothwell and Dodgson, 1991) (*Note: the statements in brackets represent areas of potential disadvantage)*

	Small Firms	Large Firms
Marketing	Ability to react quickly to keep abreast of fast changing market requirements (Market start-up abroad can be prohibitively costly)	Comprehensive distribution and servicing facilities High degree of market power with existing products
Management	Lack of bureaucracy Dynamic, entrepreneurial managers react quickly to take advantage of new opportunities and are willing to accept risk	Professional managers able to control complex organisations and establish corporate strategies (Can suffer an excess of bureaucracy Often controlled by accountants who can be risk-averse Managers can become mere 'administrators' who lack dynamism with respect to new long-term opportunities)
Internal communication	Efficient and informal internal communication networks Affords a fast response to internal problem solving provides ability to reorganise rapidly to adapt to change in the external environment	(Internal communications often cumbersome, this can lead to slow reaction to external threats and opportunities)
Qualified technical manpower	(Often lack suitably qualified technical specialists Often unable to support a formal R&D effort on an appreciable scale)	Ability to attract highly skilled technical specialists Can support the establishment of a large R&D laboratory
External communications	(Often lack the time or resources to identify and use important external sources of scientific and technological expertise)	Able to 'plug-in' to external sources of scientific and technological expertise Can afford library and information services Can sub-contract R&D to specialist centres of expertise Can buy crucial technical information and technology
Finance	(Can experience great difficulty in attracting capital, especially risk capital Innovation can represent a disproportionately large financial risk Inability to spread risk over a portfolio of projects)	Ability to borrow on capital market Ability to spread risk over a portfolio of projects Better able to fund diversification into new technologies and new markets
Economies of scale and the systems approach	(In some areas scale economies form substantial entry barrier to small firms Inability to offer integrated product lines or systems)	Ability to gain scale economies in R&D, production and marketing Ability to offer a range of complementary products Ability to bid for large turnkey projects
Growth	(Can experience difficulty in acquiring external capital necessary for rapid growth Entrepreneurial managers sometimes unable to cope with increasingly complex organisations)	Ability to finance expansion of production base Ability to fund growth via diversification and acquisition
Patents	(Can experience problems in coping with the patent system Cannot afford time or costs involved in patent litigation)	Ability to employ patent specialists Can afford to litigate to defend patents against infringement
Government regulations	(Often cannot cope with complex regulations Unit costs of compliance for small firms often high)	Ability to fund legal services to cope with complex regulatory requirements Can spread regulatory costs Able to fund R&D necessary for compliance

such equipment. Furthermore, investment in flexible technology may enable small firms to achieve increased economies of scale, normally only associated with large firms

Small and large firms may also try to emulate each others' advantages, as discussed by Nooteboom (Nooteboom, 1994) Many large firms have decentralised towards having autonomous business units, in order to encourage flexibility and innovation (whilst maintaining control of management, R&D, finance and marketing at the corporate level) The increase in outsourcing to smaller suppliers (discussed in section 2.1.1 2) is a similar means of capturing the benefits of dynamic complementarities (Nooteboom, 1994; Rothwell, 1983). Meanwhile, small firms sometimes try to gain some of the advantages of large firms by forming networks of independent firms (Nooteboom, 1994) Hanna and Walsh observe that this tactic can be used by groups of small firms to enable them to move up the supply chain, by offering a portfolio of capabilities (Hanna and Walsh, 2000)

Despite the attempts described above of large and small firms attempting to capture each others' advantages without losing their own beneficial characteristics, fundamentally large and small firms tend to be different and contribute to innovation in different ways (Nooteboom, 1994). This often means that large and small firms actually work together in innovation – for example small firms may innovate to develop customer-specific add-ons (Rothwell, 1983). Pavitt (Pavitt, 1984) also noted that in certain industry sectors, small firms "live in symbiosis" with large firms, providing them with technologically innovative and specialised production equipment and instrumentation Networking between firms is recognised as a vital part of the innovation process (Rothwell, 1992), and this is explored further in section 2.2.1.

2.1 2.3 Agents of Change

Large and small firms may have particular roles in innovation according to the age of the industry and the progression of the industry cycle In the early stages of the lifecycle of an industry or market, firms compete on the basis of product innovation. Once a dominant design has been established, the emphasis has traditionally turned to process innovation to manufacture in higher volumes and at lower costs (Abernathy and Utterback, 1975). Entrepreneurial small companies can play a key role in radical product innovation at the start of a new industry, while in a mature industry, large firms will dominate, with process innovations to drive costs down (Rothwell, 1983).

Small firms therefore have a particular role as agents of ındustrial change. As dıscussed ın the prevıous sectıon, large firms are less flexıble and more bureaucratic than small fırms. Sınce they tend to have more vested ınterests ın continuing wıth exıstıng products and markets, ıt ıs dıfficult for them to change course Bower and Chrıstensen provıde evıdence of how large dısk-drıve manufacturıng companıes repeatedly found themselves losıng theır markets to small fırms offering dısruptıve new technologıes (Bower and Chrıstensen, 1995)

Although small firms act to create new markets and new ındustrıes, Audretsch (Audretsch, 2001) explaıns that theır ınnovatıons wıll often stem from R&D actıvıty in large firms Ideas may come from an ındıvıdual wıthin a large organısatıon, but the best way to commercıalıse the ıdea wıll sometımes be to start up a new company. One reason for thıs ıs that the decısıon-makers ın the large fırm often do not recognıse the value of the ıdea, partıcularly ıf ıt does not serve their exıstıng market, and may not be wıllıng to rısk ınvesting ın an unproven idea. Another problem may be that even ıf senıor management support the new ıdea, resıstance to change and vested interests wıthın the organısatıon may result ın resources beıng dıverted back ınto the exıstıng product markets (unless a unıt ıs establıshed wıth dedıcated personnel and a rıng-fenced budget) (Leıfer et al , 2000) Rothwell (Rothwell, 1989) commented that whıle large firms "*are adept at utılısıng the results of theır ınventıveness ın-house (*new *technology for* exıstıng *applıcatıons), they are less well adapted to the rapıd exploitatıon of their inventions ın new markets (*new *technology for* new *applıcatıons)*". Spın-off companıes therefore play an ımportant role ın exploıtıng such ınventıons and creatıng new markets Through thıs, small firms play a sıgnıficant role ın dıffusıng new technologıes ınto general use and creatıng new ındustries (Rothwell, 1984, Rothwell, 1989)

The role of small firms ın ınnovatıon depends not only on the maturıty of an ındustry, but also on the partıcular nature of the industry, and this will be consıdered next

2 1 2 4 Industry Sectors

Small firms contrıbute to ınnovatıon ın dıfferent ındustry sectors ın dıfferent ways. Pavıtt (Pavıtt, 1984) ınvestigated the source of ınnovations ın varıous ındustry sectors, and found that whıle large firms dominate ınnovatıon ın sectors such as electronıcs and chemıcals, small specıalıst firms contrıbute sıgnıficantly to ınnovatıon ın mechanıcal and instrument engıneerıng Pavıtt developed a useful classificatıon of firms based on hıs

Table 2.3 A technology-based classification of business firms (Pavitt, 1994)

	Category of Firm				
Characteristics	**Supplier dominated**	**Scale intensive**	**Information intensive**	**Science based**	**Specialised supplier**
Typical core sector	Agriculture, Housing, Private services, Traditional manufacturing	Bulk materials (steel, glass), Consumer durables, Automobiles Civil engineering	Finance, Retailing, Publishing, Travel	Electrical/ electronics, Chemicals	Capital goods, Instruments Software
Size of firm	Small	Large	Large	Large	Small
Type of user	Price sensitive	Mixed	Mixed	Mixed	Performance sensitive
Main focus of technological activities	Cost reduction	Mixed	Mixed	Mixed	Product improvement
Main sources of technological accumulation	*Suppliers* Production learning, Advisory services	*Production engineering* Production learning, Suppliers, Design	*Corporate software and systems engineering* Equipment and software suppliers	*Corporate R&D* Basic research, Production engineering, Design	*Design and development, Advanced users*
Main direction of technological accumulation	Process technology and related equipment (*upstream*)	Process technology and related equipment (*upstream*)	Process technology and related software (*mixed*)	Technology-related products (*concentric*)	Product improvement (*concentric*)
Main channels of imitation and technology transfer	Purchase of equipment and related services	Purchase of equipment, Know-how licensing and related training, Reverse engineering	Purchase of equipment and software, Reverse engineering	Reverse engineering, R&D, Hiring experienced engineers and scientists	Reverse engineering, Learning from advanced users
Main strategic management tasks	Use technology generated elsewhere to reinforce other competitive advantages	Incremental integration of new technology in complex systems, Improvement and diffusion of best practice, Exploit process technology advantages	Design and operation of complex information-processing systems, Development of related products	Develop related products Exploit basic science, Obtain complementary assets, Reconfiguring divisional responsibilities	Monitor advanced users needs, Integrate new technology in products

findings and on the SPRU database of innovations in the UK (described in section 2 1.2 1 above). Pavitt's technology-based taxonomy, shown in Table 2.3 (reproduced from (Pavitt, 1994)), categorises business firms as being supplier dominated, scale intensive, information intensive, science based or specialised suppliers. Small firms are typically found in the supplier dominated or specialised supplier categories according to this classification system. Recent years have however seen the emergence of different kinds of small firms - university and company spin-offs which are very definitely science and technology-based (e g in areas such as biotechnology), and also small companies which are clearly information intensive, with the growth in the ICT sector. In addition, it has been observed that high-technology small companies can be found in sectors that are considered to be traditional and low-technology (Baldwin and Gellatly, 1999) Pavitt's classification is therefore somewhat dated.

Autio has made a particular study of new technology-based firms (NTBFs), distinguishing between science-based NTBFs and engineering-based NTBFs (Autio and Geust, 1996) Science-based NTBFs are seen as transforming scientific knowledge into basic technologies – either industry-specific technologies or "paradigmatic" technologies which can be easily integrated with other basic technologies, and have a broad scope of applications across traditional industry sectors Engineering-based NTBFs then either utilise industry-specific basic technologies in industrial applications, or paradigmatic technologies in functional applications. On the basis of this, four distinct innovator roles are identified: application innovators, technology innovators, market innovators and paradigm innovators (see Table 2 4 and Fig 2.2) *"Application innovators employ existing basic technologies in an existing market environment. Technology innovators introduce new basic technologies in an existing market environment Market innovators employ basic technologies in a new market environment Paradigm innovators develop new basic technologies for new market environments "* (Autio, 1997a)

Table 2.4 Tentative classification of interrelationships between transformator roles, innovator roles, and systemic influences **(Autio, 1997a)**

Characteristic	**Engineering based industry specific**	**Science based industry specific**	**Engineering based paradigmatic**	**Science based paradigmatic**
Likely innovator role	Application innovator	Technology innovator	Market innovator	Paradigm innovator
Characteristic of knowledge base	• Tacit, complex • Non-systemic • Application specific	• Codified, complex • Non-systemic • Industry specific	• Mixed, complex • Systemic • Concept specific	• Codified, complex • Systemic • Function specific
Source of differentiation	Customer	Industry	Product or service concept	Scientific discipline
Location of technology source	Industry	Academic research	Industry, R&D organisations	Academic research

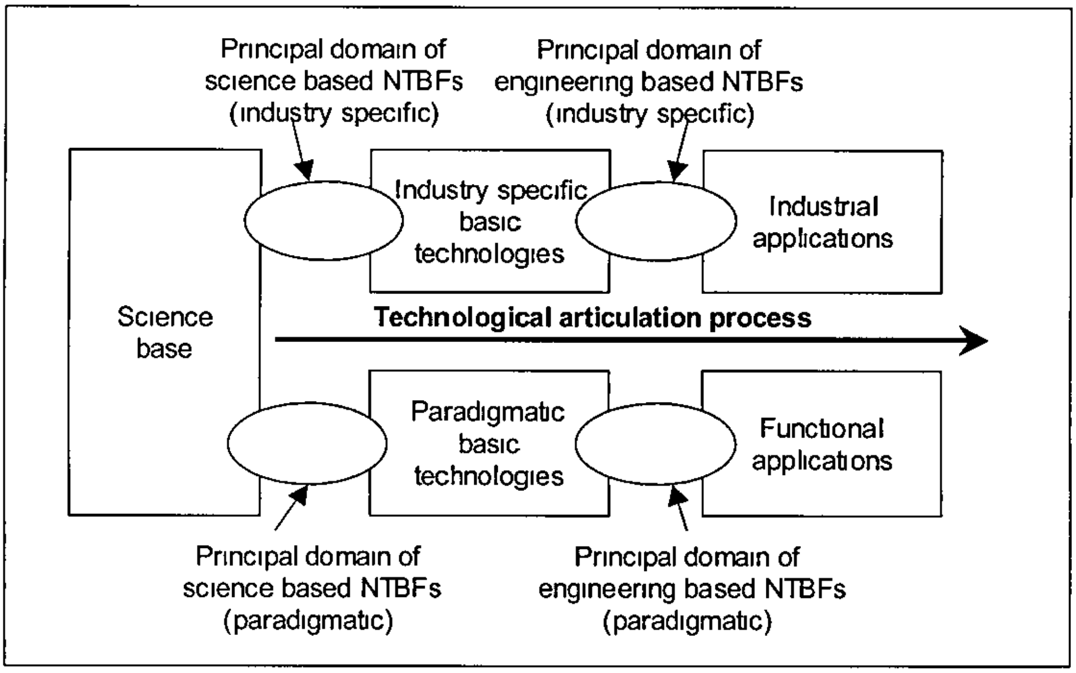


Figure 2.2 Functional roles of science based and engineering based NTBFs in industry specific and in paradigmatic technology systems (Autio, 1997a)

While the work of Autio and Pavitt implies that large and small firms play different roles in innovation in different industry sectors, a study by Miller and Blais (Miller and Blais, 1993) identified four distinct modes of innovation in 43 firms in six industrial sectors, but did not find firm size to be a (statistically) significant factor. Firms classed as "entrepreneurial fast-track experimenters" and "conventional reliance on IT and process adaptation" were not characterised by their size. It did appear, however, that of the four innovation modes, firms classed as "global cost leaders" were all large firms, while those classed as "science-based product innovators" tended to be medium-sized This does support the fact that large firms will dominate certain industry sectors (and may in fact choose strategies such as investing in areas such as R&D and advertising to such a level as to disadvantage smaller competitors (Kwoka and White, 2001)). SMEs may be prevented from participating in some industry sectors by the dominant technology, while in other sectors the dominant technology may lend itself to opportunities for small firms (Rothwell, 1989) One industry sector where both large and small firms are competing is the satellite industry (Carayannis and Roy, 2000) Although this has traditionally been dominated by large companies with major government-funded research projects, small start-ups are now competing through smaller, cheaper satellites based on advanced miniaturisation technologies. The small firms in this sector have the advantage of sensitivity to technological advances and changes in market need, while the large firms are better placed to control the market by influencing market requirements, government regulations and technical standards. Thus, although small and large firms are competing in the same market, their innovation roles are not the same.

In certain industry sectors the symbiotic relationship (Pavitt, 1984) of large and small firms means that it is difficult to untangle their individual contributions to innovation Hobday's research into high cost, complex products and systems (CoPS) shows that innovation in these types of sector involves producers and users, suppliers, regulators and professional bodies (Hobday, 1998) In such sectors, systems integrators maintain networks of specialised technology suppliers who are effectively locked into the network by their customer-specific competencies (Autio, 1997b)

2 1 2 5 Role of Small Firms in Innovation – Summary

The literature identified in this section demonstrates that the role of small firms in innovation is complex and varies according to the maturity and type of each industry sector The behavioural advantages of small firms give them certain advantages in innovation, but this is countered by the resource disadvantages they face.

A major limitation of the innovation literature is that it does not provide a complete, dynamic picture of how the roles of large and small firms are changing as industry structures change The finding that small firms were responsible for an increasing share of innovations (Pavitt et al , 1987), and the emergence of industries based on new technologies (Autio and Geust, 1996) and complex products and systems (Hobday, 1998) only provide glimpses of how roles may be changing. In section 2 1.1.2, industry dynamics were considered with respect to the increasing level of outsourcing Large firms are outsourcing more design and manufacture to suppliers – not only of components, but also of whole sub-systems and sub-assemblies. Activities which previously relied on the internal R&D facilities and specialist staff of large firms have now become the domain of smaller firms with a very different set of skills Small firms are typically more responsive to market needs than large firms – but in this situation they can only respond to the requirements of their immediate large customer since they are at least one step removed from the end user. In some senses, this appears to be the antithesis of dynamic complementarities (Rothwell, 1983) – blending the resource disadvantages of small firms in R&D with the behavioural disadvantages of large firms in market responsiveness It also remains unclear what is happening to the types of R&D previously conducted by large firms to support their internal design and manufacturing activities – have these activities been taken up by small suppliers, or by other technology-based firms, research institutes or universities – or have they been abandoned altogether? Since some of the literature suggests that small firms often exploit the technologies developed through large firm R&D (Nooteboom, 1994), this could begin to have a broad impact on technological innovation.

2.1.3. So which Suppliers are of Interest to this Research?

To conclude this section, a summary is given of the nature of the manufacturing suppliers which are at the centre of this research These are the firms to whom large systems integration companies are outsourcing increasing amounts of design and manufacture. Since the market already exists and the large firms are outsourcing activities previously undertaken in-house, these firms are clearly operating in mature industry sectors. The suppliers are likely to be small firms, because the focus is on the lower volume niche products such as those found in the aerospace sector. Although they may be small firms, they may be quite different from the entrepreneurial small firms which create entirely new markets with disruptive technologies – traditional manufacturing suppliers rather than science park SMEs, with the greater reliance on customers and weaker bargaining power that is associated with manufacturing embeddedness (Autio, 1997c). Dankbaar describes such companies as technology-contingent (Dankbaar, 1998).

These companies are the specialised suppliers of Pavitt's classification (Table 2.3) and are closest to the industry-specific, engineering-based NTBFs of Autio's classification (Table 2 4) (although they may in fact be neither new firms nor based solely on new technology) As such, they can be expected to develop industrial applications for commercially available technologies, without needing to rely on formal R&D. Yet industry and market requirements increasingly demand the blending of what Autio terms "paradigmatic" technologies, to produce complex sub-systems and sub-assemblies This fusion of technologies has been described by Kodama (Kodama, 1992), who considers the implications for large firm R&D Technology integration necessitates a new level of expertise from suppliers – in understanding how to design and manufacture products combining a number of different technologies, and how to identify the appropriate technologies in the first place. It is here that the resource limitations of small firms may pose serious difficulties. Small firms remain best placed to provide customised solutions for niche market needs, but their role in exploiting technologies is increasingly becoming more challenging

2.2. Literature

Having "set the scene" for the research, attention is now given to what the existing literature has to say about the influences on technological capability in small manufacturing suppliers This review will consider what is currently "state of the art", and where there are gaps in academic knowledge The first topic to be discussed is what external and internal factors influence small firm technological capability. The focus then moves to the sources of information used by small firms in innovation. Customer influence is explored, and small firm use of technology management techniques to develop their own capabilities.

2.2.1. What Influences Small Firm Technological Capability?

Small firm technological capability is influenced by a range of external and internal factors In terms of external factors, a useful concept to be found in the literature is that of the "innovation system" The innovation system comprises the network of different actors who contribute to the innovation process – not only companies, but other organisations including universities, government organisations and research institutes (Edquist, 1997) This idea reflects the "networking" aspect of the fifth generation model of innovation (Rothwell, 1992), which was described in section 2.1 1 1 In this context, technological innovation is not seen as something which happens exclusively within a large firm or a small firm, but instead it is the product of collaboration and the diffusion of information and technology between elements in the system. Small firm technological capability is therefore influenced by other organisations within the innovation system and by the strength of their links with these organisations.

Some policy research has focused specifically on national innovation systems – for example, the DTI undertook a study of the national innovation system in the UK (Vithlani, 1995), while another study compared the national innovation systems in a number of the Organisation for Economic Cooperation and Development (OECD) countries (OECD, 1997). Freeman observed that despite increasing globalisation, there remain major differences between countries in innovation, and "*the influence of the national education system, industrial relations, technical and scientific institutions,* *government policies, cultural traditions and many other national institutions is fundamental*" (Freeman, 1995). Research into national innovation systems generally focuses on knowledge transfer among formal R&D, educational and economic organisations, and on the processes of innovation and learning (Edquist, 1997) Martin and Johnston (Martin and Johnston, 1999) specifically considered the role of Technology Foresight programmes in strengthening the national innovation systems in the UK, Australia and New Zealand – by improving the linkages between the organisations within those systems

There has also been a certain amount of interest in innovation systems at the regional level, as regional authorities attempt to boost the competitiveness of local businesses. For example, Cooke et al (Cooke et al , 1997; Cooke et al., 1998) identify the characteristics required for successful regional systems of innovation, both in terms of financial and infrastructure, and in terms of the culture of institutions and organisation A distinction is made between simple geographical clustering of industry sectors and situations of regional embeddedness, where interactions are based on relationships of trust and cooperation Geographical proximity is not considered to be enough to attain the benefits such as interactive learning which come from regional embeddedness (Cooke et al , 1998) Bryson and Daniels appear to promote a contrasting view, that small firms have too many strong ties with their local business community (Bryson and Daniels, 1998) They cite Granovetter's hypothesis (Granovetter, 1982) that "weak ties" are critical to diffusing innovations. The suggestion is that within a close-knit community, much of the knowledge is shared, so that for new information and expertise it is often necessary to look to the "weak ties" of looser acquaintances and business connections. The best source of information or technology may be found outside the local region.

Some of the linkages between small firms and other organisations are manifested in collaborative R&D projects and formal networks funded by national government or European initiatives These public programmes provide linkage to external and international networks which can benefit small firms in innovation (Cooke and Wills, 1999). In the past, such programmes have been criticised for failing to meet small firm needs because they have been restricted to "far-from-market" activities, and also ignore the importance of vertical supply chain links to small firm innovation (Rothwell and Dodgson, 1991; Cosh and Hughes, 1998). There are also implications in trying to impose formal networks on groups of companies (Macdonald and Lefang, 1998), since some types of information are transferred more readily through informal networks Attempts to formalise mechanisms for information acquisition are likely to suppress and distort the informal information flows which are important for both strategy formulation and innovation (Macdonald, 1996; Macdonald, 1998). (Information flow is "informal" where there is no formal accounting of each information exchange – trying to monitor information flow (and put a price on it) is likely to hinder the process.) Formal networks can nevertheless prove to be sources of innovation in themselves, and also act as a catalyst for informal networking (Malecki and Tootle, 1996)

Other external factors which may influence small firm technological capability indirectly include the current economic climate (affecting funds available for technological development and recruitment), government policies (for example the availability of tax credit for R&D expenditure or in training and education) and legislation (such as the current environmental focus on end-of-life issues for products).

The individual employees within firms have a significant impact on the technological capability of small firms – for example, personal networks are cited as particularly important for key employees in high-technology industries, where innovation is critical for gaining a competitive edge (Macdonald, 1998). The importance of personal relationships is also apparent from the way in which entrepreneurs are able to leverage and combine the capabilities of several different suppliers to provide innovative solutions (Lipparini and Sobrero, 1994). As well as the personal networks of individuals, their educational background is significant (Souitaris, 2002), since without suitably qualified scientists and engineers it can be difficult for a small firm to "*assimilate and further develop technological know-how, even when it does succeed in acquiring it from external sources*" (Rothwell and Dodgson, 1991)

Other internal factors which are likely to influence small firm technological capability include the top management of the company. for example, the attitudes of SME owner-managers are considered to influence their innovation support needs (North et al , 2001). Management approach to risk and their strategic approach to technology will also have an impact (Entrialgo et al , 2001, Dodgson, 1993)

While all of these factors are interesting because they influence small firm technological capability, this thesis will focus on the particular elements where this researcher can contribute to understanding. This process of narrowing down the research area is depicted in Fig 2 3. This shows that matters of education, manager characteristics, economics and public policy are not pursued further here, and are set aside for suitably qualified researchers to address Instead the linkages between small firms and their environment and the flows of information which influence technological capability are explored further.

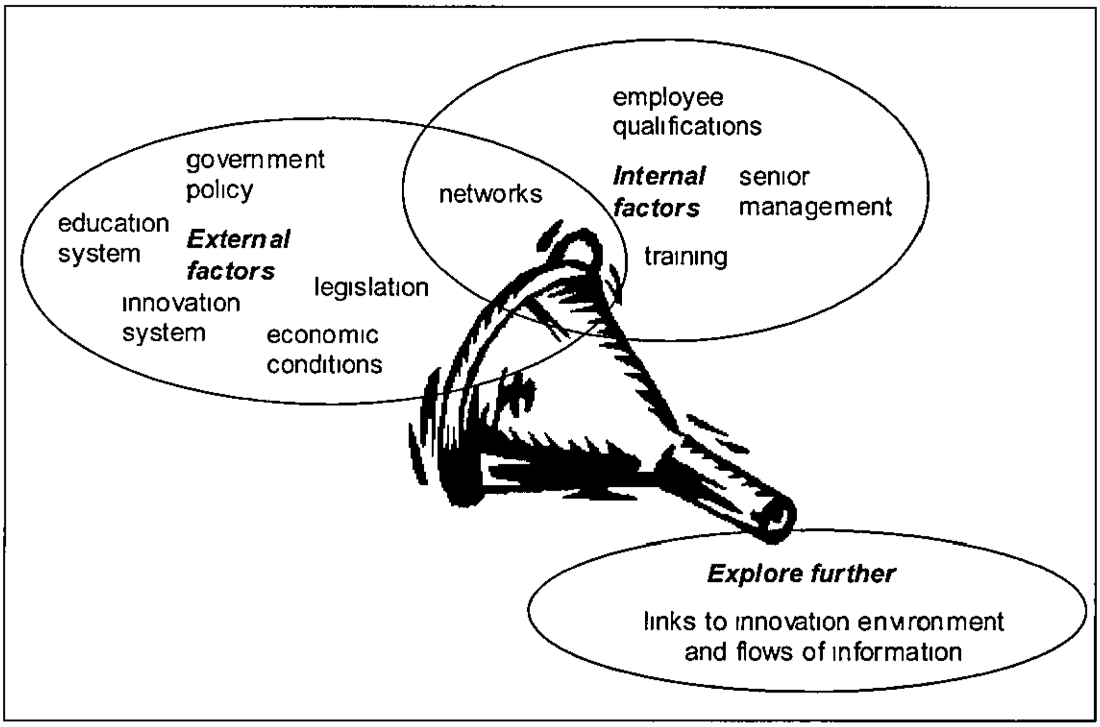


Figure 2.3 Influences on small firm technological capability – "funnelling" ideas to explore further

2 2 1 1 Sources of Information for Innovation Used by Small Firms

Having examined how small firms operate as part of an "innovation system", the next consideration is how they utilise other organisations within the system to draw out information for innovation. (N B The other organisations within the system will be referred to as the "innovation environment" in order to centre on the perspective of the small firm The term "innovation system" emphasises the systems perspective instead.)

In some cases, the sources of information in the innovation environment will also be the sources of new technology – for example in Table 2 3, Pavitt's supplier-dominated firms will look to suppliers as sources of both information and technological accumulation, while in Table 2 4, science-based NTBFs will need to access information about academic research before being able to acquire the necessary technology from the university. In other cases, the sources of information for innovation and the sources of new technology may not be the same: in Table 2.3, the specialised suppliers will accumulate technology by design and development but will utilise information from advanced users to stimulate their design and development activities

There are a number of published surveys available which have analysed innovation in UK SMEs These include

- UK Department of Trade and Industry (DTI)/Office for National Statistics (ONS) Survey 1995
  - Sampled SMEs (with 20-250 employees) in the manufacturing sector (Lambert and Barber, 1998; Marsh, 1996)
- Economic and Social Research Council (ESRC) Centre for Business Research (CBR) (University of Cambridge) Surveys 1991, 1993, 1995, 1997, 1999
  - Sampled SMEs (with 1-500 employees) in the manufacturing and business service sectors (Cosh and Hughes, 2000, Cosh and Hughes, 1998; Cosh and Hughes, 1996, Small Business Research Centre, 1992)
- Confederation of British Industry (CBI)/3M/NatWest Innovation Trends Surveys (Annually 1989-2002)
  - Sampled large and small companies in manufacturing and non-manufacturing sectors (CBI, 1995-1999; Coombs and Tomlinson, 1998; CBI, 2001, CBI, 2002)
- Community Innovation Survey (UK) 1998 and 2001 (conducted by ONS for DTI)
  - Sampled firms with greater than 10 employees in the manufacturing sector and most of the service sector (Craggs and Jones, 1998, Stockdale, 2002)

These quantitative surveys begin to reveal the importance of the various elements of the innovation environment to small firms The different surveys consistently identify customers and suppliers as the prime external sources of information for innovation, which is confirmed elsewhere in the literature (Belotti and Tunalv, 1999; Vos et al , 1998, Hall et al , 1999; Hall et al., 2000, Fuellhart, 1999). Fig. 2 4 illustrates the importance of the supply chain in graphical form using data from the 1995 CBR survey The 1995 DTI/ONS survey separated process and product innovation (Fig. 2.5), demonstrating that customers are particularly useful sources of product ideas, while equipment suppliers are useful for process ideas

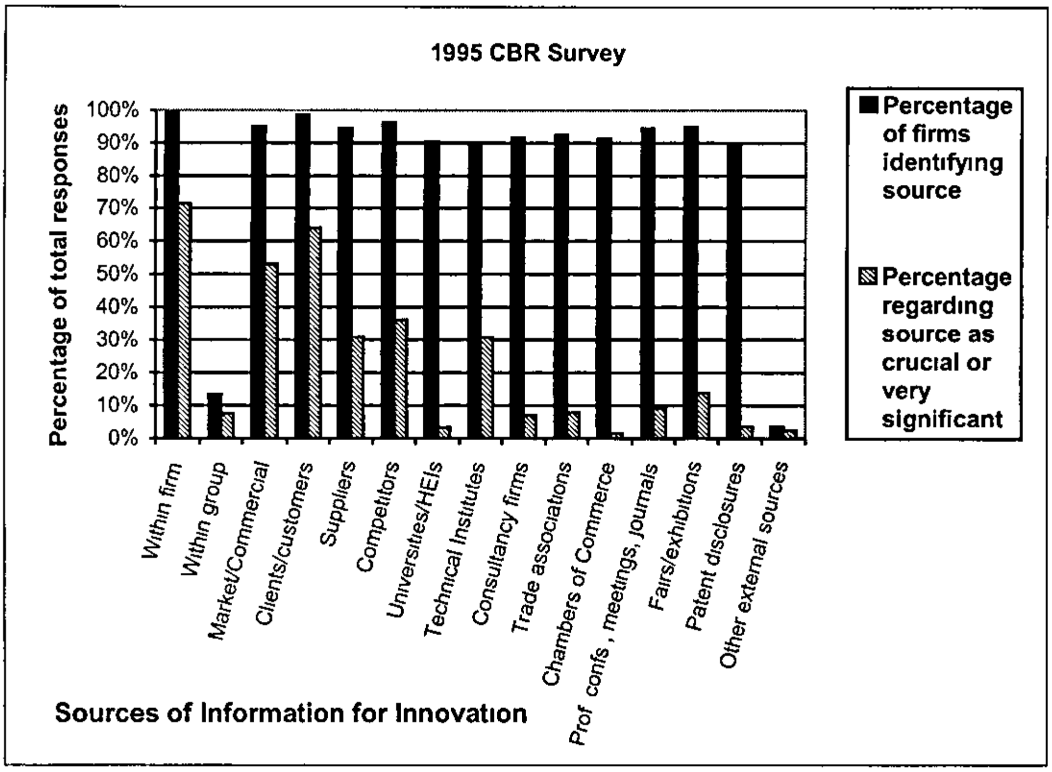


Figure 2.4 1995 CBR survey (Cosh and Hughes, 1996) – sources of information for innovation (data plotted by author)

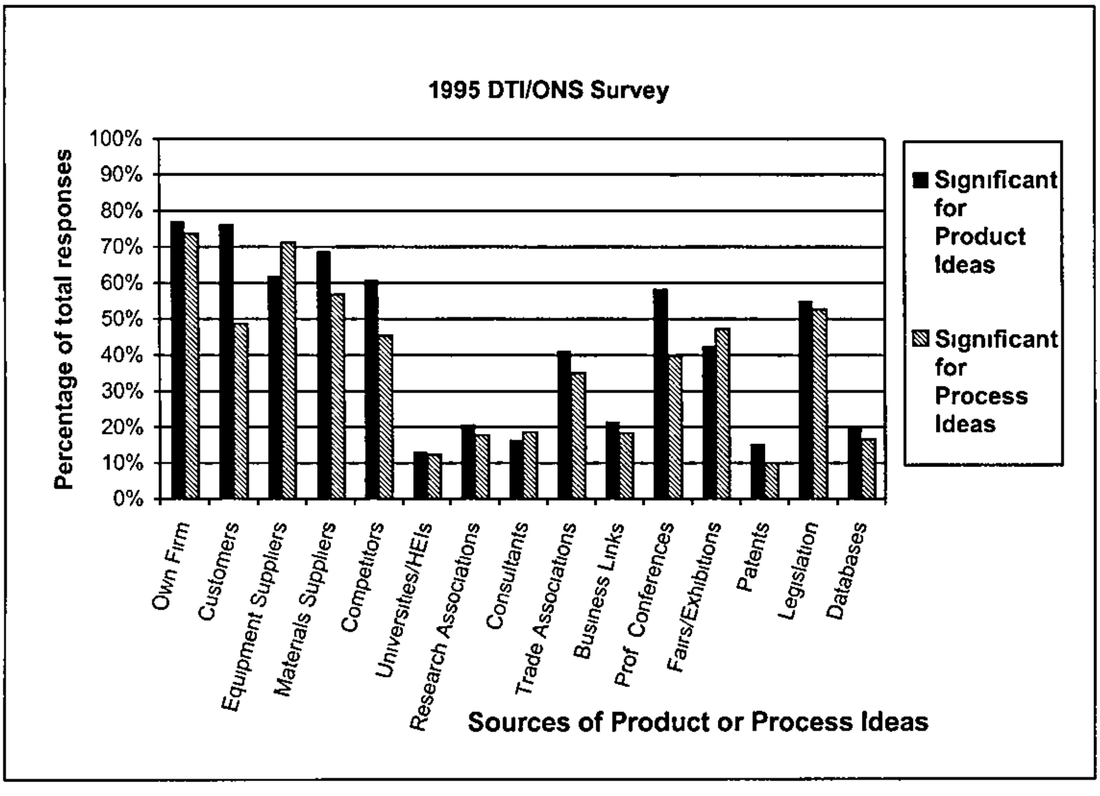


Figure 2.5 1995 DTI survey (Lambert and Barber, 1998) – Sources of product/process ideas (data plotted by author)

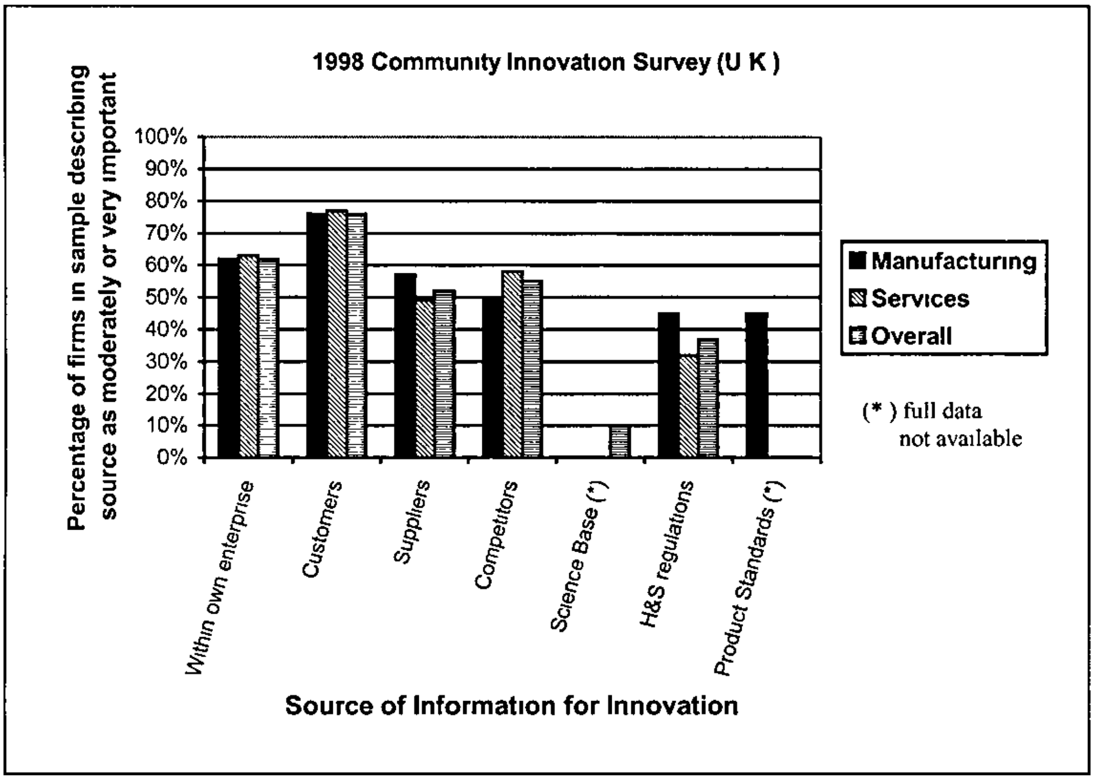


Figure 2.6 1998 CIS survey (Craggs and Jones, 1998) – sources of information for service and manufactui ing sectors (data plotted by author)

Differences between manufacturing firms and service firms were identified in the 1998 Community Innovation Survey (Fig.2 6) - competitors are a more important source of information for service companies, whereas suppliers are more useful to manufacturers.

Contributions to the innovation process were also found to come from the information and informal networking opportunities provided by conferences and exhibitions and by trade associations (small firm regard for trade associations is confirmed elsewhere in the literature (North et al., 1997)). Other sources of information did not rate particularly highly, except in the CBI survey for 1998 (CBI, 1998), which implies that Business Links, higher education institutes (HEIs) and commercial research organisations provide a reasonably high input. The CBI survey, however, does not distinguish between sources which firms regard as important and those that are not so significant: it simply records the percentage of firms which mention the source. Nevertheless, 50% of SMEs cited universities as a source of information in 1998, compared with 35% in 1997 – at the same time as the overall percentage of manufacturing firms citing universities dropped from 63% to 57% This suggests that universities could be gaining a higher profile with SMEs

There is some scepticism that SMEs actually need access to high level university research, since the majority of small firms perform only incremental process innovation with relatively low level needs (Belotti and Tunalv, 1999; Bessant, 1999). Of course, small firms are not a homogeneous group, and the approach to information sources varies from company to company. Major and Cordey-Hayes (Major and Cordey-Hayes, 2000) categorised SMEs as "involved", "open" and "uninvolved", and observed that only the middle group would be responsive to business support Each group tends to use different sources – "uninvolved" SMEs are characterised as being reliant on supply chains and using little external networking, very much in contrast to the "involved" SMEs who work directly and strategically with universities, institutes and non-member research and technology organisations (RTOs) The "open" SMEs are those who use Chambers of Commerce, Trade Associations and membership RTOs. The focus of this research is on the more "typical" SMEs who are likely to fall into the "open" or "uninvolved" categories

The literature demonstrates the importance of customers and suppliers as a source of information for innovation for small firms, and the lesser (but still significant) role played by other elements in the innovation environment. It does not specifically reveal how or whether these sources are used to gain information about future technology requirements The important relationship with customers is now explored in order to probe this further, before investigating how small firms use other organisations in their innovation environment through their own strategic management of technology.

Key findings:

- **significance of supply chain sources of information**

Explore further:

- **influence of customers**
- **how small firms utilise rest of innovation environment**

2.2.2. What Does the Literature Say about Customer Influence?

In the previous section, the importance of customers as a source of information for innovation was identified Customer influence on small firm technological capability may be evident in the formal interactions between the buying firms and their suppliers. The literature concerning such formal interaction focuses on two areas: firstly the involvement of suppliers in the new product development process, and secondly supplier development. These two areas are explored below in order to discover what the literature has to say about customer influence on small firm technological capability

2 2 2 1 Concurrent Engineering and New Product Development (NPD)

Involving suppliers in new product development is an extension of concurrent engineering It is relevant to this research because often it involves companies working with their suppliers on technological issues and potentially influencing the technological capability of the supplier.

Concurrent engineering has become popular as a means to cut product development times, to improve quality and design-for-manufacture and to cope with the increasing complexity of products (Swink et al., 1996, Haddad, 1996; Nevins and Whitney, 1989; D'aveni, 1999). Traditionally new products have been developed through a series of stages, passing sequentially from concept creation to design, testing and production, with each stage controlled by a different function – e g the R&D department or the manufacturing department. The alternative offered by concurrent engineering is for cross-functional teams to work on various parts of the new product development at the same time This does not alter the natural order of the tasks involved in product development, but by overlapping those tasks and increasing communication between the different departments involved in the development, costly design iterations can be avoided because the earlier tasks are performed with due consideration of the requirements at later stages of the development (Kusiak and Belhe, 1992; Dwivedi et al , 1990)

Inter-organisational concurrent engineering is a logical extension of the concept, since it encourages the input of customers and suppliers in the design process. The practice of "early supplier involvement" (ESI) in new product design and development has been found to be related to the number of supplier base initiatives, lower product integration, broader supplier scope and a higher proportion of purchased parts (Bidault et al , 1998a) Bidault et al. found that ESI levels were lower at both low and high purchase volumes. For high volumes, this may be because the parts purchased tend to be standard products or because custom parts are produced in-house due to economies of scale. At low volumes, suppliers are unlikely to get too involved since there is little opportunity to recoup design expenses.

The literature concerning ESI covers a variety of research themes, from ESI "best practice" (Dowlatshahi, 1998) and success factors (Ragatz et al., 1997), to customer perceptions of suppliers' contributions (Hartley et al., 1997; McCutcheon et al , 1997) Handfield et al consider the optimum time at which to integrate suppliers (Handfield et al., 1999). suppliers of complex items, systems or subsystems, critical items or technologies should be involved earlier (towards the idea generation stage), as should strategic alliance suppliers and "black box" suppliers. Conversely, suppliers of simpler items, single components, less critical items or technologies should be involved later, towards the prototyping stage – alongside non-allied suppliers and "white box" suppliers. The rate of technological change is another important factor since ESI could result in design lock-in with an obsolete technology The ESI literature does not appear to consider the size of firm to be an issue and there are few references to small firms.

There is a question as to whether ESI and concurrent engineering have an impact on innovation. Swink et al observe that supplier involvement is critical for highly innovative products, where the information provided by suppliers helps to reduce the technical uncertainty of the project (Swink et al., 1996). Handfield, however, observes that while concurrent engineering may provide benefits for incremental innovation, it appears to be less successful when applied to "breakthrough" or radical innovation (Handfield, 1994) The concurrent engineering mindset focuses on speed (i.e cutting product development time), which may have a detrimental effect on the development of breakthrough products by increasing defect levels This is partly because breakthrough products often incorporate state-of-the-art technology which may not have been fully de-bugged, but there is also danger of mistakes due to lack of familiarity with the technology. Gagnon (Gagnon, 1999) identifies the current optimisation for product development speed as creating a significant challenge for the development of electric vehicles The automotive industry has become accustomed to using concurrent engineering for incremental innovation, but radical innovation requires creativity rather than speed. The organisational structures employed in concurrent engineering - such as the use of cross-functional, cross-organisational teams - lend themselves well to technological innovation, but different targets for performance will be necessary. A greater focus on generating knowledge about core technology, rather than on design, is also required

Since the focus of this research is on the development of suppliers' technological capabilities, processes that relate particularly to technology and long-term issues are of particular interest. The process of involving suppliers in new product development is very likely to relate to technological capability in some way, although there appears to be little evidence in the literature of technology transfer resulting from such collaboration. It may lead to the informal exchange of long-term technology lookahead information, but it is debatable as to whether NPD can be described as a long-term activity with today's ever-shortening development cycles Inter-organisational NPD tends to work towards product specifications which have already been broadly defined, and is often limited to the use of proven processes and technologies (particularly where there are qualification procedures to be followed, as in the automotive industry). In terms of formal processes designed to enhance long-term supplier capability, supplier development could potentially be more relevant than new product development.

Key findings:

- **inter-organisational concurrent engineering focused on cuttin product development time rather than on innovation**
- **no direct link established between customer-supplie interactions in new product development and long-ter supplier technological capability**

2 2 2 2 Supplier Development and Supply Chain Learning

The discussion in section 2.1 1 highlighted the need to think about technological capability as a supply network issue The supply chain management literature provides insight into the manufacturing supply network, but some of the research in this field is however biased towards concerns over logistics (e g. (Christopher, 1998)), which is not of direct relevance to the topic under consideration here. Supplier development could be one mechanism to help suppliers in developing their technological capability, and so this particular subject was examined in detail.

The introduction of supplier development by many large firms indicates that they are taking a supply chain view rather than simply ignoring matters outside of their own firm. A small body of literature concerning supplier development has appeared over the past decade, mainly arising from purchasing and materials management research. A helpful summary of this literature is provided by Krause and Handfield (Krause and Handfield, 1999). The following review looks broadly at the supplier development literature, and also pays particular attention to the way in which the supplier development literature addresses technology

Monczka et al (Monczka et al, 1993) put forward a strong case for the need for supplier development, explaining that despite a clear trend towards increased reliance on suppliers, supplier performance is "*not improving at a rate that will satisfy future expectations or requirements*". The literature distinguishes between supplier development which is simply a process to select appropriate new suppliers to meet a firm's requirements, and that which involves active intervention to upgrade existing suppliers' capabilities e g. (Hahn et al, 1990; Watts and Hahn, 1993). The emphasis of the supplier development literature is however generally on active intervention (Monczka et al, 1993, Watts and Hahn, 1993, Hartley and Choi, 1996; Krause, 1997; Krause et al., 2000; Krause and Handfield, 1999). Here the term supplier development will be used solely to describe active intervention with existing suppliers, although this intervention could include anything from direct firm involvement to providing incentives for improvement or enforced competition (Krause, 1997) Monczka et al. called for aggressive approaches to improve supplier performance, suggesting that direct involvement such as providing personnel, capital, technology and equipment resources will accelerate supplier capability improvements. US businesses prefer a "hands-off" approach, e g increasing performance goals for suppliers, and providing limited education and training to suppliers. This approach may however only result in steady improvement at a rate inadequate to meet their future need for world-class suppliers (Monczka et al., 1993)

Supplier development schemes have been widely in use by large companies for over a decade (Watts and Hahn, 1993) The roots of supplier development are particularly associated with the automotive industry, when Japanese car manufacturers recognised the need to make significant improvements in the local supply base in their European and North American manufacturing operations (Lamming, 1993) Most intervention by customers has been limited to the first tier level, with first tier suppliers expected to work with their suppliers and so on There can be a certain arrogance on the part of large companies who take advantage of their dominant role in their supplier partnerships and impose "improvements" on their suppliers that may not necessarily benefit their performance outside of their business with that particular customer It is however possible to co-operate for the mutual benefit of both parties (Lamming, 1996), recognising that problems may not always originate with the supplier.

Krause et al. (Krause et al , 1998) distinguish between strategic and reactive approaches to supplier development, based on survey research. Companies engaged in supplier development are either using it reactively to deal with poor supplier performance or are using it strategically to enhance the long-term capability of the supply base The supplier development activities are similar for both the reactive and strategic groups, but firms with a strategic approach begin by identifying suppliers of commodities that are high supply risk, high volume or high value-added, and focus their supplier development efforts on these companies Watts and Hahn (Watts and Hahn, 1993) did not find a particularly strategic approach in their survey of supplier development programs, which revealed that companies were rather more interested in improving the products purchased than improving their suppliers' capabilities This demonstrates a short-term focus on improving the product "*to reduce the delivered cost, rather than looking at the process and systems related capabilities that can facilitate future improvements and cost reductions*"

Another study by Krause (Krause, 1999) investigated factors which precede a buying firm's involvement in supplier development Firms with a strategic approach might be expected to "*rely on suppliers to share the burden of designing and producing products that incorporate the latest technology, and the related production capabilities that accompany such an effort*" (Krause et al , 1998) Therefore there was a proposal that "*firms that compete in markets characterised by high rates of technological change are more likely to be involved in strategic supplier development*" (Krause et al , 1998). It was not however possible to confirm that the level of technological change in the buying firm's industry has a significant impact on the buying firm's perspective towards suppliers (Krause, 1999) The buyer's positive perception of supplier commitment has been found to increase the propensity of the buying firm to engage in supplier development, as does effective buyer-supplier communication. Informal communication with suppliers has been linked elsewhere to improved supplier performance (Giunipero, 1990).

The need for improvements in the technological capabilities of suppliers has been identified in the supplier development literature e g (Morgan, 1993). Hahn et al. (Hahn et al , 1990) in fact list technical capability before quality, delivery and cost capabilities in their supplier development activities matrix. Surveys of companies engaged in supplier development show that they give a lower priority to technology, however. Improving quality, cost and delivery (QCD) performance clearly remain the top goals of supplier development (Watts and Hahn, 1993, Krause and Handfield, 1999), with improving supplier technical capability and increasing supplier product development capability ranked 6th and 7th respectively (Krause and Handfield, 1999)

The priorities of supplier development programs probably reflect the nature and interests of the teams involved in supplier development Watts and Hahn (Watts and Hahn, 1993) found that procurement and quality control specialists participated in most supplier development activities, Engineering was involved in over half the cases, while materials management and production departments were involved to a lesser extent Marketing, research and development and finance representatives were also occasional participants Krause and Handfield (Krause and Handfield, 1999) identified cross-functional support as a critical success factor for supplier development and their findings, shown in Table 2 5, suggest an increased role for engineering in supplier development. Supplier development was often originally introduced as an extension to vendor assessment and open-book negotiation (Lamming, 1996) It can also be seen as an evolution from total quality management (Krause et al., 1998; Tan et al., 1998), and is linked to the field of logistics (Christopher, 1998). It is natural therefore that quality, cost and delivery are high priority areas for supplier development, particularly since purchasing usually have overall responsibility for supplier development (It is also easier to identify targets for improvement in QCD than in technological capability, due to the relative ease of performance measurement)

Table 2.5 Functions involved in the supplier development effort (Krause and Handfield, 1999)

Department	Percentage
Purchasing	97 0%
Quality Assurance	76 4%
Engineering	68 1%
Materials Management	52 1%
Manufacturing	49 7%
Accounting	11 4%
Marketing	8 5%
Other functions	4 0%

Supplier development has nonetheless been shown to be effective in improving suppliers' manufacturing processes (Hartley and Choi, 1996), as well as QCD The success of customers in providing a catalyst for improvement is attributed to their ability to provide an outsiders perspective, legitimise the need for change, and overcome the supplier's organisational inertia Sustaining these improvements without further customer involvement can be difficult for many suppliers For strategically important suppliers, a process-orientated supplier development programme may be used to build the supplier's capability for change (Hartley and Jones, 1997) and help sustain long-term improvement.

The UK Department of Trade and Industry have identified the supply chain as a route to transfer learning about best practice (DTI, 1999), and commissioned a report to investigate supply chain learning (Bessant et al , 1999). Among the conclusions was that supply chain sharing of best practice could only occur where trust, co-operation and mutual dependence were the underpinning values. One of the main exemplars of supply chain learning in the UK is the Society of Motor Manufacturers and Traders (SMMT) Industry Forum, which is seen as best practice for other industry sectors (DTI, 1998) The SMMT Industry Forum is industry-led and uses master-engineers from vehicle manufacturers and other external sources of "best practice" in training and support programs designed to improve competitiveness at the shop-floor level. (This programme is similar to - and is possibly based upon - the Japanese supplier association model described by Hines (Hines, 1994)) Master-classes are usually hosted by a first tier supplier, focussing on e g. one particular product and involving selected suppliers There are also supply chain programs looking at quality, cost and delivery, with a strong cost-down focus From discussions with a researcher based at the SMMT Industry Forum, it is clear that the focus is on issues such as removing unnecessary manufacturing processes, rather than anything which might be considered to advance technological capabilities. Reducing costs is the priority rather than long-term technological innovation.

Despite ranking technology as a relatively low priority, automotive and electronics companies in the US still estimate that a 15% improvement in access to new technologies is attributable to their supplier development effort (Krause and Handfield, 1999). The same study links long-term technological capability to supplier development as part of its vision of "integrative development" (i e development aimed at achieving a globally aligned supplier network). This includes the integration of suppliers in new product and process development, and considers issues such as outsourcing design, sharing technology roadmaps and supplier co-location, using case-study examples To date, only a few companies in the study had made any inroads at this, the most advanced level of supply base management.

Part of the challenge for "integrative development" (Krause and Handfield, 1999) described above includes establishing performance improvement in second-tier suppliers as well as first-tier suppliers This issue has also been addressed by Scannell et al. (Scannell et al , 2000), who studied how first-tier automotive suppliers are using supply chain management practices with their upstream suppliers Supplier development was considered alongside supplier partnering and Just-In-Time purchasing practices, looking at their effect on performance in terms of flexibility, innovation, quality and cost The only significant link found between supply chain management and innovation performance was the association between supplier development and process innovation performance. Scannell et al suggest that first-tier suppliers may "*allocate their training and technical resources to develop and align specific process capabilities, both internally and at their suppliers' facilities, to support long-term process improvements*" Product innovation and design quality were not correlated with supply chain management practices, but this could be because these practices have only recently been deployed upstream by first-tier suppliers

The literature described in this section suggests that supplier development often addresses technological issues to a greater or lesser extent, and may therefore be influencing supplier technological capability. Research in this area has however typically been conducted from a purchasing perspective rather than from a technological viewpoint, and therefore there is scope for more in-depth research on developing supplier technological capabilities. The literature has also tended to focus on the buying firms rather than exploring the impact of supplier development from the suppliers' perspective, and this gap has been acknowledged (Krause, 1997, Krause et al , 2000). There is also scope to take a systems approach to technology in the supply chain, which appears at present to be missing.

Key findings:

- **supplier development addresses technological issues as part of holistic approach to supplier capabilities**

Gaps:

- **no systems approach to technology in supply chain management**
- **supplier development research predominantly conducted by procurement specialists not engineers**

The next section considers the extent to which small firm technological capability is influenced by their own strategic technology management processes.

2.2.3. What Does the Literature Say about Small Firm Strategic Technology Management?

Having explored what the literature has to say about how customers influence small firm technological capability, consideration is now given to the way in which small companies utilise other elements in their innovation environment by examining the literature concerning strategic technology management and small firms

In fact, very little research has been published which directly addresses strategic technology management *within* small companies In one study, technology management was identified as a success factor for SMEs in innovation (Birchall et al., 1996), and in another it was linked to international competitiveness (Lefebvre et al., 1993). Technology management tools were also tested in both large and small companies as part of a major European collaborative research project into technology management, known as TEMAGUIDE (TEMAGUIDE). This appears to be the current extent of the small firm research addressing technology management as a general topic, although some Canadian research has considered technological scanning by small manufacturers (Raymond et al., 2001). This subject is approached instead from two different angles – firstly reviewing holistic approaches to technology management, then considering strategic planning as it relates to small firms, attempting to draw inferences for technology management

2 2 3 1. Holistic Approaches to Technology Management

There are a limited number of papers concerning holistic approaches to technology management in the academic literature. Durrani et al. (Durrani et al , 1999) describe an integrated approach to technology acquisition management. They review the technology management literature and partition it into three categories· technology management systems, technology management methodologies, and technology acquisition practices. Under this classification, the first category is the area which has been researched the most thoroughly, and addresses the management of technology as part of a broader set of activities - e g. management of core competencies. The second category contains a much smaller body of literature which is specifically focused on practical application of the technology management process The third category addresses particular techniques concerned with technology acquisition, e g technology scanning. Durrani et al. identify the need for an approach which is integrated across the three categories, allowing cross-functional company-wide activities but also practical implementation of distinct activities Their model involves first establishing market-place requirements (classified as essential, valued or desirable), then identifying technology solutions (classified as basic, core or future core) and establishing the source of acquisition (internal, alliance or external).

The identification, selection and acquisition of technologies are identified as distinct phases in the technology management framework process developed by Gregory (Gregory, 1995), which also considers two further phases, namely technology exploitation and intellectual property protection. The framework is set out as a cycle rather than a linear process, and considers the links outside the company and within the company. Further work has examined how to integrate technology management as part of the business planning process (Probert et al , 1999), although the original framework falls into the second category described by Durrani et al. and therefore addresses purely technology management rather than other management issues

An approach which integrates technology management and corporate strategy is the strategic technology scanning procedure proposed by Van Wyk (Van Wyk, 1997) Technology and corporate strategy are linked in such a way as to involve all levels of the company, from board level to individual technologist Strategic technology scanning is seen as an "*integral part of overall environmental scanning*" and should produce results which assist in the corporate strategic planning process.

Given the resource limitations of small firms discussed in section 2.1 2 2, perhaps it is unsurprising that the application of technology management in small firms does not feature highly in the literature. The holistic approaches described here would be extremely resource intensive for an SME

> **Observation:**
>
> - **frameworks and formal processes for technology management may be too resource intensive for small firms**

2 2 3 2 Small Firms and Strategic Planning

There have been rather more studies linking SMEs and strategic planning than SMEs and technology management. According to the literature, however, the majority of SMEs do not engage in strategic planning Where planning is carried out, it tends to involve short time horizons, it is generally informal (sometimes purely a mental activity), sporadic and non-comprehensive - but it can be made more effective by engaging external consultants (Robinson, 1982, McKiernan and Morris, 1994).

The literature is inconclusive about the effectiveness of strategic planning for SMEs in terms of any benefit to their financial performance McKiernan and Morris (McKiernan and Morris, 1994) attribute this to methodological and theoretical differences in the research Piest (Piest, 1994) instead reasons that the value of strategic planning (and hence its effectiveness) depends on each SME's circumstances As a first step to examining the link between those circumstances and the importance of strategic planning, Piest hypothesised that planning comprehensiveness is linked with the complexity and variability of strategies pursued by SMEs. The hypothesis was however only partly supported, with strategic variability found to be positively related to the comprehensiveness of forecasting the future strategic position It was not inferred that comprehensive planning processes *should* be used in situations of high strategic variability, and reference was made to earlier findings which showed that where perceived uncertainty was high, companies with limited planning processes were likely to outperform companies with a comprehensive planning process (Frederickson and Mitchell, 1984) Nevertheless, Peel and Bridge (Peel and Bridge, 1998), in a study of UK SMEs, also found a positive association between strategic planning intensity (i.e.

planning detail) and the levels of perceived environmental change (as well as perceived profitability and achievement of primary objectives)

Some of the literature does clearly support a link between strategic planning and small firm performance. Bracker and Pearson (Bracker and Pearson, 1986) studied a sample of small (mature but entrepreneurial) dry cleaning firms, and found a positive relationship between the level of planning sophistication and financial performance. Firms with long (greater than 5 years) planning histories significantly outperformed those with short planning histories. (Bracker and Pearson do however raise the question of whether having a structured strategic planning orientation diminishes the firm's ability to respond to change) Aram and Cowen, who are small business consultants, describe how a small investment in strategic planning can guarantee the growth and adaptability of the firm, leading to increased profits (Aram and Cowen, 1990) They note that it is helpful to have a core group of executives with the freedom "*to engage in unstructured activity with a long-term time horizon*" According to Aram and Cowen, a major precondition for successful planning is that the firm is not already faced with a survival crisis, since at this stage it is too late.

In the cases where the literature does not support a link between strategic planning and small firm performance, the main issue appears to be the *formality* of the planning processes. For example, Robinson and Pearce (Robinson and Pearce, 1983) examined a sample of small US banks, and found that *formal* planning procedures appear to provide no benefit in terms of financial performance. Formal and informal planners placed similar emphasis on scanning the environment, identifying distinct competencies, aligning organisational structure, deploying internal resources and monitoring the implementation of strategic processes, but formal planners naturally placed more emphasis on formulating goals and objectives. While it may be appropriate for large firms to fix long-term objectives and company mission before planning, this may in fact be of little benefit to small firms Robinson and Pearce suggest that small firms should concentrate on the more tangible aspects of planning such as resource and capability assessment and environmental analysis. They also observe that the success of the informal planners does not mean that less planning is necessary, but there may not be such a great need for formal written documentation. Richardson (Richardson, 1995), on the other hand, believes that having a written business plan stimulates a more thoughtful and disciplined approach to the planning process (although he does warn against too much paper and not enough action).

McKiernan and Morris (McKiernan and Morris, 1994) were also unable to establish a link between formal planning and better than average performance. They observe that it is possible that processes which may start out as formal planning systems become embedded in day to day operations, and cease to be recognised as a formal activity. McKiernan and Morris note that there is general agreement in the literature that formal strategic planning in SMEs is important, particularly in turbulent environments where conventional forecasting mechanisms are less effective and *"the possession of formal, flexible systems, with in-built scanning mechanisms, becomes a prerequisite of survival"*. Richardson observed although it is difficult to prove financial improvements are due to the business planning process, there are clear benefits to the decision-making capability of the firm. In his view, business planning is beneficial to small firms, and he suggests that where it is unsuccessful, it is due to certain problems with the planning philosophy, implementation process or use in an inappropriate context (Richardson, 1995) There are particularly serious dangers involved in trying to water down strategic planning processes designed for large companies. These tend to be "top down" processes, starting from the long-term corporate objectives "Bottom up", practical processes are much more effective in SMEs (Robinson and Pearce, 1983; McKiernan and Morris, 1994).

Key findings:

- **strategic planning in small firms addressed in literature but is not conducted by the majority of SMEs**
- **planning tends to be informal and sporadic with relatively short time horizons**
- **planning does not usually involve technology**

2 2 3 3 Small Firms and Strategic Technology Management

There is very little literature on strategic planning in SMEs that addresses technological issues directly There are however a number of lessons which can be drawn from the strategic planning literature above when considering technology strategy and planning in SMEs:

- *The importance of scanning in a rapidly changing technological environment* (McKiernan and Morris, 1994, Robinson and Pearce, 1983). Awareness of developments in technologies - and the markets for those technologies - will enable a small company to respond to those changes and make the right decisions (Richardson, 1995). (This is confirmed by Raymond et al.. who have directly investigated technological scanning in small firms (Raymond et al , 2001))

- *The precedence of adaptability over having long term fixed objectives* (Robinson and Pearce, 1983, Bracker and Pearson, 1986). The suggestion that limited planning may be more helpful than comprehensive planning (Frederickson and Mitchell, 1984) supports the concept that flexibility may be sacrificed if there is a firmly fixed idea of which technologies will be most important to the company in the future Rather than focusing a lot of attention on the details of how to implement a long term technology plan, it may be better to spend a little more time re-evaluating the plan in the light of developments in the technological environment, and ensuring that the plan *should* be implemented.
- *The benefits and disadvantages of formal documentation* As with any business process, a system of formal documentation can help to raise the profile of technology planning, and ensure it is not overlooked It also encourages the process to be taken seriously and given more thought (Richardson, 1995). On the other hand, since there is no evidence of formality being beneficial to small firms in general strategic planning (Robinson and Pearce, 1983), it seems likely that the same will be true for technology planning and strategy. The activity itself is more important than the formality of the documentation.
- *The dangers of attempting to water down large company processes for use in small companies* (Richardson, 1995) Small companies operate in a very different way to large corporations, and technology planning processes which are designed for large companies may not be appropriate, even in a cut down form, for small companies

Most of the conclusions summarised above are based on inference, because there is a gap in the literature concerning strategic technology management within small firms This gap in the literature is however likely to remain unless small companies become much more widely motivated to engage in technology management processes, and have the resources to do so. There is potential to conduct action research in this area to stimulate technology management activity in small firms, but this avenue is not pursued here.

Gaps:

- **direct research on small firm technology management (requires action research to stimulate such activity)**

2 2.3 4 Information Acquisition for Technology Management

While few small firms engage in formal technology management processes, they do monitor and scan their environment for technological information (e g. (Raymond et al , 2001)). In many cases the companies will not be conscious that they are acquiring information, since it will occur naturally during the course of their daily business activities. Very few firms will mentally distinguish between searching for technological information and other types of information, and the literature tends to confirm this in its treatment of small firm information acquisition· the broad information and support needs of small firms are usually approached holistically without singling out technology for special consideration

The literature on sources of information used by SMEs reviewed in section 2 2 1.1 is very relevant to the discussion of small firm information acquisition The importance of supply chain sources can be attributed partly to small firms tending to innovate incrementally to satisfy customers (Belotti and Tunalv, 1999), and to small firm dependence on their "daily environment" (i.e suppliers, competitors and customers) for the acquisition of new knowledge (Vos et al., 1998) Research in the carpet industry (Fuellhart, 1999) found that small firms prefer to use sources which are personal and easily accessible, making supply chain, trade shows and publications popular, but institutional sources were at the bottom of their list. Other research has found that sectorally-based agencies such as trade associations are often used by small firms for external advice and support (North et al., 1997) SMEs also have a propensity to use local sources, even in preference to better sources of expertise (Bryson and Daniels, 1998) It is suggested that it is more efficient for small firms to use their networks to access information, rather than trying to extract information from a large number of sources Where their own network is inadequate, they can also access more specialised but more distant networks through contacts in their own immediate network (e g. through a "friend of a friend") (Julien, 1995).

There is a perceived mismatch between small firm needs and sources of support, which is highlighted in the literature. SMEs often do not recognise what their real needs are (Autio and Klofsten, 1998), but instead want help in dealing with short-term issues which may have no impact on their longer-term competitiveness (Turok and Raco, 2000) That research was aimed more at small business support than information acquisition, but other research has focussed on the alignment between small firm needs and particular information and technology sources such as universities (Storey and Tether, 1998b) and government programmes (Bessant, 1999, Julien, 1995). There appears to have been relatively little research into how small firms perceive their own information needs, despite the fact that this will be an important driver for their information acquisition processes.

In terms of identifying barriers to information acquisition, Vos et al (Vos et al., 1998) noted that SMEs regard knowledge sources as widely distributed, poorly sign-posted and hard to find Hall et al (Hall et al., 1999) found the main barriers to firms using patent information to be lack of resources, lack of relevance, problems obtaining access and lack of awareness. Lang et al. (Lang et al , 1997) observed that small firms differ from large in information acquisition as follows· a lack of management information systems; a concentration of information-gathering responsibilities in just a few people, fewer resources, and lower quantity and quality of information available. The concentration of information-gathering responsibilities in just a few people could in fact be considered an advantage which small firms have over large firms – making it easier for them to synthesise the information they need.

The actual processes of information acquisition in SMEs (how and why information is sought) have not been given a great deal of attention in the literature, although Lang et al. (Lang et al., 1997) observe that small firms are motivated to seek external information both in times of perceived opportunity and in times of perceived threat – whereas large firms look more to trusted internal sources in times of threat. A greater understanding of information acquisition would help to shed light on how these processes affect small firm technological capability

Key findings:

- **some evidence exists about which sources of information are preferred by small companies.**

Gaps:

- **how do small firms perceive own information needs (the drivers which make them seek technological information)?**
- **scope for greater understanding of information acquisition processes**

2.3. Chapter Summary

This chapter presented first the literature which forms the background context to this research, then focussed in on the influences on small firm technological capability.

The first part provided evidence of why the technological capability of manufacturing suppliers is increasingly of interest, and looked at the importance of technological innovation in providing competitive advantage and the reasons why it increasingly falls to suppliers to provide those advanced technological capabilities Justification was then given for focussing on small firms, with a review of the role of small firms in innovation setting the context for much of the research presented here. The first part concluded with an indication from the literature of what type of suppliers would be of most interest to this research

In the second part, the review was concerned with how the existing literature deals with the influences on small firm technological capability. After a broad look at possible influences, the scope was narrowed to focus on the flows of information between small firms and organisations in their environment

Having identified customers as a dominant source of information for innovation, the influence of customers was then explored further through a review of the literature surrounding the involvement of suppliers in new product development, and of the supplier development literature The new product development route was considered to involve time horizons which were too near for the development of technological capability, but gaps were identified in the supplier development literature which provide scope for new contributions. Supplier development has not been approached from the perspective of the development of technological capability (instead most research focuses predominantly on the quality, cost and delivery priorities of procurement specialists).

Balancing the "customer push" angle, the review then turned to "supplier pull" – how small firms access the innovation environment and strategically manage their own technology Very little activity has been documented in this area, so the review considered technology management in general, alongside strategic planning in small firms, to draw some inferences for technology management in SMEs (While there is a gap in the literature, it is likely to remain unless action research is undertaken to stimulate formal activity by small firms) Finally, supplier information acquisition was related to technology management, and reviewing the literature in this area revealed a need to understand more about how small firms perceive their information needs and how their information acquisition processes may influence their technological capability.

3. Top-Level Research Design

This chapter begins by placing the research in the context of its philosophical standpoint, and links this to the research approach adopted and the overall aim of the research The basic assumptions behind the research are identified, along with limitations of the scope of the research The top-level research design is then introduced: an iterative approach based on the development of frameworks or mental models An initial framework is presented which centres on the innovation environment for small manufacturers, which is to be explored through a scoping study Finally the research methodology for the scoping study is described

3.1. Philosophical Position

The theme of this research has already been outlined in the first two chapters: our interest is in factors which will enable small manufacturing suppliers in the UK to develop their technological capability in such a way as to continue to meet market needs and be globally competitive. There are a number of philosophical assumptions and value judgements inherent in the selection of such a topic

The statement of the subject as it stands implies that this researcher sees small firms as cognisant entities with an awareness of market needs and the ability to develop This is not entirely the case – the characteristics ascribed to "firms", "organisations" and "companies" throughout this work are intended as "shorthand" to describe the collective actions and attributes of the individual people employed within these structures Nevertheless, this researcher comes from an engineering tradition which is inclined to see organisations as functional units and the activities of employees as "processes" (parallel to automated production lines). This mechanistic view of organisations (as seen in business process re-engineering) has not been without critics since it tends to ignore political, ethical and moral issues (Johnson and Duberley, 2000)[Ch 3]

The mechanistic view of organisations emerged partly from a desire to put the social sciences on the same footing as the natural sciences, by using a similar positivist research approach This allows researchers to identify causal explanations by testing theory against empirical observations – with the ultimate goal of allowing managers to predict and control even the social interactions within their organisation Many management researchers (and academic journals) make positivist assumptions, even without realising it, because this approach fits with our "common sense" view of the world that is ingrained in our Western culture (Johnson and Duberley, 2000)[Ch 3]. This includes, for example, the perceived importance of being "objective" when conducting research. Many of the alternatives to positivism are much more subjective in nature. for example, a phenomenological approach takes the stance that reality is socially constructed and that the role of management research is to generate understanding of social interactions.

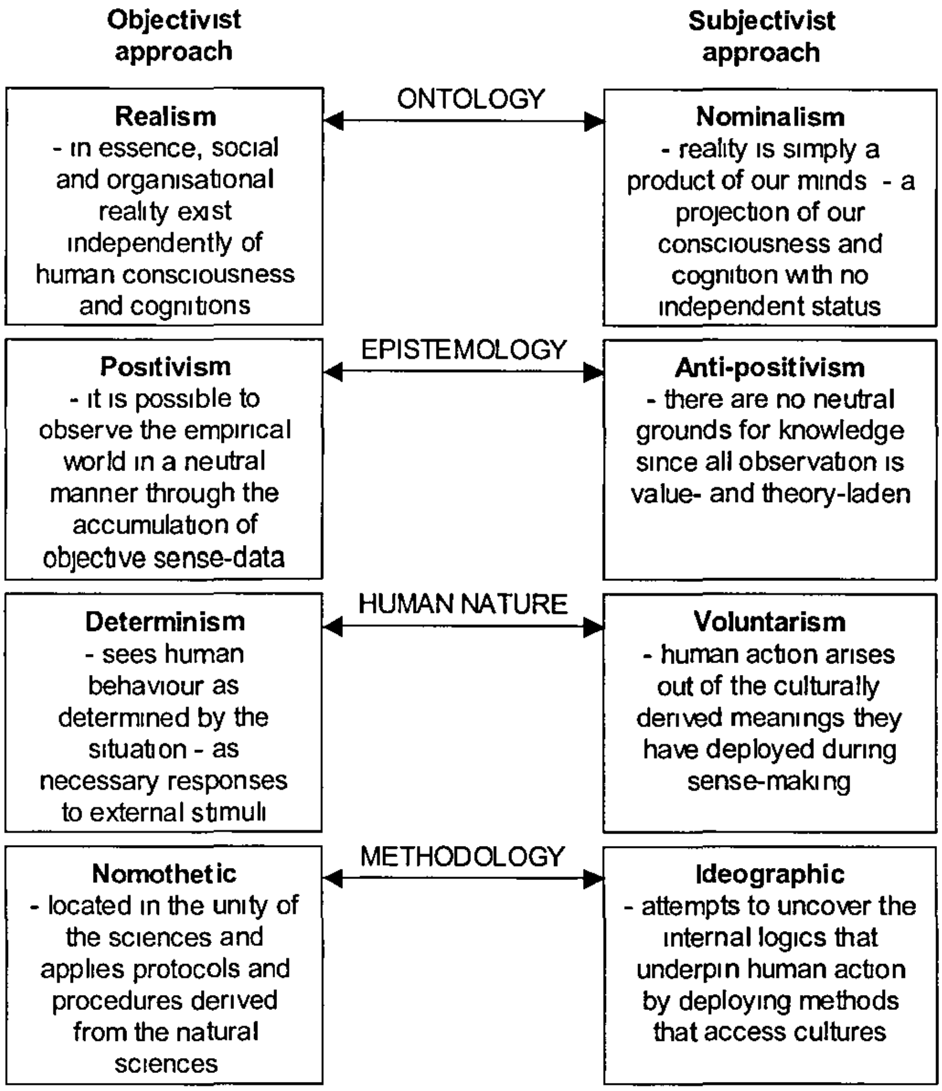


Figure 3.1 Burrell and Morgan's metatheoretical assumptions about the nature of social science (Johnson and Duberley, 2000; Burrell and Morgan, 1979)

By distinguishing between objectivist and subjectivist positions, it is possible to highlight some of the choices made by researchers in terms of basic assumptions about the nature of their research Burrell and Morgan's "metatheory" of the nature of social science

(Johnson and Duberley, 2000; Burrell and Morgan, 1979) is shown in Fig. 3.1. The first axis considers ontology (the nature of reality), where the objectivist position is that there is an external and independent reality, while the subjectivist view is that reality is "created" by human minds. The second axis is concerned with epistemology (the nature of knowledge), where choices are made regarding whether it is possible for the researcher to be a neutral observer, or whether values and language will shape how they perceive and describe the world In studying organisations, it is also necessary to form an opinion about human nature and whether human behaviour is determined by external factors, or by their own subjective interpretation of the world. The fourth axis distinguishes between methodological approaches which focus on "scientific method", emphasising systematic protocol and technique, and those which try to understand the internal mechanisms of human interaction through getting close to the subject.

The ontological and epistemological debate influences what is seen as "truth", or valid research findings. With a realist ontology and positivist epistemology, a "correspondence theory" of truth can be employed. This means that a theory can be proved or disproved by comparing it with the facts - which are neutrally obtainable. In contrast, a "consensus theory" of truth suggests that theories are judged according to whether they fit with the established "paradigm" (the view of a particular community). Kuhn suggested that science progresses through a series of "paradigm shifts" whereby scientific observations that do not fit with the established paradigm may lead to its eventual breakup and the establishment of a new paradigm. While Kuhn saw only one paradigm as dominant at any one time, Burrell and Morgan's view was that many different paradigms could co-exist (Johnson and Duberley, 2000). The choice of a subjectivist epistemology has some significant implications for shared understanding between different paradigms, however Kant combined realism with a subjectivist epistemology, asserting that although there was an independent reality of "noumena" (things in themselves), we can only access a version of reality through "phenomena" (things as they appear) – a reality filtered by our own prior experience and cognitive structures. Regardless of whether or not there may be an external and independent reality, if we cannot refer to it then our version of reality is created within our own paradigm and cannot be shared. Therefore research results that make sense within one paradigm are likely to be meaningless in another, because the whole frame of reference is different. Ultimately, this can lead to relativism where there can be no neutral, independent means of judging knowledge – implying for example that the sun used to rotate around the earth, until a "paradigm shift" in people's beliefs caused the earth to rotate around the sun instead.

There are philosophical problems associated with the various different approaches to management research. The positivist approach may not be reflexive enough – while researchers in this tradition may evaluate their own methodology for bias and influence, they do not question their own ability to be a neutral observer, failing to consider that their thinking may be constrained by the community within which they operate Equally there are problems with very subjective approaches which are unable to compare and judge research results, since they would tend to paralyse management into inaction – because no researcher could claim to be "right".

It is possible to find a middle ground by accepting an objectivist ontology and a subjectivist epistemology, as long as there is some neutral means by which research findings can be tested (other than accepting the existence of theory neutral language and a correspondence theory of truth). For pragmatic-critical realists, truth is not a question of empirically testing theory against reality, but instead, an assertion may be considered true if it actually helps people within their own contexts. (So although knowledge is socially constructed, it is bounded by the real world - which will influence what works and what does not work) The emphasis is upon action and dealing with real problems, with an acceptance of fallibility This school of thought encourages methodological pluralism, because no individual methodology can be seen as superior or complete, and using different methodologies will allow different aspects of a situation to be explored

The philosophical position favoured by this researcher is that of pragmatic-critical realist, but with some sympathy for the neo-positivist position. Neo-positivists occupy similar ontological and epistemological territory to positivists, but adopt a much more interpretative approach This means that they favour qualitative research over quantitative research, and the inductive generation of theory rather than the deductive testing of theory (Johnson and Duberley, 2000)[Ch 7]. The suggestion is that by accessing enough opinion it is possible for the researcher to apprehend the reality of a situation. The main difficulty with the neo-positivist position for this researcher is the assumption that it would be possible then to share this knowledge with other researchers in a theory-neutral language, without the account being influenced by the researcher's own beliefs and background. Returning to Fig. 3.1 in summary, this researcher finds herself towards the objectivist side of the "ontology" axis, but towards the subjectivist side of the remaining axes of "epistemology", "human nature" and "methodology"

3.2. Research Approach and Top-level Research Aim

Given the philosophical position outlined above, the research approach adopted in this thesis is aimed at gaining understanding of information flows in order to engage with practical situations within manufacturing industry. Although some would argue that a pragmatist approach demands action research (Gill and Johnson, 1997) (since research results can only be validated if they are found to be helpful in their specific situations), this researcher believes that developing understanding is a valid precursor to the practical implementation of ideas.

The methodology is ideographic rather than nomothetic (see Table 3.1). Rather than testing *a priori* hypotheses which assume that the correct questions have already been identified, an inductive approach is taken whereby the key issues are identified through research. The methods employed are predominantly (but not exclusively) qualitative rather than quantitative in nature, and include surveys, semi-structured interviews and case studies

Table 3.1 A comparison of nomothetic and ideographic methods (Gill and Johnson, 1997)

	Nomothetic methods emphasise:	**Ideographic methods emphasise:**
1.	Deduction	Induction
2.	Explanation via analysis of causal relationships and explanation by covering-laws (etic)	Explanation of subjective meaning systems and explanation by understanding (emic)
3.	Generation and use of quantitative data	Generation and use of qualitative data
4.	Use of various controls, physical or statistical, so as to allow the testing of hypotheses	Commitment to research in everyday settings, to allow access to, and minimise reactivity among the subjects of research
5.	Highly structured research methodology to ensure replicability of 1,2,3 and 4	Minimum structure to ensure 2,3, and 4 (and as a result of 1)

The research approach could also be described as grounded theory, which was originally proposed by Glaser and Strauss (Glaser and Strauss, 1967) This method emphasises building theory from empirical data, through a process of coding and categorisation of concepts. In an ideal world, all preconceived notions should be set aside to allow the data to "speak for itself", through a process of "bracketing". It is however necessary to cultivate "theoretical sensitivity" (Locke, 2000)[Ch 5] in order to be able to conceptualise the data. This means that the researcher's background and training, and influences from the literature and other sources, will shape the emerging theory to a certain extent.

Certain academics have attempted to make qualitative research and grounded theory more "rigorous" by prescribing techniques and procedures to be followed (e.g. (Miles and Huberman, 1994, Strauss and Corbin, 1998)) This seems to be influenced by the positivist tradition (Denzin and Lincoln, 1998)[Ch 1], which is not embraced by this researcher Instead, the focus will be on creating frameworks or conceptual models which are pragmatically helpful in the context of the overall research aim.

The top-level research aim, as stated in Chapter 1, is.

> - To identify and evaluate mechanisms for maintaining and developin technological capability in small manufacturing suppliers

The "social reality" under investigation here is one where awareness and knowledge of potential new technology resides within the individual employees of companies, and it is assumed that this knowledge is refreshed via information flowing from the outside world to those employees. The aim is therefore to explore the processes through which such information flows occur It would be perfectly possible to address the overall research aim from a different angle, such as investigating the availability and effectiveness of technical training or exploring the funding of capital equipment expenditure The approach selected however arose from the initial research and literature review (see section 2.2 1), which pointed to information flows as an interesting area to study.

It is proposed here that it is possible to gain understanding of such information flows through people's descriptions (accessed through interviews), and by considering how such information flows are framed in formal business processes. The role of information flows in maintaining and developing technological capability is not an idea that is widely discussed in the daily operations of business, so the purpose of the research is to find evidence to build a framework to shed light on this topic It is clear that those interviewed may or may not understand things (or describe them) in the same terms as the researcher, and a certain amount of interpretation may be necessary. The motivation and agenda of those interviewed should also be considered, acknowledging the power relationships that exist within supply chain hierarchies and within the management structures of individual firms.

This research may benefit the larger, more powerful firms within the supply chain, who are concerned that they should be able to procure good technology (cheaply) into the future From this researcher's perspective, however, it also empowers small firms if they are able to offer advanced technology to the market. It may be necessary to challenge existing social structures and perceptions in order for small firms to be more successful in enhancing and maintaining technological capability

3.3. "Industry-view" Assumptions

Firstly it is assumed that technological progress is ipso facto "a good thing" and therefore desirable for UK business. The researcher's own background as an engineer has certainly orientated her towards perceiving advantages in creating better tools and more elegant solutions for society Unlike the scientists and engineers of the Industrial Revolution, however, this researcher does not anticipate that technological progress will cure all the ills of society – technology can always be used equally for good or for bad. Yet technological progress does play a part in economic growth, and it seems very likely that if UK firms fail to innovate, they will lose business to firms whose technology *has* evolved to meet market needs

A second major assumption is that it is important for *small* firms to provide technologically advanced solutions. This is intertwined with a third assumption – that the prime contractors will continue to see their role as systems integrators and will increasingly outsource the design and manufacture of sub-systems and sub-assemblies. The bases for both of these assumptions have already been discussed in Chapter 2 and are summarised below.

The preference for outsourcing is consistent with the emphasis on core competences seen over the past two decades, and is backed up to a certain extent by aerospace industry statistical data confirming downsizing of large firms and the increase in the number of small firms (see Appendix I). There is however no guarantee that the trend will not swing back the other way (see Fig. 3 2a), particularly if suppliers are unable to satisfy the requirements of the systems integrators, but the assumption is based on the consensus of industrialists interviewed at the time of conducting the research, and on the literature (e.g. (Bhattacharya et al., 1995; Dana, 2001))

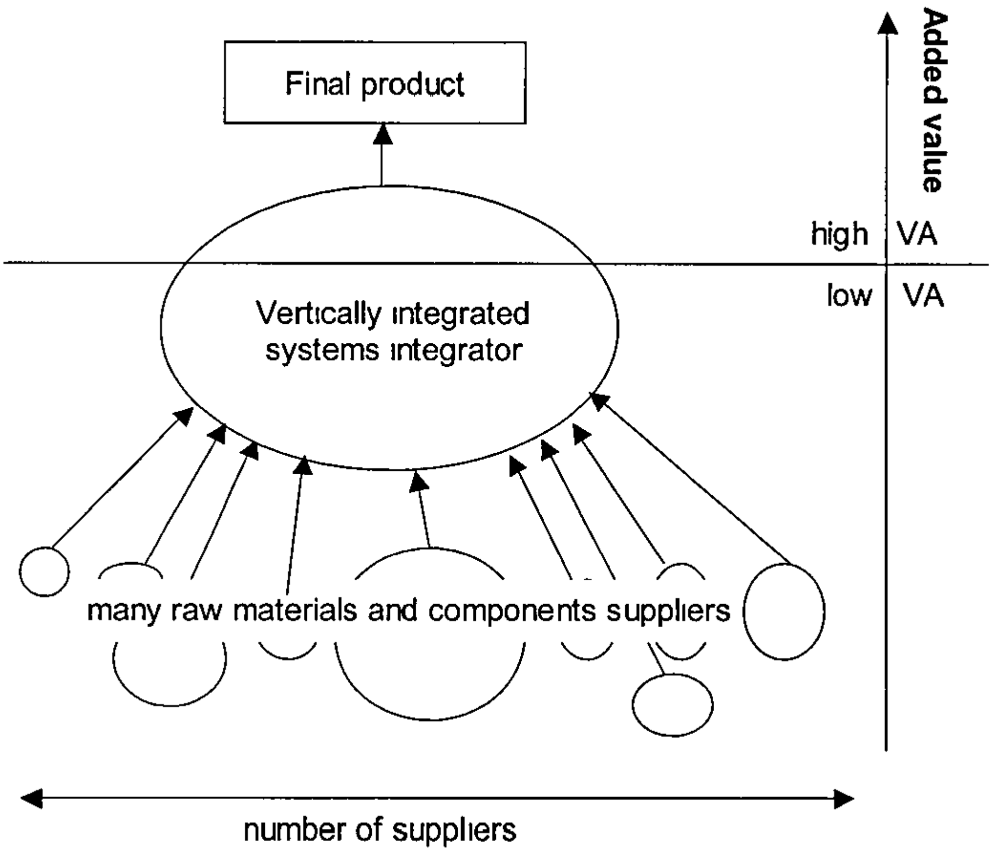


Figure 3.2a Return to vertical integration

That the systems integrators will continue to outsource to *small* firms is an assumption based on the current state of affairs in the aerospace and defence industry where a high proportion of the firms in the value chain fall within the definition of SME If *existing* suppliers are to provide sub-systems and sub-assemblies that integrate advanced technologies, it means that it will be incumbent upon small firms to create these value-added solutions which the prime contractors increasingly require (see Fig. 3.2b). It is of course possible that the current small suppliers will not be able to adapt to changing market needs, and that a new supplier base will evolve comprising a small number of "super-suppliers" which are much larger firms (such as the first tier suppliers to the automotive OEMS (Oakes and Lee, 1996)) More research is required to establish which situation is more likely to occur – the main defence of the assumption chosen here is that because aerospace and defence markets are generally low volume markets, it seems more likely that small firms will continue to serve as niche suppliers, while larger firms would be more interested in the mass consumer markets – unless the value associated with the niche market is very high indeed.

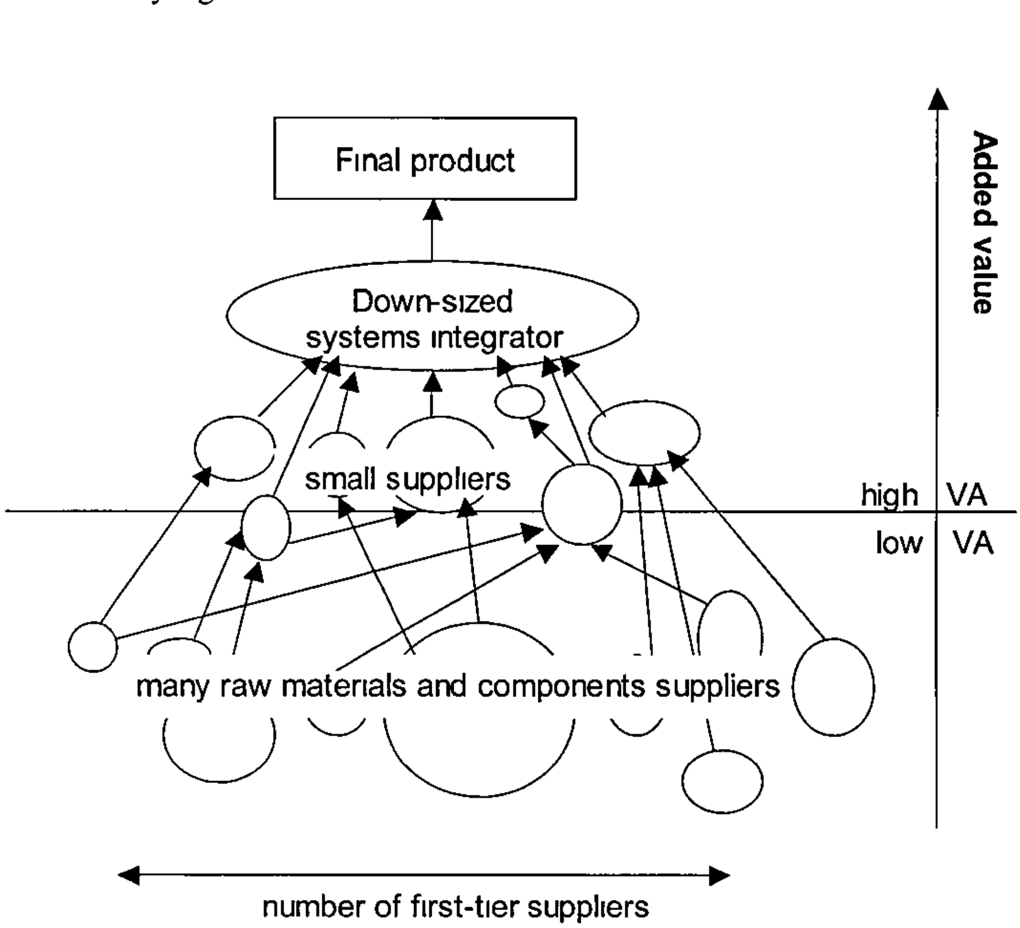


Figure 3.2b Increased outsourcing to small suppliers

A further assumption or limitation of the research is that the small manufacturing suppliers under consideration here are probably only those operating in a relatively stable, mature industry sector. Since the focus is on how small firms maintain and develop their technological capability to meet future market needs, the basic premise is that the market itself has already been established, but technology can be used to gain competitive advantage by providing superior or cheaper solutions, whether in a radically new way or by incremental improvements. Markets may of course evolve dramatically – for example the technological requirements to build the conceptual "Future Offensive Air System" (FOAS) (MOD, 2002) may differ dramatically from a current fighter jet. There might however be some merit in a small firm considering how it might develop technologies for FOAS as the market requirements become clearer – whereas for a new start-up firm trying to establish a completely new market, the technological considerations form only a part of an extremely complex and undefined problem While many of the techniques a firm might use to anticipate future technological needs should help them to adapt in a wildly uncertain environment, the starting point for this research is that there should be some sort of industry stability

Due to the above assumptions, the findings of the research are possibly limited to the aerospace and defence industry in the UK. The low production volumes and high value-added nature of products in the aerospace industry also gives rise to the situation where design interactions tend to continue into the production cycle. Where these characteristics are found in other stable and mature industry sectors, the research findings may be applicable to the supply network there.

Table 3.2 Summary of research position

Philosophical Position
• Realist ontology • Subjectivist epistemology - Pragmatic-critical realist
Research Approach
• Inductive, qualitative (grounded theory) • Generate understanding of information flows
Assumptions
• Able to access knowledge through interviews with company employees • Technological progress is desirable for small firms • It is important for small firms to provide technologically advanced solutions • Systems integrators will continue to outsource design and manufacture of sub-systems and sub-assemblies to suppliers
Limitations of Research Scope
• Only considering information flows • Only considering mature, stable industries with - Low volume, high added-value products and processes

3.4. Top-level Research Design and Methodology

As stated earlier, our over-arching research aim is to identify and evaluate some of the mechanisms for maintaining and developing technological capability in small manufacturing suppliers The nature of this research is exploratory and inductive, and therefore the design of the research also follows a pattern of exploration and discovery. Frameworks are generated and refined in an iterative manner alongside the analysis of primary and secondary research data, to aid consideration of the issues. The frameworks are conceptual diagrams or "ways of thinking about things" which try to capture an interpretation of "reality"

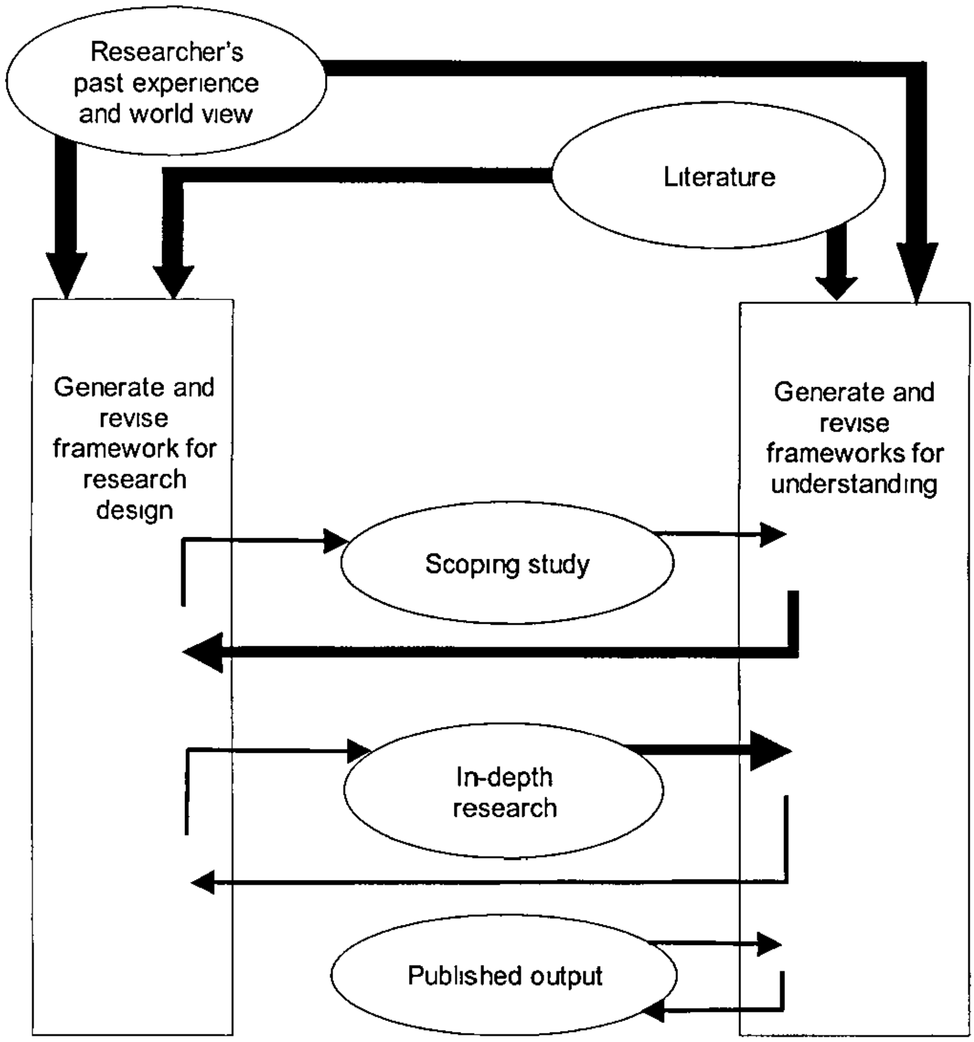


Figure 3.3 Research process

The top-level research design process is depicted in Fig 3.3. This shows how frameworks are created and revised both in terms of the research design and in terms of the understanding of the topic studied. Initially the frameworks arose from the author's (and her colleagues') past experience and world view, and from early literature searches. Both of these factors then continue to provide a significant input into framework revision throughout the course of the research The scoping study contributes to understanding enough to shape the framework for the research design, and subsequently the role of the in-depth research is to contribute significantly to the framework for understanding (which will then be fed back into the research design to a lesser extent) The process of writing for publication then further refines the frameworks for understanding

The starting point for the primary research is a scoping study of five small manufacturing companies in the UK, to find out more about the influences of the innovation environment in which they operate. The findings from this study are then used to identify specific areas for more in-depth research

3.5. Scoping Study Design and Methodology

The positivist research approach is to study the literature, and from the literature to propose hypotheses to be tested by empirical research. The pattern for the scoping study design below is to some extent similar, but the draft framework which emerges from the literature is not intended to be a testable hypothesis – instead it represents the researcher's embryonic conceptual picture of the innovation environment in which her scoping study sample firms might operate

3.5.1. Draft Framework of Innovation Environment

The purpose of the scoping study was to gain understanding of the influences of the innovation environment on small manufacturing companies. The literature review in Chapter 2 has already provided some analysis of the innovation system in which firms operate, outlining some of the actors within the innovation system, the relative benefits of regional embeddedness and the "weak ties" of broader communities, and some of the problems and benefits of formal collaborative networks. The innovation surveys described in section 2.2 1.1 are of particular interest, especially the data concerning how useful SMEs find various sources of information, since a key assumption for this research is that accessing relevant information is a critical part of developing technological capability. Whilst the quantitative data published in the innovation surveys show the relative influence of customers and other sources, they do not explain how this influence is manifested The scoping study will therefore be based on qualitative research in order to gain more insight.

The innovation surveys described in section 2.2.1.1 suggest a draft framework of innovation influences on SMEs. This is shown in Fig. 3.4 which attempts to represent the innovation environment in which UK SMEs find themselves - the innovation environment is a complex, evolving system and this representation is simply an initial perspective focussing on the information flows within the system. Fig. 3.4 uses a pipeline analogy, so that a thicker line indicates that information can pass easily, and conversely a thin or dashed line suggests a poor link between the two points. Thus the thick line shown between the SME and customers and suppliers indicates a good line of communication throughout the supply chain The strength of the links may be controlled by a number of different factors – e.g. the level of awareness amongst SMEs of the source, or the cost in terms of time and money to access the source. The draft framework forms the back-drop to the scoping study interviews.

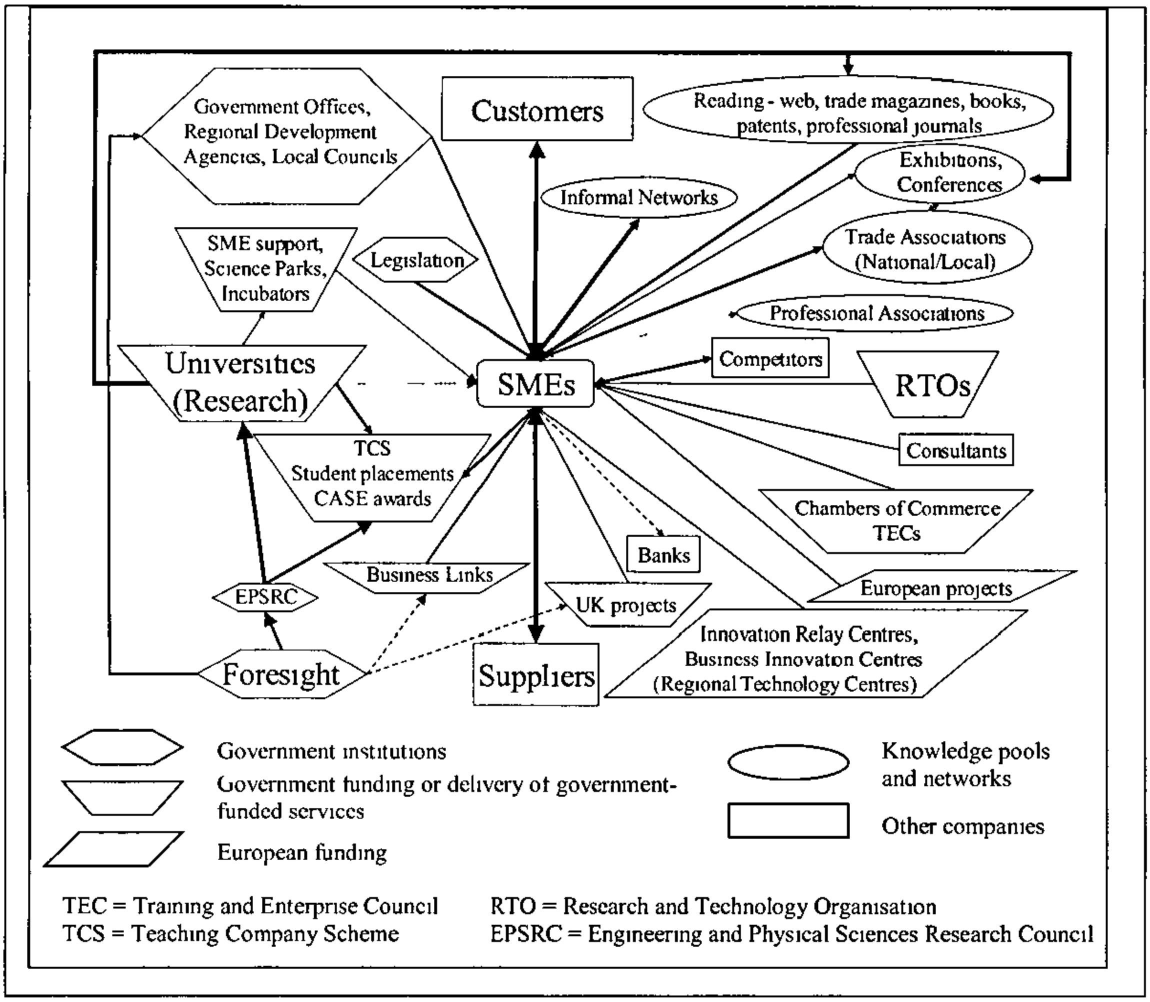


Figure 3.4 Innovation environment for SMEs

3.5.2. Scoping Study Design and Methodology

The aim of the scoping study was to investigate the influences of the innovation environment on small manufacturing companies. The approach taken was to try to access the views of senior managers within such firms which suggested using interviews to provide the rich qualitative data needed.

The sample of companies was selected on a pragmatic basis, as firms with which this researcher's university department already had some connection This naturally made it easier to approach the firms and set up interviews with a senior manager in each company. (The interviewees and companies are summarised in Table 3.3). On reflection, however, the sample will not be typical of small manufacturing firms, since involvement with universities tends to require an outward-looking attitude and implies a certain degree of dynamism This is likely to place the sample firms towards the upper end of the spectrum in terms of potential likelihood of successfully developing technological capability

Secondly, although the research agenda has been presented in terms of the particular concerns of the aerospace and defence sector, only one of the sample firms could be categorised as a supplier to that sector It is possible therefore that the findings from the scoping study should not be automatically applied to that sector The sample companies did however fall within the scope outlined in Table 3.2, since they operated within mature and stable markets, and tended to provide low volume, high added-value products and processes. This is also a scoping study, a first step in generating greater understanding of how firms can successfully develop technological capability A sample of firms which is taken from a variety of technologically-based manufacturing sectors should offer perspectives on this subject. In addition, a sample which may be more technologically innovative than the average manufacturing SME is also more likely to demonstrate good practice in our area of interest

Table 3.3 Scoping study companies

Company	No. of employees	Type of business	Interviewee role(s)
V	135	Data storage	Development and Quality Manager
W	116	Control and monitoring products	Executive Chairman and another Director (both part owners)
X	64	Precision engineering services	International Projects Director
Y	85	Microelectronic interconnection	Technical Manager
Z	15	Electronic assembly and system design	General Manager (owner and main product designer)

The data collection for the scoping study was conducted between June and October 1999 via structured interviews, using a questionnaire-style instrument such as the one included in Appendix III.1. The choice of a relatively structured interview format was preferred at this stage in the research while the researcher's skills in interviewing were being developed. The interviewees did not see the questions in advance, and the interview format allowed enough flexibility to allow promising lines of enquiry to be pursued as they arose Initial questions concerned the background of the company, before discussing the company's products and services with a view to gaining an understanding of product, process and technology innovation patterns within the firm The interviewees were then asked about relationships with customers and suppliers and their influence on innovation. Finally the interviewees were asked which sources of information were useful to them in providing ideas for new products and processes, and specific questions were asked about the usefulness of external organisations and sources of information and technology.

The interviews were conducted by two researchers, with this researcher acting as the main interviewer while her colleague took notes and provided some supplementary questions. The duration of each interview was between one and two hours. Each interview was written up from the notes recorded against the interview questions, and through this process and also through research meetings, common themes were drawn out. Further analysis, alongside consideration of the literature, then allowed the topics for further in-depth research to be identified.

3.6. Chapter Summary

This chapter explained the top-level research design First the philosophical stance taken by the researcher was outlined, and then the overall aim of the research was described in the context of the research philosophy. The main assumptions and limitations of the research were also discussed. The research process was described as an iterative procedure of developing frameworks (or conceptual models), beginning with a scoping study to identify topics for in-depth research. The design and methodology for the scoping study was then described.

The results of the scoping study are presented in Chapter 4, while Chapter 5 returns to the topic of research design and methodology in setting out the plan for the in-depth research phase (see Fig. 1 1)

4. Scoping Study Interviews: the innovation environment for small manufacturing firms

This chapter describes the results of the scoping study, which was conducted in order to gain further understanding of the innovation environment of small manufacturers. Semi-structured interviews were conducted with senior managers in five small firms (see section 3 5 for details of the research methodology, and Table 3.3 for a summary of the interviewees and firms) Descriptions of the findings from the five firms are given in sections 4 1 to 4 5, with common themes drawn out in section 4 6 The results are used to identify topics for in-depth research in section 4 7

4.1. Company V

The first company visited was the largest, with 135 employees and a turnover of £18m. They were established 13 years ago, after a management buyout from a large, well-known company. The company has a niche market in data storage products, and they supply mainly to large computer manufacturing companies at present

The interview was carried out with a senior manager with the combined role of Development Manager and Quality Manager.

Company V makes significant use of market research consultants, to plan future products Market analysis and industry trends are examined, and users of the product are asked which features they like and dislike. A new marketing strategy has been developed to sell to end users rather than OEMs.

R&D is seen as a key function, with around 30 employees involved in product development. At present the company has 3 product lines, each with several models. Rather than step changes, the strategy is for evolutionary product change, consistent with existing strengths and capabilities One product is an industry standard and is still selling after 10 years, but future products are not expected to achieve similar lifecycles.

The manager considers internal resources to be more important than external resources in generating new product and process ideas - from brainstorming sessions to the formation of cross-functional design and manufacturing teams. External links are still evident, however. Customer comments are considered useful to the innovation process A strategic alliance has given the company access to particular technologies and expertise, they have been involved in several European collaborative research projects, and they have links with universities and research organisations The company has filed patents.

The company has won a number of awards, and appears to have a strategic approach to product development. Products incorporate new technology, and evolve to meet new legislation and product standards. There appears however to be no plan to move out of their niche market, which could disappear in the fast moving world of information technology.

4.2. Company W

The second company was the oldest, having been formed 225 years ago to service the UK coal-mining industry The company, formerly a public limited company with 500-600 employees, had declined with the mining industry until it was bought 7 years ago and diversified into overseas mining, logistics and materials handling Currently there are 116 employees, and the turnover is £7-£7.25m

The interview was conducted with the Executive Chairman and Director of the company, both of whom partly own the company. An interview with a technical manager may have elicited different responses – the interviewees in this case have a market-facing role.

Company W has a large portfolio of control and monitoring products for the mining, materials handling and logistics industries. Customers are predominantly large companies, located world-wide. Maintaining strategic partnerships is important to the company, since many of their products form part of larger systems and will become increasingly embedded in their customer's products

Historically their product lifecycle was around 20 years, but now lifecycles are around 3 years and products are planned approximately 2 years ahead. Company W has 14 people employed in product development Decisions to invest in particular products are influenced by the company's strong understanding of the marketplace, by the company's particular strengths, by their competitor's activities and by opportunities that arise from informal networking The interviewees felt that strategic planning is not appropriate for

SMEs, and that new product, process or technology implementation is driven by customer requirements. Customers make suggestions about the product, its features, and the technology within the product – one example is the incorporation of fibre optic technology for a particular customer.

External links appear to be very strong, with the company co-designing with customers and suppliers, working with a number of universities and taking part in a European project. The interviewees are very involved with the CBI. They see new standards and legislation as opportunities rather than threats, using their trade association and other opportunities to influence legislation at the drafting stage. The company has filed patents, and has bought licences to use outside technology as well as licensing out one of its products.

The company sees its future as part of the supply chain in Europe – they will not be able to compete on their own.

4.3. Company X

Company X has around 64 employees, and a turnover of £4.3m. It is an engineering service company, providing computer aided design and analysis, rapid prototyping, precision engineering services, tool making, model and pattern making, vacuum casting and rapid injection moulding. The company was established 53 years ago, as a 2-man precision engineering company.

The interview was carried out with the International Projects Director.

Since this company's products are manufacturing processes, the innovation issues are rather different. R&D is production orientated, and there are no employees specifically allocated to this function. Often new technology comes in the form of new machines, so the biggest challenges are in training personnel in the use of equipment, and in optimising the process. Customers can influence the decision to use new materials in a process, or to bring in new processes – although the high capital investment required for new equipment means that the company must be convinced that there is a real market. In the rapid prototyping area, however, technology push is more influential as newer versions of machines are brought out It is also necessary for the company to have the latest software releases in order to be able to take customer data

External sources of information are seen as critical in providing ideas for new products and processes, particularly customers and competitor's customers. Internal and external resources are employed to gather intelligence from journals, seminars, universities, competitors and the Internet. The information is formulated, condensed and discussed – Company X consider this to be part of their competitive advantage, and will not reveal their methods. Internal resources are important in the introduction of new processes, and in the use of new parts or raw materials The local Regional Technology Centre has proved very useful in providing basic market information.

The company has a strategic research agreement with one UK university, and links with 10 other universities in the UK, Europe and the Far East. It also has a high-level link with a German research organisation. Commercial partnerships with competitors are used as a means to find out whether particular technologies are worth investing in. These partnerships are reviewed quarterly. Company X has a policy of not patenting, in order to preserve confidentiality It has bought licences to use technology from other organisations, but does not sell licences following a strategic decision to avoid becoming a technical consultancy.

Company X believes that it is critical for their sector that a trade association is established, to provide a number of benefits including the development of standards, joint venture opportunities, technological support and benchmarking.

Strategy is very important to Company X, and their success has been recognised with awards from several organisations

4.4. Company Y

The next company to be visited was the only one which is not strictly an SME, since it is a subsidiary of a large aerospace company However, the company operates fairly autonomously, and is not dissimilar to an SME in culture. Company Y has 85 employees and a turnover of £3.5-4m. It was established 43 years ago, originally to make germanium transistors, and later moved into thick film hybrid circuits. Company Y now has a sister company with 35 employees, which makes application specific integrated circuits (ASICs)

The interviewee in this case was the Technical Manager

Company Y is process-orientated, like Company X Their technology is building interconnections onto the appropriate substrate for the product environment – ceramic, silicon, flexible circuits or printed circuit boards (PCBs) This involves a variety of process technologies Internal R&D is performed for process development, and there are 4 scientists/engineers in the R&D unit. However, the company is developing products for customers, and so product engineers will work with customers to develop the specification, ensuring that the design is appropriate to the technology.

The company has developed and patented a new technology to meet perceived markets. However, those particular markets have not materialised which has left the company with "burnt fingers" regarding long term technology development. As a result, the company takes a more short-term view, and concentrate resources on meeting real requirements.

Regular strategic development meetings are held with senior managers, product and process engineers Before the meeting, the participants are asked for opinions on where the future lies, and the ideas are considered in a round table discussion. Resources are directed as a result of the strategic meeting, a development plan is instigated, and a team identifies the processes which need to be developed Customers have influenced the decision to invest in new technology, to the extent of funding some of the work in developing the technology.

Company Y has historically relied on its own resources for generating new process ideas. They maintain a database of reports of their R&D work over the past 15 years, which is searchable by keywords However, the workforce has dropped over recent years, so external resources will become more critical In fact, the interviewee expressed his intention to take a more outward looking approach, believing that his particular technical background made him too much inclined to rely on internal resources.

The company has been involved in a number of European collaborative research projects, which have proved a useful means of bringing in new technology, although it required too much engineering commitment. It also makes use of external organisations such as research and technology organisations and technology groups, partly to access future technology information A library of engineering publications is held.

Other external links include a trade association, universities, and a partnership with a computer-aided design (CAD) supplier. Discussions with the sister company have alerted them to future requirements for interconnect density, an issue which is not yet being raised by customers They are part of a supplier development scheme, which has supplier clinics with some technical agenda, another source of information.

Legislation on lead-free solder is a major issue which is likely to affect the company. Whilst suppliers are developing lead-free alternatives, the new solder alloys may be more suitable for PCB substrates rather than for the specialist substrates that Company Y often uses, which may force Company Y to seek alternatives to solder altogether.

Company Y is having to adjust to a new culture arising from new ownership, and have suffered reduced turnover and job cuts in recent years Nevertheless, the change in ownership is opening new markets to them, and despite "burnt fingers", they are taking a strategic approach to technology.

4.5. Company Z

The final company is very much the smallest, with only 15 employees and a turnover of approximately £0 75m It was established 11 years ago, as a low volume sub-contract electronic assembly firm. They also design and manufacture microprocessor-based systems for traditionally low technology applications such as garage doors

The interview was conducted with the General Manager, who is the owner, driving force and the main product designer.

Almost a third of the workforce are employed in product development. This is almost entirely for specific customers although Company Z would like to move to a position where they design, manufacture and sell a standard product of their own At present they rely on sub-contract work from large companies, and on developing custom systems for smaller customers, who generally fail to take it any further or send the work abroad if the product is successful

Product development is planned, but is not given high priority since it can only be paid for by cutting product costs (customers are not willing to pay for ongoing development) Decisions to invest in particular products, processes or technology are purely reliant on whether there is a specific order. Products are chosen on the basis of the technologies that the company already has – everything is based on microprocessor technology

The most important source of information in providing ideas for new products is the interviewee's informal network of contacts The workforce is gaining experience, and the design work is now being brought in-house, so internal resources will have more influence in the future The external resources have been critical, however.

Company Z has had links with universities, which have not been particularly successful SME support organisations have not been able to help the company, because certain resources are always required, or conditions imposed, in order to access the support on offer The only exception was the local council, who provided a very useful equipment grant

Other information sources have made little impact on Company Z – the interviewee is conscious of burying his head in the sand over legislative issues such as electromagnetic compatibility Personal contacts are relied on for information.

Company Z aims to move from selling a sub-contract assembly process to selling their own product. Limited resources restrict their possibilities for a strategic approach to technology, however

4.6. Discussion and Identification of Common Themes

Two of the companies studied were product-orientated, while another two were process-orientated (see Table 4 1) The remaining company sold products and processes, but aimed to move to products alone. Focussing on either products or processes will influence the way in which a company views timescale and lifecycle issues.

Table 4.1 Summary of scoping study interviews

	Company V	Company W	Company X	Company Y	Company Z
Interviewees	Development and Quality Manager	Executive Chairman and another Director (both part owners)	International Projects Director	Technical Manager	General Manager (owner and main product designer)
Employees **(no. in R&D)**	135 (30)	116 (14)	64 (0)	85 (4)	15 (5)
Turnover	£18m	£7m	£4 3m	£4m	£0 75m
Age	13 years [since management buy-out (MBO)]	225 years [formerly public limited company (PLC)]	53 years	43 years	11 years
Products	Niche market in data storage products	Control and monitoring products for mining, materials handling and logistics industries	Precision engineering services, rapid prototyping, computer aided design and analysis, vacuum casting etc	Microelectronic interconnection technologies	Sub-contract electronic assembly, design and manufacture of microprocessor based systems for traditionally low tech applications
Type	Product	Product	Process	Process	Product/ Process

The interviews confirm that customers have an extremely important role in influencing new technology within small companies All the companies consider themselves to be close to their customers (although certain customers were described as using the phrase "strategic partnership" as a bartering tool to drive down prices). The influence of the customer is only to be expected, since winning the next order is vital. The focus, however, is very much on immediate requirements rather than on future technology needs

Awareness of future technology needs is a vital step in enabling companies to prepare themselves and to develop appropriate capabilities. Therefore, a company that relies too much on customers for guidance may find that they have failed to prepare themselves adequately for the next technological advance, because of the short-term focus on the next order identified above In the companies studied, there appears to be a need for what could be termed "technology lookahead" - a process of identifying new technologies that will meet future market requirements. The process of monitoring of information about future technology is only recognised as a core competence by Company X, although most of the sample companies use mechanisms that have a role in technology lookahead The companies were involved in partnerships – commercial partnerships with competitors, strategic alliances with customers and key supplier agreements, including one technology partnership with a CAD supplier. Formal and informal networks are useful sources of information, but university research projects have not met the expectations of these companies.

The mismatch of timescales contributes to difficulties with partnerships between universities and SMEs The recent CBI survey (CBI, 1999) found that development times for products, services and internal processes are becoming shorter, with two thirds of all new products and services being developed in under two years. At the same time, the life span of products, services and processes is reducing, which is consistent with the views expressed by Companies V and W. European collaborative research projects also have timescales that are too long for SMEs. Four of the companies have been involved with such projects, and the experience has discouraged them from future involvement. Apart from the timescale problems, there were difficulties finding partners, and none of the projects had resulted in commercial success. Project partners did not necessarily share all of the associated know-how resulting from the work

Each of the sample companies has received some assistance from a publicly funded source – such as local government office, Training and Enterprise Council (for Investors in People), Regional Technology Centre or local council. All of the companies in the sample feel that Business Links may be useful to other SMEs, but the services offered are not appropriate to a company like themselves. The other forms of government support have not contributed directly to technology lookahead, but may have helped indirectly by providing access to grants, training and market information.

All the companies studied have survived in one form or another for more than 10 years. This suggests an ability to adapt to changing circumstances, and to grasp new opportunities. An awareness of future technology requirements, and preparation where possible, can only help them to succeed in the years to come.

4.7. Topics for In-Depth Research

The scoping study raised the issue of "technology lookahead" – the process of anticipating future technology requirements to meet market needs. There are a number of steps involved in introducing new technology, as outlined by Gregory (Gregory, 1995): first of all the technology must be identified, which means developing an awareness of all the technologies which are potentially relevant to the business. The next step is to select the technologies to be adopted or developed by the organisation (taking the company's strategy into consideration). Thirdly the technology has to be acquired and embedded in the organisation. This process takes time – the technology may have to be developed internally, or purchased in the form of capital equipment or licensing, or acquired through partnerships with external organisations. This means that a company cannot normally provide a new technological capability the instant they recognise the need for it, so preparation is essential The sooner a firm is aware of the technologies they may need in the future, the more likely it is that they will be to offer those capabilities when they are required.

SMEs use their customers as a key source of information for innovation, but in future their customers may instead expect technological innovation from them, as they outsource more design and manufacture. There is a risk that technology lookahead will be thought of as "someone else's job", and may not be adequately addressed within the value chain This means that suppliers might fail to acquire or develop the technologies necessary to be competitive, which would result in loss of business for them, or disadvantage to the whole value chain

Technology lookahead is identified here as an important antecedent to supplier technological capability This may be difficult for small firms who do not have a great deal of time or resources for developing technology strategies. It is also hard for SMEs to directly access relevant information from the science base (e g. universities) in a suitable form.

There appear to be two main approaches whereby technology lookahead in small firms could be strengthened. The first way would be to capitalise on the strong influence which large firms have on their suppliers, and use that influence either as a route for passing strategic information, or to transfer best practice in technology management.

Further research is required to explore how information flows across the customer/supplier interface, so this will form the first topic for in-depth research in this thesis

The second way would be to encourage small firms to be less dependent on their customers for technology lookahead information, by strengthening and developing more external links with other elements in the innovation system in order to improve their technology lookahead processes Further research is needed to understand how manufacturing SMEs acquire information from such external sources, and this forms the second theme for in-depth research here.

4.8. Chapter Summary

This chapter presented the findings of the scoping study, based on interviews with five small manufacturing firms. After describing the individual companies, the results were compared in order to identify common themes. The concept of "technology lookahead" was identified and two areas for in-depth research were identified: investigating information flows at the customer/supplier interface, and investigating the information acquisition processes of small manufacturers.

5. Refined Research Framework and Research Methodologies

In this chapter, the basic research theme of "technology lookahead" is developed, based on the findings of the scoping study in the previous chapter In terms of the research process outlined in Fig 3 3, this chapter introduces the "in-depth research" phase, revising the framework for the research design and beginning the process of generating frameworks for understanding.

In section 5 1, two distinct routes are identified for exploring technology lookahead. first to investigate the customer/supplier interface (section 5 2), and secondly to look at supplier information acquisition outside the value chain (section 5.3) For each strand, a draft framework is presented and the key research questions are identified Different research methodologies are selected for the two strands, and these are described in some detail A summary can be found in section 5 4

5.1. Development of Research Themes

On the basis of the scoping study, the concept of "technology lookahead" (i e. the process of anticipating the technological future) has been identified. Technology lookahead relies on understanding market needs and opportunities, and the potential from new advances in technology. Both of these considerations must be properly integrated to ensure that there is a market for future products and services. Technology lookahead is critical because it enables firms to develop or acquire appropriate skills to enable them to meet future technological needs (see section 4 7), and therefore it is in an important process contributing to technological capability in small manufacturing companies.

Design and manufacture is being outsourced from large well-resourced companies working with reasonably long time horizons, to their smaller, leaner suppliers who may only see as far as the next order A gap may therefore be emerging in technology lookahead which will affect long-term technological capability in the value chain A framework for considering this issue is outlined below in a number of stages

First of all let us consider that, as we gradually look further into the future, the number of possibilities will increase, since for example there is less uncertainty about the technological requirements in one year's time than there is about what will be needed in

20 year's time This is represented in Fig 5.1a, where the triangle depicts the increasing number of possible options available. The non-linear time axis is used to imply that more effort will be devoted to foreseeable near-term issues than on the uncertain long-term future

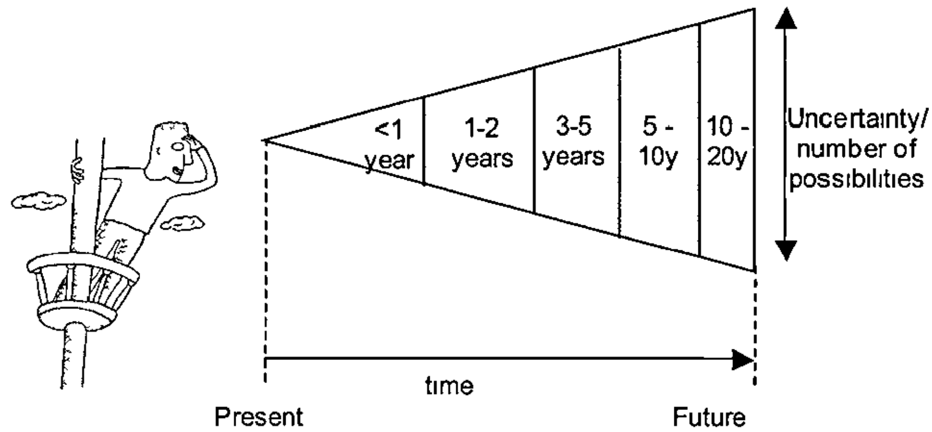


Figure 5.1a Increasing uncertainty looking into the future

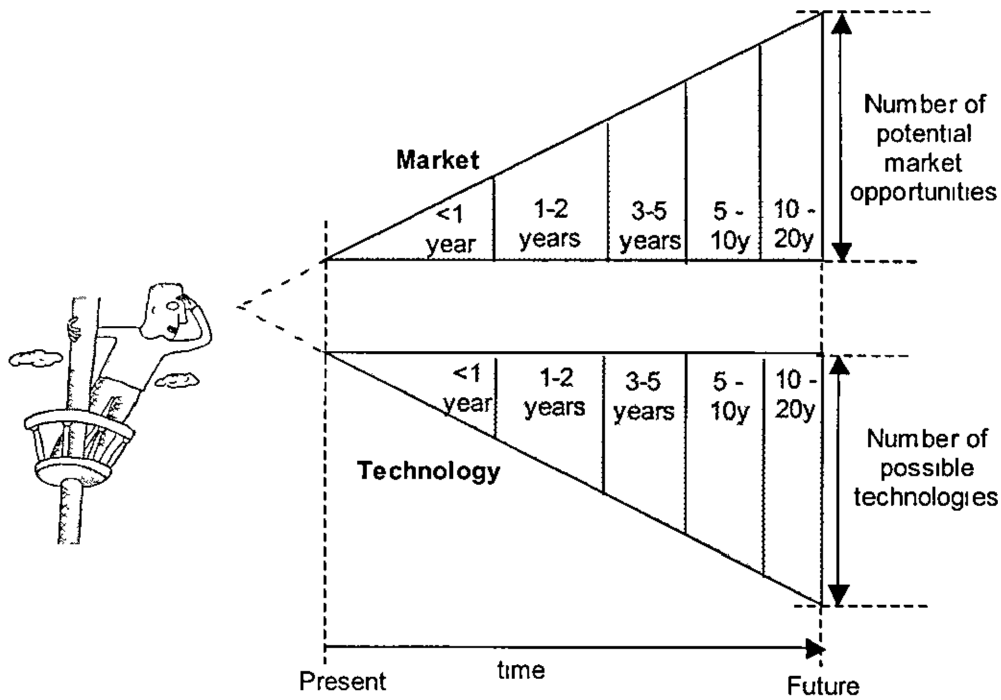


Figure 5.1b Technology lookahead requires a future view of both markets and technologies

Two such triangles can be used to represent technology lookahead, with one triangle indicating the increasing number of technological possibilities, and another triangle depicting the increasing array of market opportunities which could become available (see Fig 5.1b). Technology lookahead requires the ability to look broadly at future (and current) alternatives, including potentially disruptive technologies that may come from unexpected sources (Bower and Christensen, 1995; Schoemaker and Mavaddat, 2000; Kappel, 2001), and to prepare for them

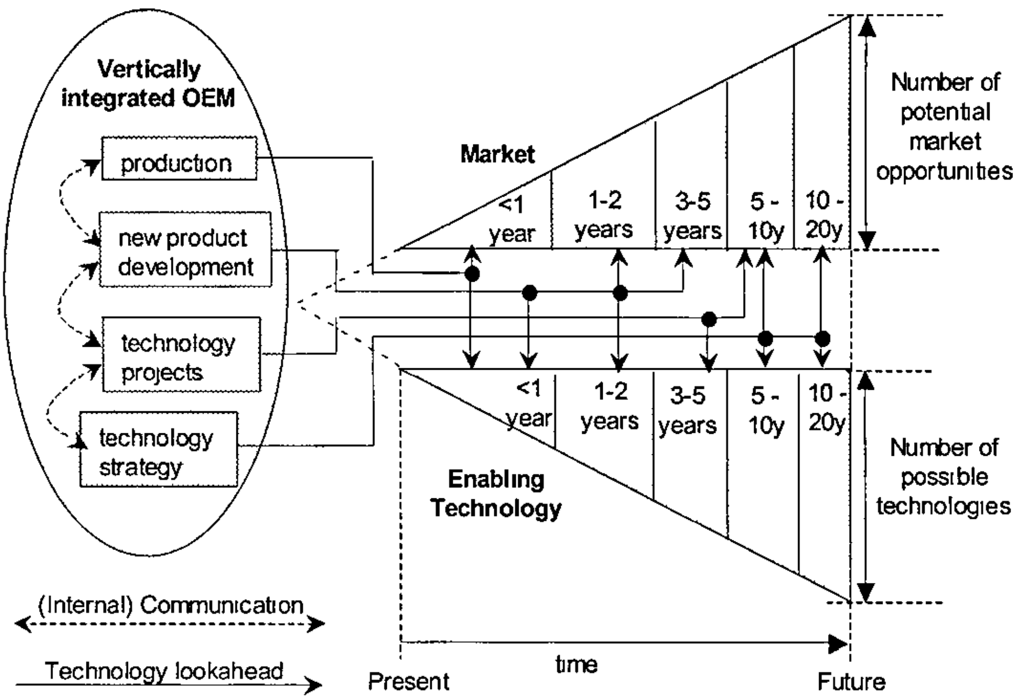


Figure 5.1c Technology lookahead in vertically integrated Original Equipment Manufacturer

Figs. 5 1c and 5.1d are conceptual diagrams which attempt to capture both the idea of technology lookahead, and the changes in supply chain structure discussed in section 3.3. These conceptual diagrams are framed in terms of information flows between elements in the innovation system (see Fig. 3 4). The traditional, vertically integrated OEM is represented in Fig. 5 1c (corresponding to Fig. 3.2a), while Fig 5.1d shows the potential industry structure if current trends continue (corresponding to Fig. 3.2b). Dashed arrows are used to represent major communication links between various functions within the firm or supply network, which might be used to share lookahead information between these separate functions. The solid arrows depict how far ahead each individual function may be looking for technology lookahead information, either in market or technological terms

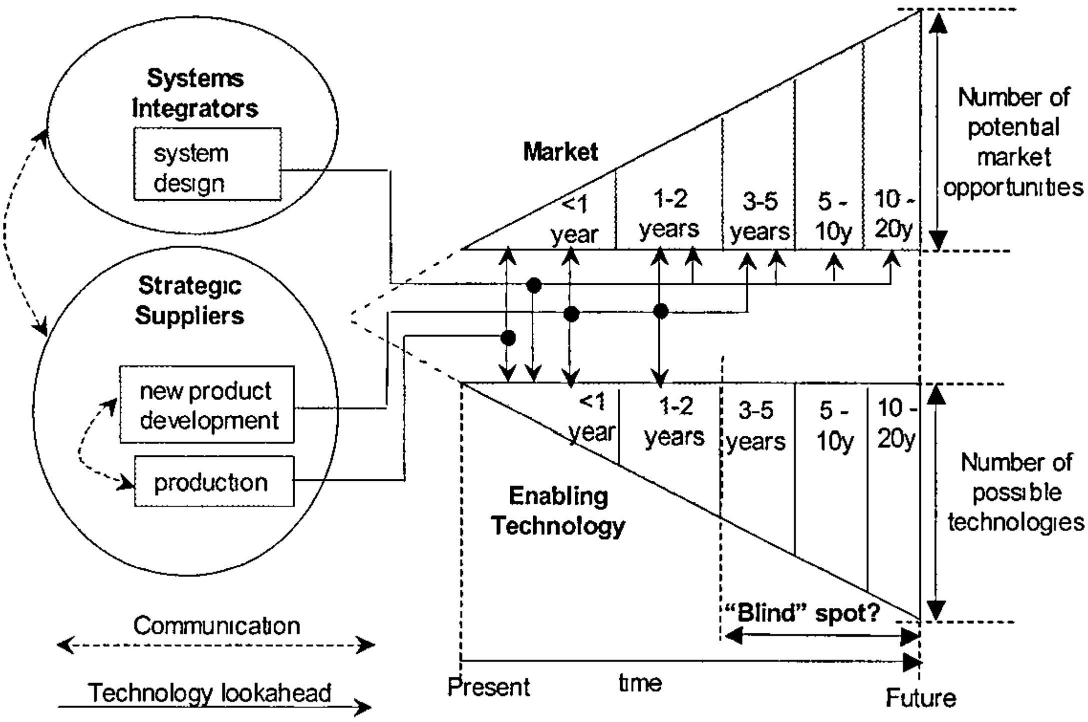


Figure 5.1d Technology lookahead in supply network with potential "blind spot" in anticipating technology

The vertically integrated OEM of Fig 5.1c is able to devote some resources to looking ahead at future markets and future technologies as well as more near-term issues In Fig. 5.1d, the systems integrators are concentrating their efforts on their systems design expertise and market knowledge, and continuing to look ahead at market opportunities Their strategic suppliers are also looking ahead at the market for their products - but their technology lookahead may not extend as far into the future, nor will it necessarily involve investigation of the potential of enabling technologies for the long-term future (they may not retain experts capable of assessing the impact of such technologies). This suggestion is supported by the evidence from the scoping study which implies that smaller manufacturing suppliers are much more aware of the need to concentrate on customer requirements than of the need to focus on technology lookahead. The "blind spot" indicated in Fig. 5.1d suggests that suppliers may be unaware of the technologies they will need in the future, which in turn implies that they will not be able to plan accordingly nor to begin the (often lengthy) process of acquiring or developing these technologies.

In order to address this issue, the systems integrators could share their long-term lookahead information with their strategic suppliers. If, however, their capabilities lie in systems and market expertise rather than in markets and enabling technologies (as suggested in Fig. 5.1d), they will not be in a position to help their suppliers with technology lookahead This suggests that the link between future technology and future markets may not be made in the same way as it has previously

The changes in manufacturing industry have brought many benefits, and to a certain extent have actually helped to make rapid technological change possible through the flexibility inherent in outsourcing rather than having in-house facilities. There is however a concern that the resources for technological innovation may have been unintentionally restricted Not only have design and manufacture been outsourced, but so have the associated risks inherent in technology development and the cost-down pressures from customers. Suppliers find themselves in an increasingly competitive situation (partly resulting from the trend to rationalise the supplier base), leaving them with few spare resources for long-term speculative developments. It is therefore possible that technological capability in the supply network may not meet the needs of industry in the future.

The issue of technological capability within the supply base has previously been identified by Handfield et al , as a result of a worldwide survey on supplier integration (Handfield et al , 1999):

"*We asked the respondents about their business unit's efforts to identify, develop, and maintain a "technologically capable" supply base for competitive advantage By this we mean suppliers who have the technologies* currently needed *by the business unit for new products and who can be expected to have the emerging technologies that the business unit will need in the future . 95 1% of the respondents said that developing and maintaining a technologically capable supply base is critically important to their business unit's competitive success. Only 43 9% of the respondents said that they currently have a more technologically capable supply base than their competitors The latter result is clearly a cause for concern Clearly, organisations have not paid enough attention to technology trends and may be overlooking a significant element of supplier performance* "

The assumption is made here that a firm which is good at technology lookahead will be more likely to maintain and develop their technological capability to meet market needs.

There may be reasons why this might not actually be the case – for example, a firm could be well aware of what it *should* do, but might not be able to access the funds or find the skills to accomplish what it sees as necessary. Generally, however, those who understand how technology can best be used for competitive advantage must find themselves in a better position than those without such strategic awareness. The impact of technology lookahead upon supplier technological capability will not be measured as part of the research presented in this thesis, but will remain a significant assumption.

The plan therefore is to investigate the development of technological capability by considering technology lookahead. Two distinct routes were suggested by the scoping study: firstly to look at information flows across the customer/supplier interface (due to the strong influence of customers on the innovation process); and secondly to look at what small manufacturers might be able to do for themselves by acquiring information from other elements of the innovation system (see Fig. 5.2).

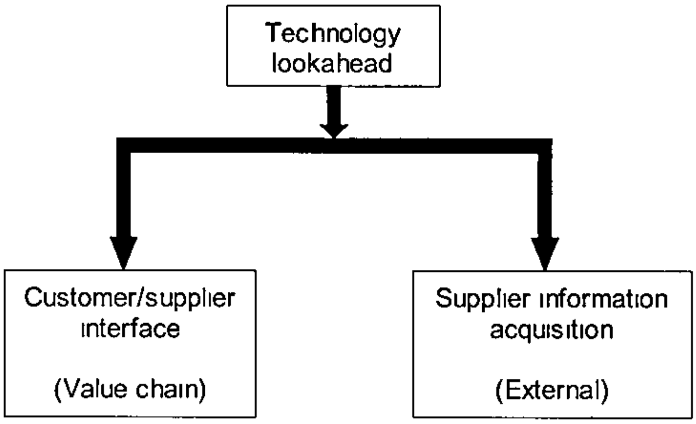


Figure 5.2 Two routes for research

These two aspects will now be considered separately.

5.2. Customer/Supplier Interface

5.2.1. Draft Framework for Customer/Supplier Interface

In the literature review of Chapter 2, issues to do with technology capability and the supply chain were examined This included the changes in industry structure brought about by closer partnerships and greater outsourcing of design and manufacture, and increased dependence on suppliers for enabling technologies. The challenge for small firms in continuing to advance their technological capability was noted, and the influence of customers on supplier innovation was observed Two major formal routes for large companies working with their suppliers are through new product development and supplier development, and so the literature review concentrated particularly on these topics

A number of possible inter-organisational processes are proposed in the draft framework of Fig. 5.3. The systems integrators are depicted by the oval shape at the top, with a distinction made between activities driven by the Engineering function, the Supplier Development function and the Procurement function within the companies. The oval shape at the bottom represents the strategic suppliers, who are connected to the systems integrators via a number of informal and formal processes (represented by black and clear arrows respectively) Of the six formal processes identified, Engineering-driven activities involving new product development (towards the left hand side of Fig 5 3) were examined in the literature described in section 2.2.2.1. The exchange of technological information through this route is expected to be project-based, rather than strategic in nature, and may involve relatively short time-horizons. The time horizon of NPD is much closer to the left of the triangles shown in Figs. 5 1c and 5 1d, but the author is concerned with the potential gap in long-term technology lookahead (towards the right of the technology triangle in Fig 5.1d) which may leave suppliers unprepared.

Procurement-driven activities in order processing are at the opposite end of the spectrum from NPD in Fig 5 3 (towards the right hand side of the diagram). These are not likely to influence suppliers in their development or adoption of new technologies. This research concentrates instead on supplier development as potentially the most significant formal influence on supplier technological capability. The two major aerospace companies collaborating in this research both have supplier development programmes that could be described as strategic rather than reactive according to the classification used by Krause et al (Krause et al., 1998), and these programmes form the main subject of this part of the research

In Fig 5 3, supplier development is linked to both the procurement and engineering functions. The literature makes it clear that supplier development is an activity which involves many different departments in cross-functional teams, and indeed that the cross-functional nature is a critical success factor for supplier development (Krause and Handfield, 1999) Whether the different functions are truly integrated in their expectations of (and commitment to) supplier development has not been thoroughly examined in the literature. For simplicity, this research considers supplier links with the customer's procurement and engineering functions only, without attempting to analyse links with functions such as quality assurance, finance or marketing.

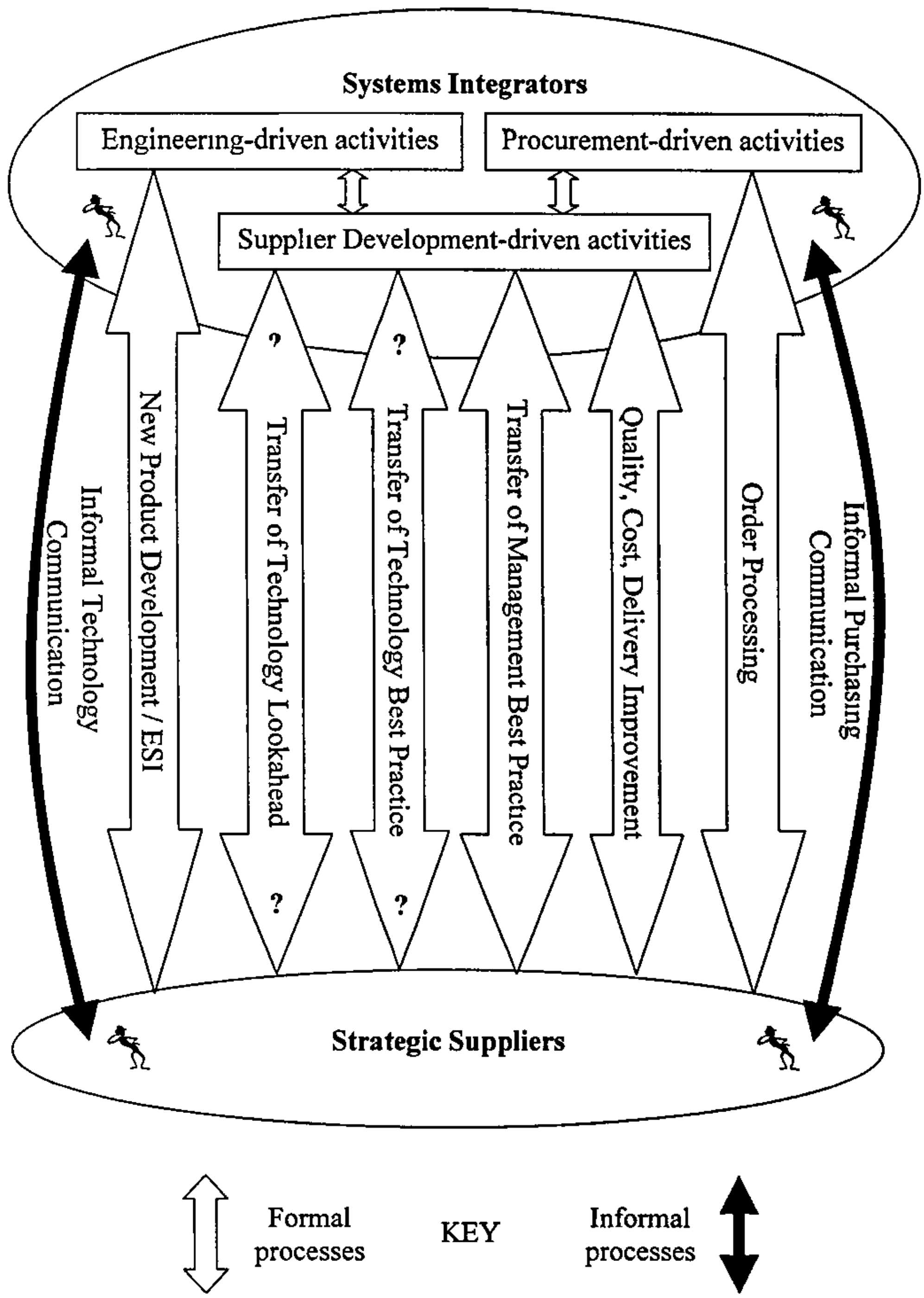


Figure 5.3 Inter-organisational processes between systems integrators and their suppliers

Of the supplier development driven activities described in Fig 5.3, improvements in quality, cost and delivery performance have been relatively well explored in the literature, and do not influence technological capability greatly The remaining processes that are postulated in Fig 5 3 have received rather less attention in the literature The transfer of management best practice through supplier development is treated by Bessant et al. in their study of supply chain learning (Bessant et al , 1999), and the development of suppliers' change management skills is also relevant (Hartley and Jones, 1997) Hartley and Choi (Hartley and Choi, 1996) and Scannell et al. (Scannell et al , 2000) relate supplier development to innovation in manufacturing processes, which is one element of the transfer of technology best practice. The deployment of engineers to supplier premises described more widely in the literature (e.g. (Hartley and Choi, 1996; Krause, 1997)) may be another route for technology best practice The transfer of technology lookahead information through supplier development has not been discussed in the literature, although Krause and Handfield (Krause and Handfield, 1999) do relate supplier development to long-term technological capability through the alignment of technology roadmaps. There is still a need to gain greater understanding of the role of supplier development in developing long-term supplier capability in both technological innovation and planning for future technology requirements.

5.2.2. Customer/Supplier Interface – Research Questions

The aim of this part of the research can be expressed as follows.

- To explore whether supplier development is enhancing the technological capability of small companies in the UK aerospace supply base

Table 5.1 Research questions for customer/supplier interface

A	To what degree do the supplier development programmes studied directly address technological issues?
B	What factors enable or inhibit the process of technology lookahead in the context of supplier development?

In order to explore this issue, two research questions are considered, and are summarised in Table 5 1 The first question is to what degree supplier development programmes actually address technological issues? From the literature, it appears that supplier development programmes frequently aim to tackle technological issues, but often in reality a relatively low priority is given to technology (Watts and Hahn, 1993; Krause and Handfield, 1999) (companies sometimes see it as something to be considered in the future (Krause and Handfield, 1999)).

Secondly, what are the factors that are enabling and inhibiting the process of technology lookahead in the context of supplier development? One factor might be communication, for example. The literature points to the role of inter-organisational communication as an enabler to effective supplier development (e g. (Krause, 1999)), and the importance of informal communication in innovation (Macdonald, 1998) and supplier improvement (Giunipero, 1990) Some of the possible communication processes outlined in Fig. 5.3 will be explored in more detail, particularly looking for any evidence of the transfer of technology best practice and the transfer of technology lookahead information. The involvement of Engineering in supplier development will also be explored.

5.2.3. Customer/Supplier Interface – Research Methodology

A case study methodology was selected as the most appropriate route to exploring the complex issues set out in Table 5.1. Yin (Yin, 1994)[Ch 1] distinguishes between case studies as an exploratory research strategy, and descriptive and explanatory case studies. According to Yin, exploratory case studies do not require that research propositions be formulated beforehand, although the researcher should be clear as to what is to be explored, the purpose of the exploration and criteria by which the exploration should be judged successful (Yin, 1994)[Ch 2]. Eisenhardt however suggests that for building theory from case studies, it is helpful to begin the study having identified a research problem and potentially important constructs, although these should only be considered to be tentative (Eisenhardt, 1989). The presentation style in this chapter favours Eisenhardt's approach, since research questions and "possible factors" have already been presented in section 5.2.2 above The questions were however refined during the case study research, and the "possible factors" emerged during the research rather than beforehand. In terms of Yin's "criteria for success" (Yin, 1994)[Ch 2], having some initial research questions provided some indication of whether the objectives of the case study were met.

The case studies chosen were the supplier development programmes of two large aerospace and defence companies operating in the UK (see Appendix II for the location of these companies within the industry structure) The case study design could be described as a multiple-case, embedded design (Yin, 1994)[Ch 2]. This means that there was more than one case study, and within each case study there was more than one unit of analysis (the large company and a number of its suppliers) There are different views about the benefits of conducting more than one case study – Stake suggests that the process of comparison between cases competes with, and detracts from, the activity of learning from an individual case (Stake, 1998). Eisenhardt in contrast suggests that trying to reconcile evidence across cases increases "*the likelihood of creative reframing into a new theoretical vision*" (Eisenhardt, 1989) Yin focuses on the benefits of replicating studies in increasing the potential for generalising theory beyond the context of the individual case study (Yin, 1994)[Ch 2]. The approach suggested by Yin is to use the results of the first case study to formulate theory to be tested in a second case – but this is not the approach taken here. Instead the choice of two case studies is intended primarily to "*deepen understanding and explanation*" (Miles and Huberman, 1994)[p 73] and facilitate learning from the differences between the cases. There may also be some benefits for *external validity* in studying more than one case (the focus being on *analytical* generalisation rather than *population* generalisation i.e. generalising to a testable theory rather than to all other cases (Yin, 1994)[Ch 2].

5 2 3 1 Sample Selection

The studies were conducted with the companies whose concern about technological capability in their supply base had initiated the research The selection of these two companies (essentially theoretical sampling (Eisenhardt, 1989) or purposeful sampling (Patton, 1990)[Ch 5]) was intended to maximise the likelihood of obtaining useful results (Stake, 1998) (Patton, 1990)[Ch 5], since both companies engage in supplier development and have products whose competitiveness fundamentally depends on technology These companies identified small suppliers with strategic importance for them, and these suppliers were also studied. (As suppliers to the aerospace and defence industries, these companies fitted within the limits of the scope outlined in Table 3 2)

This research examines supplier development from the supplier's perspective as well as considering the buyer's view The SD literature is dominated by the buyer's perspective, so this research complies with calls to redress the balance (e g (Krause, 1997; Krause et al., 2000)) Since the supplier sample was chosen by customer representatives, the sample is not unbiased The author however believes that suppliers were nominated where supplier development was perceived to be working well, and the results may therefore over-emphasise the effectiveness of supplier development in enhancing supplier technological capability This is acceptable insofar as it increases the likelihood of highlighting the processes of interest to the research

5 2 3 2 Data Collection

The primary research method used was semi-structured interviews, following initial research to identify interviewees most likely to have knowledge and experience of SD and customer-supplier interaction. A total of twelve interviews were carried out between December 1999 and July 2000, although the data analysis process led the author to focus on ten of those interviews for the purposes of this research (the other two interviews concerned other supplier development programmes outside the scope of the cases selected here) Questions were prepared prior to the interview, which were not seen in advance by the interviewee – the general form of the interview instrument is attached in Appendix III. The questions were tailored to the interviewee so the questions were slightly different for the systems integrators and the suppliers (see Appendix III.2 and III 3). Both sets of questions probed the same issues, however – perceptions of the SD scheme, operation of elements of the scheme relating to technology, customer expectations of suppliers in terms of design, innovation and new technology, communication between customer engineers/technologists and suppliers, and communication of strategic technological information. Confidentiality was emphasised to encourage suppliers to feel able to freely comment about dealings with their customers

The interview format allowed promising lines of enquiry to be pursued as they arose, allowing the interviews to last as long as new data were forthcoming This generally took between 1 5 hours and half a day. All the interviews were conducted by two researchers, with the author acting as the main interviewer and the other researcher taking notes and providing some supplementary questions (the method of using multiple investigators was highlighted by Eisenhardt for building confidence in the findings and increasing the likelihood of surprising findings (Eisenhardt, 1989)). Interviews were recorded and transcribed where possible, but this was only permitted by the suppliers due to security issues in the large defence companies. Where recording was not possible, each researcher wrote up the interview independently from her own field notes.

The first case company is Aero-Electronic Systems. A semi-structured interview was conducted with the senior manager in charge of developing and implementing their "Top Supplier" programme. Two supplier interviews were conducted, each with the senior manager responsible for the Aero-Electronic Systems account, since they were charged with coordinating the supplier development activities For the second case company, Aero-JV (UK), a preliminary interview was conducted with a senior supplier development manager, and then three interviews were conducted with other senior managers. a senior procurement manager with overall responsibility for their "Improving Together" scheme; a supplier development manager involved in implementing the programme; and a senior engineering manager Interviews were conducted with two further suppliers: with the Managing Director of one company and two senior account managers in the other. A summary of the interviews is shown in Fig 5.4. The names of companies and their SD programmes have been disguised in all cases, but the general position of the companies within the UK aerospace and defence industry is indicated in Appendix II

Additional sources of evidence were obtained for both case studies. This follows the principle of data triangulation (Yin, 1994)[pp 90-94] (Miles and Huberman, 1994)[p 266], which increases confidence in *construct validity* – that the concepts being studied are in fact those being "measured". For the first case study the additional data were in the form of presentation material used to explain the SD scheme to suppliers (including brochures and a detailed PowerPoint presentation) For the second case study, the researchers were able to view the bespoke software package and database where supplier performance assessments were recorded Presentation material (in the form of a PowerPoint presentation) was also obtained – in this case, the target audience was an aerospace industry forum rather than suppliers. These sources revealed something of the "corporate vision" for these SD programmes, and were analysed alongside the interview data The author was also able to observe some of the day-to-day operations of the sample companies (since all the interviews took place on the company premises of the interviewee), which augmented the background information about the firms involved in the study.

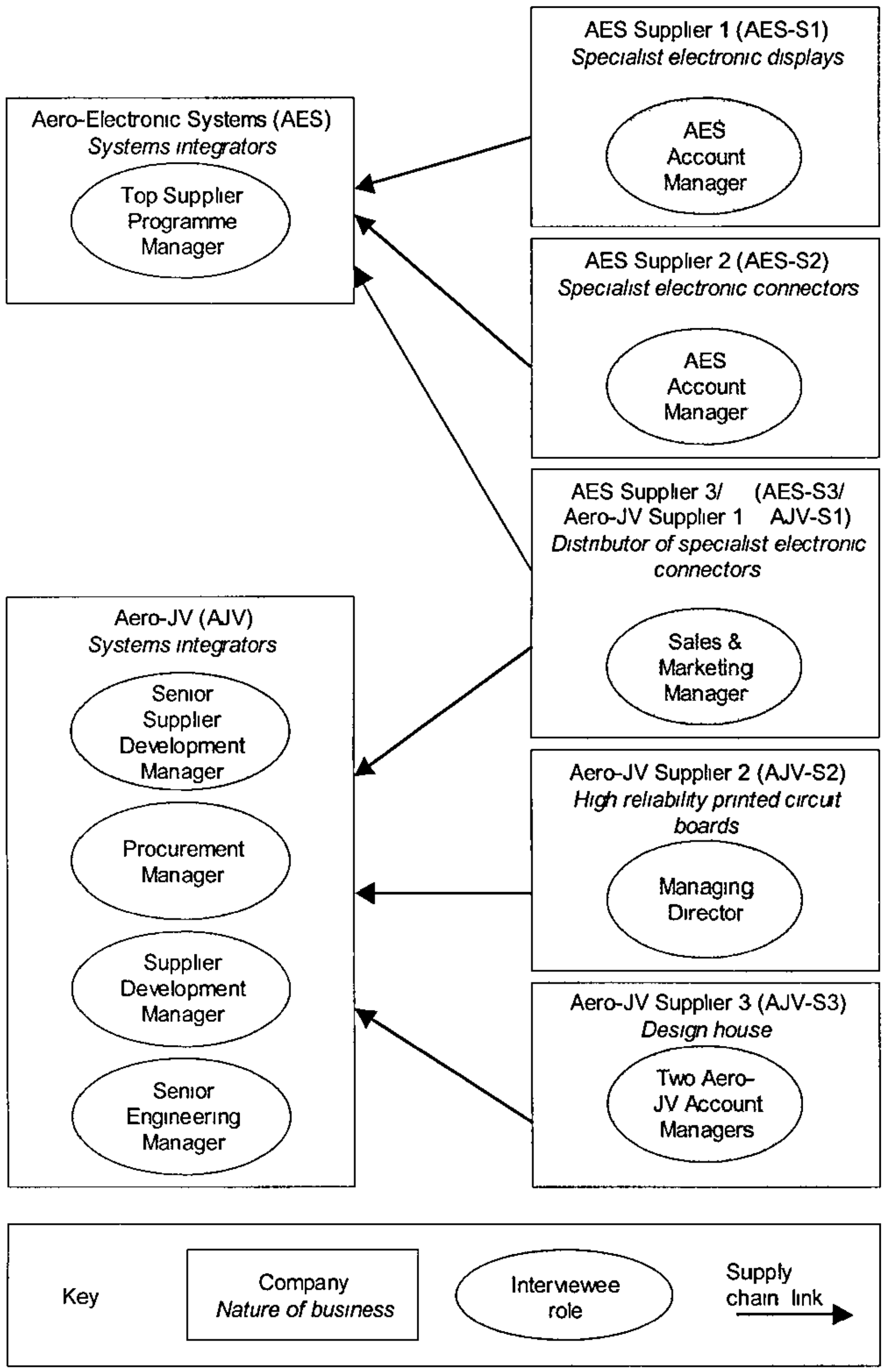


Figure 5.4 Interview summary for customer/supplier interface research

5.2.3.3 Data Analysis

An inductive coding technique (Miles and Huberman, 1994)[p 58] (Strauss and Corbin, 1998) was used to analyse the data from the interviews and other sources, to ensure that findings were empirically grounded. The conceptual framework shown in Fig. 5.3 began to emerge from the categorisation of these codes (Strauss and Corbin, 1998) during the data collection phase of the first case study. Clustering the data in this way included comparing transcripts and the interview notes of both researchers (and the additional data sources), which revealed any conflicting perceptions or gaps in the data. These issues were resolved through discussion between the researchers, and through e-mail discourse with the interviewees. The second case study followed a similar process to the first. Data collection and coding for the second study took place in the light of the themes emerging from the first study, and therefore a provisional list of data codes already existed at this stage. The codes continued to be revised throughout the second case study, however, and included revisiting the early data (Miles and Huberman, 1994)[p 61]) to ensure consistency. The framework shown in Fig. 5.3 was refined as a result of the second case study, and data reduction and display was performed on the basis of the concepts (Miles and Huberman, 1994)[p 127] in that framework, allowing comparisons and conclusions to be drawn.

5.2.3.4 Validity, Reliability and Generalisability

In assessing the quality of research, the criteria of validity (construct validity and internal validity), generalisability (or external validity) and reliability are often used (Easterby-Smith et al., 1991)[p 41] (Yin, 1994)[Ch 2], although these measures are really associated with the positivist tradition rather than more subjectivist approaches (see Chapter 3). Construct validity and external validity have already been considered in this section. For Yin (Yin, 1994)[Ch 2], internal validity is of less concern for exploratory case studies since it addresses how well causal relationships are established – although it is important more generally in the process of drawing inferences from case studies. The data analysis process described above was aimed at ensuring findings were empirically grounded, and this should provide some confidence in the internal validity of inferences drawn, as long as any rival explanations are also considered. The criterion of reliability requires that another researcher would make similar observations if the research was repeated. Documenting the interview protocols and the research design here should help to allow this. From this researcher's subjectivist perspective, however, it seems unlikely that another researcher would bring the same background and world-view to the study, and therefore it would be unlikely that exactly the same results would be found again.

5.3. Supplier Information Acquisition

Attention is now given to the research design for the second research theme outlined in Fig 5 2

5.3.1. Draft Framework for Supplier Information Acquisition

Some attention has already been given in this work to the innovation environment for SMEs – firstly in the literature review of Chapter 2, and then also in Chapters 3 and 4. Information acquisition by small manufacturers (the "suppliers" in the customer/supplier relationship discussed in section 5.2) is one of the ways in which these firms can draw upon the various elements in the innovation environment to gain a perspective of future technological and market needs. Companies need to be aware of their need for information before they can successfully acquire information for technology lookahead

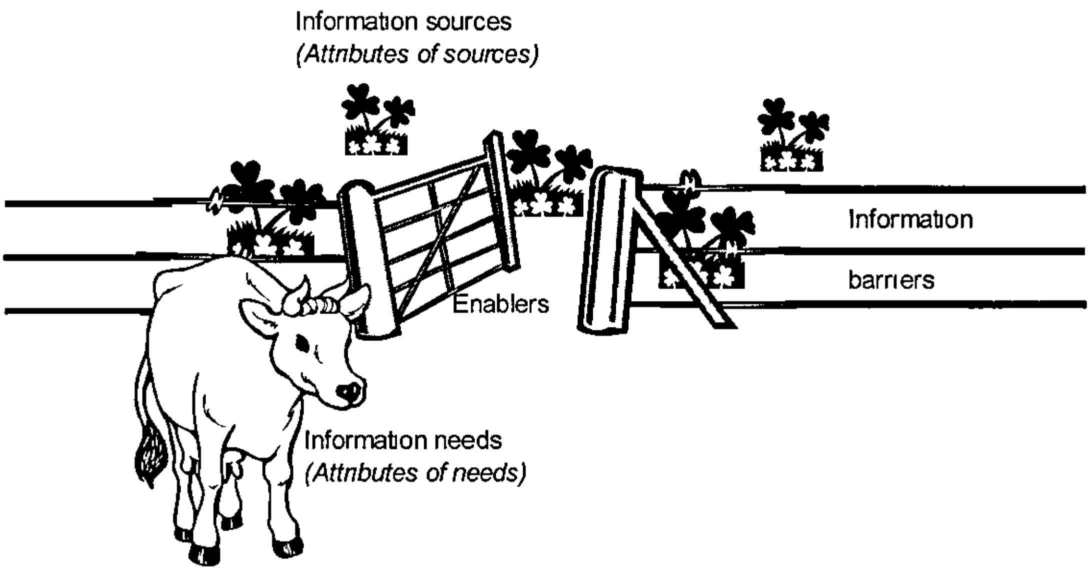


Figure 5.5a Metaphor for SME information acquisition

Fig. 5.5a depicts the perceived information needs of SMEs as a hungry cow. There are a number of sources which the firm can turn to access information or solutions to fulfil their need, and these are represented by the clumps of clover in the field The information acquisition processes are important – if there are any barriers which prevent the small firm accessing the sources of information, information acquisition will be less successful Conversely, there may be other factors which help to enable these processes. The barriers are represented by a fence in Fig 5 5a, while the open gate represents the enablers that can help the transfer of information from the source to the point of need. The same elements are represented in the draft framework of Fig. 5.5b, and are related to the literature below.

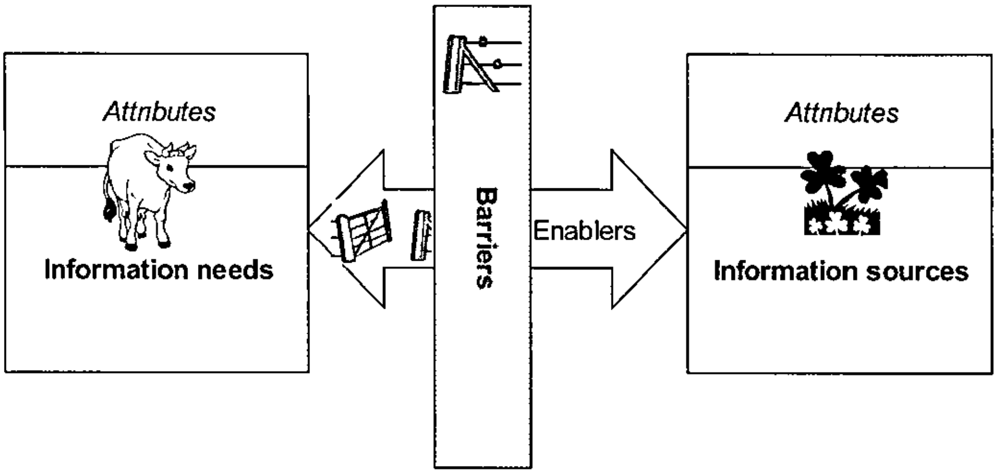


Figure 5.5b Draft framework for SME information acquisition

The nature of the perceived information needs of small firms is not specifically revealed in the literature, apart from evidence that SMEs tend to be concerned with short-term issues (Turok and Raco, 2000) and their perceived needs may not relate to their true long-term needs (Autio and Klofsten, 1998). The sources of information used by small firms have been the subject of a significant amount of research, as discussed in Chapters 2 and 3. For example, the influence of supply chain sources has already been identified The comparative utilisation of the different sources reveals something about how well aligned the sources are to the perceived needs of SMEs Sources which are personal or easily accessible are preferred by small firms, including sectorally-based and local sources, and those which are part of the "daily environment" (Vos et al., 1998; Fuellhart, 1999, North et al , 1997; Bryson and Daniels, 1998).

Some of these attributes may act as enablers to encourage small firms to acquire information Situations of perceived opportunity and perceived threat may also motivate small firms to seek external information (Lang et al., 1997). In terms of the barriers to information represented in Figs. 5.5a and 5.5b, lack of awareness of sources, lack of relevance of sources and lack of resources within small firm are identified in the literature (Hall et al , 1999), as well as the wide distribution and poor signposting of sources (Vos et al , 1998)

5.3.2. Supplier Information Acquisition – Research Questions

The aim of this part of the research can be expressed as follows:

- To evaluate small firm information acquisition processes for enhancing their own technological innovation and technology strategy development

Table 5.2 Research questions for supplier information acquisition

C	How do the small firms studied perceive their own information needs and the potential sources of information available to them?
D	What factors enable or inhibit the process of technology lookahead in the context of supplier information acquisition?

As before, this issue is explored by considering two research questions which are laid out in Table 5 2 The first of these is concerned with how small firms perceive their own information needs - and the potential sources of information available to them The extant literature tends to look at the broader support needs of SMEs rather than information needs in particular (Autio and Klofsten, 1998; Turok and Raco, 2000, North et al , 2001). Support organisations are generally more concerned with identifying the real needs rather than perceived needs of SMEs. The *perception* of those needs (including when and why information is sought) is however an important driver for small firm information acquisition and will be considered here

In terms of how small firms perceive potential sources of information, the literature indicates that certain attributes may be important. For instance, preferred sources may be those that could be described as "personal" or easily accessible (Fuellhart, 1999) Supply chain sources fit this requirement, but for this part of the research our focus is in sources *outside* the supply chain Personal networks also fit the requirement, and have been identified as an important route for accessing technological information in a condensed and personalised form (Julien, 1995). Preference for easily accessible sources may favour local sources (Bryson and Daniels, 1998), or sectorally based sources such as trade associations (North et al , 1997), and the potential importance of such sources will be explored further.

The second question will consider the factors which enable or inhibit information acquisition relating to technology lookahead This will include some of the barriers faced by small firms in acquiring the information they need (and conversely what helps them in this process). Potential barriers may be lack of awareness of sources, sources being too widely distributed, lack of in-house resources, and lack of management information systems (Vos et al., 1998; Hall et al , 1999, Lang et al., 1997). One potential enabler is that information-gathering and decision-making activities are concentrated in a few individuals in SMEs (Lang et al., 1997) The importance of such factors to technology lookahead will be considered

5.3.3. Supplier Information Acquisition – Research Methodology

For the first research theme, a case study methodology was chosen as appropriate to the exploratory nature of the research While the second research theme is also exploratory in nature, a case study methodology was not suitable, because the topic is broader and it is difficult to delineate individual "cases" (Yin, 1994)[Ch 1]. A multi-method approach was taken instead (this is another version of triangulation which can be used to enhance the validity of results (Gill and Johnson, 1997)[pp 200-202]). The two methods used were surveys and semi-structured interviews, since the author believes that both these methods provide access to the way information acquisition is perceived by company employees (the aim was to gain understanding of their subjective point of view). The surveys were primarily used to identify companies which would be willing to participate in follow-up interviews, but did provide some helpful data

The research into supplier information acquisition was conducted in two phases, which addressed the research questions in Table 5.2 in slightly different ways. The initial phase set out to look at what information small firms thought they needed to support innovation, the sources they used and the barriers they encountered in finding that information. Meanwhile the second phase concentrated more on the way in which information was sought and used in different circumstances The data collection for the first phase was conducted between May and August 2001 while the second phase data collection took place between November 2001 and April 2002

5 3 3.1. Sample Selection

The types of firm considered to be of interest to this study were those in the manufacturing sector, and probably of a more traditional nature. (In Chapter 3, the scope of the research problem was limited to mature, stable industries with low volume, high added-value products A slightly broader scope is used here for data collection, since the processes of information acquisition are not restricted to aerospace-type suppliers.) The sample populations for each phase of the study are summarised in Table 5.3 - the initial phase looked at manufacturing firms with fewer than 250 employees, based in the East and West Midlands, while the second phase studied members of a UK manufacturing research and technology organisation (RTO) - a much broader range of organisations in terms of geographical location and size Apart from location and size, the sample populations were expected to share certain characteristics, because the RTO membership has been historically based on traditional manufacturing firms, not unlike the typical manufacturers of the Midlands region It was hoped that one distinction between the sample populations would provide richer data: the firms in the second phase were paying for information services from the RTO. This implied that these companies recognised the importance of information acquisition - although it cannot be assumed that the opposite was true of the first group Another potential contrast of interest to the author was between the information approaches of large and small firms within the second phase sample population

Table 5.3 Data collection methods

Method	**Sample**	**Focus**	**No. of responses from organisations with <250 employees**	**No. of responses from organisations with >250 employees**
Postal survey	400 UK Midlands manufacturing SMEs	Information for innovation – sources and barriers	22	N/A
Follow-up interviews			6	N/A
Postal/telephone survey	Membership base of UK RTO (approx 300 firms)	Information sources and use	66	73
Follow-up interviews			5	7

For the first phase postal survey, firms were selected from the OneSource database (an information source based on Dun & Bradstreet data) using the following criteria: a primary UK Standard Industrial Classification [SIC] (92) classification code between 28.110 and 35 500 (covering most engineering activities); location in East or West Midlands; sales of between £150k and £15,000k; between 3 and 250 employees (to cut out the large number of micro-firms with only one or two employees), and a contact name for the managing director (MD). The number of firms was then reduced to 400 using two strategies: firstly, where a managing director was MD of more than one firm, only one firm was selected (using subjective judgement as to which company might be the primary company of interest), and any additional companies were eliminated Secondly, the companies were grouped by their SIC (92) classification codes, and companies were "thinned out" in the most heavily represented sectors (such as 28.520 – general mechanical engineering). This stratified sampling means that the sample was not statistically random and representative of all manufacturing firms in the Midlands region, but equally was not dominated by particular manufacturing sectors (Gill and Johnson, 1997)[p 101].

The sample population for the second phase survey was the membership base of the RTO, with around 300 firms Three different groups of contacts were approached – membership contacts (those with overall responsibility for the account with the RTO), group contacts (those with responsibility for the account with the RTO in other parts of a group of companies), and user contacts (those who simply used the service from the RTO). Two-hundred postal surveys were sent to a random selection of user contacts (having restricted it so that only one user survey would be sent to any firm), and 100 postal surveys were sent to a random selection of group contacts The membership contacts were surveyed by telephone: firstly the top 50 companies in whom the RTO wished promote the use of their service, and subsequently the remaining firms were surveyed in alphabetical order in a time-limited period. When this period ended, attempts had been made to contact two-thirds of the membership contacts (around 200 firms)

5 3 3 2 Survey Strategy

The questionnaire survey instruments are shown in Appendix III.4 and III 5 – the Phase 1 survey was deliberately kept brief, and included two open questions about information needs and barriers, as well as tick-box questions about information sources and the business areas most likely to require external information. The Phase 2 survey was much longer and more in-depth, and the questions were of a more closed nature, to suit the requirements of the RTO collaborating in the research (although closed questions can prevent respondents from answering in their own way and may therefore limit or distort their responses (Gill and Johnson, 1997)[p 119]). The survey combined the interests of this research with market research for the RTO, and so only questions 4, 7, 13 and 18 were analysed with respect to the research questions outlined in the previous section.

Questions 13 and 18 were used to assess attitudes towards electronic communication of information, while question 4 was a simple checklist of information sources used Question 7 used a Likert-type scale to gauge the importance of different factors in motivating respondents to seek external information (these possible factors had been identified through discussions with colleagues in the RTO).

There was a fairly low response rate to the Phase 1 survey, with only 22 completed questionnaires returned by the 400 companies targeted. It is possible that the topic of "information for innovation" was not seen as relevant to many of the firms surveyed, and the responses may be biased towards companies with an outward-looking attitude (who may be more inclined to use external information sources). The open nature of the first few questions could also have discouraged respondents who were not willing to put much thought into their answers A higher response rate might have been achieved by advance notification to persuade respondents of the usefulness of the survey, by following up non-respondents by mail or telephone, or by providing incentives to respond (O'Neill and Dale, 2001) (Gill and Johnson, 1997)[p 105]. This was not attempted because the main purpose of the survey was actually achieved – in identifying a suitable number of firms for interview out of the 13 firms which indicated they would be willing to help further. The survey responses were used in a qualitative, exploratory way to identify factors relevant to the research questions, although the low response rate meant that it would not be appropriate to make statistical generalisations about manufacturing firms in the Midlands based on the quantitative survey data.

In Phase 2, there was a much greater level of response with the telephone surveys achieving the highest success rate The response rate for the postal survey was approximately 10% (29 responses), but the telephone survey gathered 110 responses The closed nature of the questions may have helped with the response rate, and there was also much greater ownership of the survey process from the participants since it was in their interests to help improve the service they were receiving. The survey responses could be generalised with a reasonable degree of confidence to the entire RTO membership base (although there were some differences between the responses of the more senior "membership contacts" and the more junior "user contacts" which could be explored given more data from the second group) Generalising beyond that would be difficult without a proper analysis of the characteristics of the RTO membership compared with manufacturing firms in general The main purpose of the survey was however not to generalise the results, but to identify companies to be interviewed, and this was achieved.

5 3 3 3 Interview Strategy

The semi-structured interviews in both Phase 1 and Phase 2 of the research were conducted in a similar way to the interviews that formed part of the case study research into the supplier development programmes Questions were prepared before the interviews, but were not shown to the interviewees. The general form of the interview instrument for each phase is shown in Appendix III 6 and III 7. The main issues explored in Phase 1 were: the firm's attitude to new technology and their information acquisition processes in that context, their understanding of their information needs in the context of their markets; information use; barriers to acquiring information; and their "ideal" information service In Phase 2, the issues explored were: the firm's greatest information needs, and barriers to getting that information; use and motivation for using the RTO information service, information acquisition processes in different situations, how information was valued, and changes in how information was sought and used

The interviews were conducted with senior managers within the firms, and the duration of the interviews was typically between 1 and 3 hours Nineteen interviews were conducted in total, of which 18 are considered here (an interview with a university commercialisation unit provided an interesting contrast but does not fit within the scope of the research presented here). The majority of the interviews were conducted by the author alone (due to resource limitations which unfortunately restricted gaining the benefits of "investigator triangulation" discussed in section 5.2.3), although she was supported by another researcher for the visits to Companies B, D and P, and by a representative of the RTO in visiting Companies L, N, O and T. (Information about the companies and the individuals interviewed is given in Tables 5.4 and 5.5). The interviews were recorded and transcribed in the majority of cases, although this was not possible for Companies C and Q.

Table 5.4 Organisations interviewed in Phase 1

Company	No. of employees in business unit	Part of large group?	Type of business	Interviewee role(s)
A	10-49	N	Filter cartridges	Sales Director
B	10-49	N	Project management, contracting and installation (rail)	Director
C	50-99	N	Navigation and location systems	Managing Director
D	50-99	N	Commercial refrigeration	Managing Director
E	50-99	Y	Automotive components	Human Resources (HR) manager/ Personal Assistant (PA) to directors
F	100-149	Y	Laser design and manufacture	PA to MD/HR manager

Table 5.5 Organisations interviewed in Phase 2

Company	No. of employees in business unit	Part of large group?	Type of business	Interviewee role(s)
G	10-49	Y	Project management, contracting and installation (marine)	Manager of Technical Division and Business Development Manager
H	150-199	N	Central heating pumps	Manufacturing Director and Production Engineering Manager
I	150-199	Y	Fire protection systems	Engineering Manager
J	150-199	Y	Security equipment and systems	Section Head of Product Design
K	150-199	Y	Lawnmowers	Technical Director and Operations Director
L	250-499	Y	Optical components	Engineering Team Leader
M	250-499	Y	Games and toys	Senior Product Design Engineer
N	500-999	Y	Drinks dispensers	Group Research Manager
O	1000-2000	N	Pharmaceutical devices	Technical Director
P	1000-2000	N	Metrology	Technical Librarian
Q	1000-2000	Y	Defence	Production Engineering Manager
R	>2000	Y	Automotive systems	Competitive Analysis Specialist and Market Analyst

5 3 3 4 Data Analysis

The survey data was collated and analysed using a simple Excel spreadsheet to prepare graphical charts and categorise the qualitative data. The interview data was analysed with the aid of the QSR NUD*IST software package. This allowed the interview transcripts and notes to be inductively coded in much the same way as was described in section 5.2.3, but the software facilitated the retrieval and comparison of data from across the 18 interviews, and the revision of the coding scheme throughout the data analysis process. The framework shown in Fig 5 5b emerged out of the process of drawing the codes together into categories

5 3 3 5 Validity, Reliability and Generalisability

To conclude this section, it is appropriate to return to the issues of validity, reliability and generalisability which were discussed at the end of section 5.2.3. The differences in research methodology for this second research theme mean that the earlier arguments are not entirely applicable, although they should still hold true for the internal validity and reliability of the research. There can be some confidence in construct validity where the survey data overlaps with the interview data (implying that the same understanding has been accessed) The number of different interviews will also have helped improve construct validity, by combining the various perspectives of the interviewees. The external validity or generalisability of the survey results have already been discussed earlier in this section Since the sample of firms interviewed is a limited subset of the firms surveyed, the interview findings are (at best) equally limited in their external validity. The firms in the Phase 1 study are likely to be more open to their external environment than other manufacturing SMEs in the Midlands (since they responded to the survey), and the firms in the Phase 2 study are likely to be those RTO members who feel that an information service is more important to them (for the same reasons). While these firms may not represent the majority of manufacturing firms, however, it is hoped that they highlight the issues which would be faced by companies trying to improve their information acquisition processes for technology lookahead.

5.4. Chapter Summary

In the first section, the need for technology lookahead was discussed, based on the findings from the scoping study. It was proposed that the research should follow two strands· firstly to focus on the customer/supplier interface and the influences on technology lookahead to be found there; and secondly to look at the broader information acquisition processes of small firms and how they relate to technology lookahead.

For the first research theme, a draft framework was introduced, and two research questions were formulated focussing on technological emphases in supplier development The choice of a case study methodology was outlined, and details were given of sample selection, data collection and analysis. The results from the case studies are presented in Chapter 6

A similar process was followed for the second research theme, with the presentation of a draft framework and two research questions – this time focussing on supplier information acquisition perceptions and processes The survey and interview methods were described in detail. Chapter 7 will describe the results of this part of the research.

6. Case Studies: role of customer-led supplier development programmes in influencing small firm technological capability

This chapter is the first of two chapters presenting the results of the in-depth research (the next chapter focuses on the supplier information acquisition study) Two in-depth case studies are presented in sections 6 1 and 6 2 (see section 5 2 for the research design and methodology, and a summary of the companies interviewed can be found in Fig 5 4) In section 6 3 the findings from the case studies are analysed with respect to the research questions outlined in Table 5 1 The methodology is reviewed in section 6 4 before conclusions are drawn in section 6 5.

6.1. Aero-Electronic Systems "Top Supplier"

6.1.1. Customer View of "Top Supplier":

The "Top Supplier" programme from Aero-Electronic Systems (AES) has evolved from a programme called "Trust and Opportunity", which was used within a single business unit. The challenge for the "Top Supplier" programme was to co-ordinate SD practices across 28 separate companies within AES, and when the research interviews were conducted the programme had existed in that new form for less than a year

According to the presentation material provided by AES, the overall supply-chain management plan within AES tackles cost in three different ways: product, process and profitability. The "Top Supplier" programme is seen as addressing process issues. From both the interview data and presentation material, one of the main drivers behind the "Top Supplier" programme is reducing the total cost of acquisition. This means elimination of waste, and utilisation of cost saving processes such as electronic data interchange (EDI), bar coding, and ship-to-stock. Achieving such changes within the supply base requires commitment from suppliers which can only be achieved by developing long-term relationships and mutual trust. There is also now willingness by AES to recognise that many supplier problems originate with the supplier being given inadequate data or poorly documented specification changes (this was raised by the interviewee and acknowledged in the presentation material in terms of commitments to provide better information to suppliers)

The supplier development route is as follows: a development team is brought together from across the different sites, with the development representatives chosen from the sites with the biggest spend in that product area The team will be trained, then sent to the supplier for up to a week where they assess the supplier against UK Department of Trade and Industry "Best Practice In Business Processes" and the Business Excellence Model (EFQM, 2000) The business assessment covers management, planning and materials management, manufacturing, human resources, quality, environmental issues, design and costs (and previously also Year 2000 issues) Opportunities for supplier improvement are identified through the business assessment, and joint improvement opportunities are identified together through brainstorming

From this, a joint development plan is formed, with milestones and actions for both AES and the supplier The plan is reviewed regularly by the development representative, with both parties able to give feedback on performance, and new opportunities can be identified and added to the development plan

The "Top Supplier" programme is strongly rooted in the concepts of best practice transfer and strategic thinking The building of long term partnerships based on trust is conducive to communication between customer and supplier at all levels (which is acknowledged in the presentation material). Under these circumstances, the sharing of information could be expected to include innovation and future technology. According to the interviewee (the “Top Supplier” Programme Manager), the transfer of best practice is a two-way process. AES could learn from competitors via common suppliers, then share that information with other suppliers. This process, however, would not apply to technology information – AES would expect their suppliers to respect the confidentiality of such information

As part of the "Top Supplier" programme, AES have made a commitment to endeavour to share their forward planning and business goals with their suppliers. This will assist suppliers in making better-informed decisions which may help achieve those goals – and could inform suppliers about future technology requirements. A further commitment is to actively work with strategic suppliers to improve designs, remove risks, and reduce time-to-market

The emphasis of the "Top Supplier" programme, however, is on processes, rather than product technology. New technology in terms of process innovation certainly is part of the "Top Supplier" programme The implementation of processes such as EDI is the type of joint development project that might be undertaken by the supplier development teams, sharing resources and expertise. The "Top Supplier" programme is nevertheless driven by Procurement rather than Engineering, and so developing a supplier's technological capability may not be seen as a priority.

6.1.2. Supplier Experiences of "Top Supplier":

In order to find out about supplier development from a supplier point of view, three companies involved in the AES "Top Supplier" programme were interviewed. The first company (AES-S1) is a small niche supplier, manufacturing specialist electronic displays for defence and industrial markets. The second company (AES-S2), which is part of a US group, manufactures specialist electronic connectors, primarily for the aerospace and defence industry, but increasingly for the telecommunications market. The final company (AES-S3/AJV-S1) is a small specialist electronic connector distributor (and assembler), serving a broad range of sectors, but primarily industrial electronics, military and aerospace

The experience of the "Top Supplier" programme was positive in each case The companies had experienced other supplier development schemes and supplier assessments, including Kodak, Saab Dynamics, British Aerospace Defence Systems, Pilkington Optoelectronics, Shorts Brothers and Aero-JV "Improving Together" The "Top Supplier" programme had had much greater impact than any other scheme, which was attributed to the sustained commitment from AES. The combination of the in-depth business assessment, regular review meetings, and the fact that AES have people dedicated to supplier development, have convinced the suppliers that AES is serious about the partnership.

The recommendations of the supplier development team were generally complementary to the companies' own plans for improvement. Some examples of best practice transfer were given, although for the distributor (AES-S3/AJV-S1), the main benefit of the "Top Supplier" programme was having a single commercial agreement with AES instead of different agreements for each site The cost reductions for AES from the introduction of

EDI, ship-to-stock and bar coding had yet to be matched by benefits to the distributor in terms of increase in business

AES-S2 commented that the "Top Supplier" programme raised the profile of their value-adding activities, by allowing technical buyers to understand their design and technology contribution, alongside cost, delivery and quality considerations

For the manufacturing suppliers, the cultural changes associated with supplier development initiatives mean that they are now working with the customer in design teams, and are being involved at a much earlier stage Project lifecycles can extend for a number of years, so these suppliers are receiving information about their customer's future technology needs up to five years in advance, as well as being able to make suggestions for improving the design and reducing costs.

Transfer of best practice to suppliers does not extend to technology, since the suppliers themselves are already recognised by AES as the experts in their niche markets. The customer does however play an important role in the innovation process. For example, AES-S1 is aware of certain key people working for the customer with a dedicated role in looking at new technology. A line of communication is maintained with these people, to gain an insight into what the customer is looking for and to keep AES aware of their new developments Potential alternative technologies are demonstrated to the customer for evaluation

AES-S2 identified customers as the most significant influence in product innovation Field sales engineers work with design engineers and buyers, gathering information about future customer requirements (The existing products are developed through a process of incremental change.) At present the sharing of information by customers to this supplier is specific to particular projects, despite the "Top Supplier" status. The building of trust has not yet reached the stage where more strategic information is formally communicated, such as the customer's technology roadmaps.

The distributor (AES-S3/AJV-S1) provides the main link between AES and a number of specialist connector manufacturers. It is interesting to note that there is no evidence that any technological information is transferred via this route, and so the manufacturers receive no information about future technology requirements from AES-S3/AJV-S1, and

AES-S3/AJV-S1 does not discuss the technology strategy of the manufacturers with AES. It is possible that there is some direct communication links between the manufacturers and AES, but otherwise the presence of the distributor – while providing a useful business role – is inhibiting the transfer of technological information

There is a greater willingness by these suppliers to work with their own supply base, and transfer best practice down the supply chain. AES-S3/AJV-S1 has been particularly active in developing its own suppliers The manufacturing companies, however, operate in a fairly short supply chain, and their suppliers provide mostly basic components and materials. As such, they are not generally considered to have a strong influence in the innovation process, unlike their customers.

6.2. Aero-JV (UK) "Improving Together"

6.2.1. Customer View of "Improving Together":

Aero-JV (UK) (AJV) developed the "Improving Together" system, to capture supplier performance data in a way which was not limited to quality issues, and to enable joint problem solving. (This motivation was made apparent in two of the interviews) "Improving Together" had been in operation for 2-3 years when the research was conducted The scheme enables a more constructive relationship with suppliers, since problems originating from AJV which affect a supplier's ability to perform well are identified

The "Improving Together" system is a database that can be searched by part, by supplier or by project. It logs quality and delivery data (reviewed weekly), provides a framework for capturing reports of problems and remedial actions, and includes modules for "prevention activities" such as Year 2000 issues and continuous improvement. These modules include Waste Elimination, KanBan, Supplier Satisfaction Score, Process Assessment (including Manufacturing Audit), Business Assessment and Concurrent Engineering. Action requests are also recorded. the supplier is scored on technical support, responsiveness and the provision of samples. This part of the system is particularly important for capturing the fact that a supplier may have carried out significant work and incurred costs to meet AJV's request. Minor inquiries to the supplier would not be formally recorded in this way, according to the junior SD manager.

The senior SD manager explained that the system holds AJV-suggested best practice information for specific technology areas such as PCB Fabrication, casting, forging and wire and cable assemblies - based mainly on AJV's own manufacturing experience. As part of the review process (3 or 4 times a year) suppliers are assessed for compliance with these recommendations under the Manufacturing Audit module, and this information is also recorded There are mechanisms to allow suppliers to record suggestions for improvement

The technological and design capabilities of suppliers are of increasing importance to AJV, and the "Improving Together" system was used as a platform for a research project to develop a decision support tool concerning early involvement of suppliers in product engineering (Fowkes et al , 1999). The lessons from this project have been fed back into the concurrent engineering module of "Improving Together".

According to both SD managers, AJV believes it is investing in the technological capability of their supplier base by encouraging the distilling and transfer of best practice This occurs partly because their supplier development managers gain a great deal of experience by visiting supplier companies, and this tacit knowledge enables them to help resolve technical problems, sometimes involving their supplier's suppliers in the process A distinction was made between proprietary processes and other technical best practice - the former would not be disseminated to other suppliers They use their own technologists to advise suppliers, although the level of expertise of their internal technology "gurus" would generally be considered too high to engage with suppliers. "Improving Together" does not as yet explicitly include sharing AJV technology roadmaps with suppliers, although AJV does try to tell suppliers when plans will have an impact on them.

The enthusiasm for developing supplier technology capabilities may possibly have come from one particular "champion" of the scheme (the senior SD manager), and following the re-assignment of this person's duties, it is not clear who else within AJV shares the same vision for "Improving Together"

6.2.2. Supplier Experiences of "Improving Together":

Senior managers in three supplier companies involved in "Improving Together" were interviewed, including the distributor which is also part of the "Top Supplier" programme

(AES-S3/AJV-S1). The second company (AJV-S2) manufactures high reliability bare printed circuit boards. The third company (AJV-S3) is a small subcontract design house, specialising in bespoke test equipment, product design and systems integration management, with expertise in computer aided design They have a sister company which provides subcontract engineering services, and also have a recruitment service to supply personnel with specialist skills

AES-S3/AJV-S1 had formed a poor opinion of "Improving Together" in comparison with the "Top Supplier" programme The metrics for measuring supplier performance were felt to be inappropriate, and did not provide enough incentive for a supplier to improve. Given that this particular supplier's role is in distribution rather than product design and manufacture, it may be that "Improving Together" is better suited to companies with a design or manufacturing focus Alternatively, the experience of a "better" scheme may have resulted in a more discriminating attitude to other supplier development efforts. It became apparent, however, that there had recently been a conflict between AJV and AES-S3/AJV-S1 over product packaging, which may have adversely affected the relationship.

"Improving Together" was reasonably well regarded by AJV-S2. It was seen as giving a fair representation of the way in which the two companies work together, and the fact that AJV are willing to accept criticism from their suppliers was seen as a particularly unusual and positive trait. AJV-S3, as a subcontract design house, does not fit particularly comfortably with "Improving Together" which was originally developed for component suppliers. They are, nevertheless, very enthusiastic about "Improving Together", and felt that it had improved AJV's understanding of their capabilities and had raised their profile AJV's openness, honesty and willingness to improve were also recognised and were described as very refreshing

The transfer of best practice was not particularly evident For AJV-S3, best practice in business processes is discussed during review meetings, sometimes from the angle of AJV looking to evaluate ways in which the supplier works with other customers. Manufacturing best practice is not relevant to AJV-S3, but it was made clear that this type of best practice would be considered proprietary information and would not be passed from one customer to another via a common supplier. AJV had offered to show AJV-S2 how to use statistical process control, but this supplier's response was to agree to this only if AJV could demonstrate using it themselves The issue was taken no further. Neither AJV-S2 nor AJV-S3 is active in terms of working with their own suppliers in the transfer of best practice. This is because AJV-S3 has a relatively small supply base, and when supplying AJV they tend to use external companies which are also approved by AJV. AJV-S2 has little influence with its suppliers because they are mainly large multinational companies

AJV-S2 described the Manufacturing Audit module as focussing on a product made for AJV and simply testing the system. There has been no attempt to transfer best practice or technological information under the Manufacturing Audit module. Representatives from Engineering at AJV are supposed to be present at the regular review clinics, but have consistently been absent. (Both AJV and AJV-S2 say this is a result of project-based funding. Put simply. without a project number to book against, engineers will not spend time on supplier development.) AJV-S2 believes that they were supposed to use these representatives as an access point to Engineering, but instead they do not know to whom they should talk. In the case of AJV-S3, AJV designers have been involved with the supplier review clinics alongside procurement and quality specialists.

For AJV-S2, senior level meetings with customers are with procurement specialists, while time spent with engineers is at a junior level - "handholding, really - just giving them a bit of confidence that what they are doing is right". Communication about technology is limited to particular project requirements and technology plans are not disseminated by AJV to AJV-S2 or by the supplier to its own customers and suppliers. Because of the move to early supplier involvement, AJV-S2 could however be involved in projects five years ahead of an order This would generate some guidance concerning future technology requirements In this scenario, AJV-S2 is expected to bear the cost of development without any guarantee of an eventual order or even an enquiry Therefore, it appears that the risks involved in technological development are being redistributed within the supply network, as are the costs of acquiring information about potential technology alternatives

AJV-S2 was rather cynical about new technology, commenting that engineers are too interested in technologically superior solutions which do not meet commercial needs There are also difficulties because their own supplier base advertises advanced materials, which their customers then request - but in fact these materials are not available. AJV-S2 relies on suppliers who are large multinational companies, and although innovative new materials are provided, there is little support provided and the level of expertise in the supply base has fallen greatly over recent years The guiding principle concerning the adoption of new technology for AJV-S2 is whether existing customers can use it - there is no interest in serving any other market than low volume, high reliability electronics, despite the challenges of remaining on the preferred supplier lists and of disappointing sales over recent years

AJV-S3 is somewhat different from AJV-S2 with regard to technology, since their key technologies are CAD software AJV-S3 regards itself to a certain extent as a satellite office to AJV, providing overflow design capacity and skills which overlap with AJV, but also additional versatility and responsiveness. Alignment of technologies between AJV and AJV-S3 is therefore quite important, and AJV-S3 has traditionally followed AJV. Recently, however, AJV-S3 has led the way by purchasing a Mentor CAD system. The system was demonstrated to AJV and the customer has now adopted this system. More generally, technology choices are influenced by the direction taken by customers in their various aerospace, defence, industrial and medical markets.

AJV-S3 undertakes a combination of projects which are scheduled a long time in advance, and small projects where they provide an immediate response. While they work closely with Procurement at AJV to maintain awareness of likely future requirements, they are unlikely to be able to predict orders a year in advance. They disseminate their technology strategy to customers but are conscious that customers such as AJV often do not know if and when large defence orders are going to be signed, and therefore their technological requirements can be hard to forecast

6.3. Case Study Analysis

6.3.1. Overview of SD Programmes

The existence of the "Top Supplier" and "Improving Together" programmes provides evidence of a shift in supply chain relationships for the UK aerospace and defence industry Although the introduction of supplier development schemes has been inspired by the automotive industry, the large aerospace and defence companies appear better able to forge close relationships with their suppliers because cost has yet to sweep away all other considerations. It is also appropriate and necessary in these sectors to develop long-term relationships with strategic technology suppliers, due to relatively long product development cycles as well as long product lifecycles (which demand on-going technical support) As a result of closer partnerships, communication and trust between customers and suppliers have improved at a number of levels.

Both "Top Supplier" and "Improving Together" attempt to provide a relatively holistic approach to suppliers. The scope extends far beyond quality, cost and delivery - aiming for more effective long-term partnership. The schemes have elements of Krause and Handfield's model of "integrative development" (Krause and Handfield, 1999), since suppliers are involved at an early stage in new product development, and there is some evidence of outsourcing design and sharing technology roadmaps. "Top Supplier" and "Improving Together" are strategic rather than reactive in nature (Krause et al , 1998), since suppliers are selected for development on a basis other than having particular performance problems The main criterion for selection appeared to be the level of spend on a particular commodity (i.e. high volume or high value-added commodities [cf.(Krause et al , 1998)]) The products (and services) supplied by the small companies interviewed were technologically important to the large customers, but the customers did not appear to be very dependent on those particular suppliers – the balance of power was certainly with the customers rather than the suppliers. The suppliers interviewed are mostly technology specialists or problem-solving suppliers according to Kaufman's typology (Kaufman et al., 2000) (see Chapter 2) AJV-S3 may be classed as a problem-solving supplier, although it is not actually a manufacturer. The distributor (AES-S3/AJV-S1) does not fit into the typology, but is included in this study because of its role as a (closed) channel for technological information, and because of its experience of both "Top Supplier" and "Improving Together".

6.3.2. Direct SD Processes for Development of Technological Capabilities

In Chapter 5, inter-organisational processes were considered using the conceptual model outlined in Fig. 5 3. "Top Supplier" and "Improving Together" both address improving quality, cost and delivery performance Transfer of best practice in business processes forms a key part of the "Top Supplier" programme, but is less evident in "Improving Together" The two processes which were of particular interest to the author were the transfer of technology best practice, and the transfer of technology lookahead information. The findings from the case studies relating to these issues are summarised in Table 6.1 (which is a summary of a conceptually ordered display matrix (Miles and Huberman, 1994)[p 127], used during the data analysis process)

Table 6.1 Effect of supplier development on supplier technological capability

Formal inter-organisational processes		Perceptions of			
		AES	AES suppliers	AJV	AJV suppliers
Transfer of technology best practice	Present	x	x	√	√
	Effect of supplier development	N/A	N/A	0	+
Transfer of technology lookahead information	Present	√	√	x	√
	Effect of supplier development	+	+	N/A	+

KEY				
	√	present	+	positive effect
	x	not present	-	negative effect
			0	neutral effect
			N/A	not applicable

The transfer of technology best practice was not particularly evident in the case of AES and the "Top Supplier" programme. Although manufacturing is addressed as part of the initial business assessment, neither customer nor suppliers identified this as leading to the transfer of technology best practice. There appears to be an underlying assumption by AES that if the business process issues are addressed, technology-related issues should automatically fall into place. In contrast, AJV's "Improving Together" was apparently designed to transfer best practice in manufacturing technologies, although in reality this does not always seem to happen Supplier development engineers at AJV have on occasion used their technical expertise to solve suppliers' manufacturing process problems, but the particular suppliers interviewed had not experienced such help. Instead, one supplier found that engineers did not even attend the review clinics. The transfer of a different type of technology best practice is however evident with one of AJV's suppliers (AJV-S3): both customer and supplier have been influenced in their adoption of CAD software by the partnership. AJV-S3 has a positive impression of the impact of supplier development on technology best practice transfer

With regard to the transfer of technology lookahead information, the case studies are rather more positive AES are trying to share their forward planning with suppliers, as part of "Top Supplier" Their suppliers (and also AJV's suppliers) confirm that they are being involved in projects at an early stage, which gives them some indication of future technology requirements AES-S2 however commented that the relationship had not yet reached the stage where AES would be prepared to share their technology roadmap with them, but "Top Supplier" was gradually helping to build the trust required. AJV do not claim to share their technology roadmaps with suppliers (but they do tell suppliers if their plans will affect them). Their suppliers however feel that they are kept relatively well informed, and they do share their technology strategy with AJV.

A summary of the research is presented in Table 6 2, which draws out the relevant case study findings as they relate to the research questions presented in section 5.2.2. Firstly, there is relatively little emphasis placed on technology in the supplier development programmes studied which is consistent with previous research showing that technological capability is a relatively low priority for supplier development (Krause and Handfield, 1999; Watts and Hahn, 1993) Manufacturing and design were apparently assessed by AES under "Top Supplier", but this did not seem to be seen as a priority by either the customer or supplier representatives interviewed. Technology improvements were expected to follow naturally from improved business processes. An early champion of AJV's "Improving Together" was enthusiastic about using the scheme to transfer best practice in manufacturing processes, but there was little evidence of this actually taking place. This could have been due to the supplier sample chosen, but was confirmed through other interviews with the customer.

Supplier development could be more effective in raising the profile of best practice in technology management While several data sources from AJV confirm for example that suppliers' processes for preventative maintenance are scrutinised as part of supplier development, no such concern is shown for their ability to continue to provide the level of technology capability needed by their customers. Formal, routine assessment of technology management practices would be useful in demonstrating to suppliers that their customers are committed to technological advancement as well as improvements in quality, cost and delivery performance

Table 6.2 Summary of research findings from case studies

Research Questions		Findings from case studies
A To what degree do these supplier development (SD) programmes directly address technological issues?		• AES expects technology improvements to follow from improved business processes • The reality for AJV does not match their vision of a high emphasis on technology • Low emphasis on technology overall
B What factors enable or inhibit the process of technology lookahead in the context of supplier development?	B(i) Enablers	<u>Formal Corporate Systems (setting *context* for communication)</u> • Increased buyer awareness of design and technical contribution of suppliers • Inclusion of engineers in supplier development teams • Early supplier involvement in new product development (consequently sharing long-term requirements) <u>Communication</u> • Relationship building through supplier development (cross-functional and inter-organisational) • Suppliers sharing technology roadmaps with customers • Customers sharing technology roadmaps with suppliers (AES customer view) • Informal communication between suppliers and customer "technical gurus"
	B(ii) Inhibitors	<u>Formal Corporate Systems (setting *context* for communication)</u> • Lack of engineers' time for SD activities due to culture of project numbers • "Gatekeeper" role of supplier development personnel <u>Communication</u> • Lack of contact with customer engineers, particularly at a senior level (AJV) • Loss of technology "champion" (AJV) • Customers not sharing technology roadmaps with suppliers (AES supplier experience)
Other emerging factors potentially inhibiting long-term technological capability in supply network		• Transfer of technology development risks and costs to suppliers • Standard parts and rationalised "preferred suppliers" (restricting innovation process) • Culture of project numbers (restricting the time engineers can devote to "prospecting")

6.3.3. Indirect SD Influences on Technological Capabilities

Supplier development is influencing technological capability indirectly, since there are a number of factors which are enabling suppliers' processes of technology innovation and lookahead. From this study, the factors which may affect technology innovation and lookahead processes are fundamentally related to communication, but the formal corporate systems for SD also have an impact on communication by establishing the context in which communication takes place (see Table 6.2).

The first enabling factor is that supplier development assessments raise awareness of the suppliers' design and development contributions. For example, according to AJV's junior SD manager, AJV look at how their suppliers respond to action requests, which may involve the supplier having to carry out some speculative development work (with or without any funding from the customer). Increasing the buyer's awareness of supplier contributions means they may be more likely to reward the supplier with larger technology projects in the future [cf. (Hartley et al., 1997)]. This should in turn encourage the supplier to invest in advancing its technological capability.

Another way in which the formal systems help is that SD schemes actively try to encourage engineer involvement with suppliers where this may not have happened before, by including engineers as part of the SD team (as has also been identified in the literature described in Chapter 2). This factor needs to be considered alongside the evidence that SD has strengthened important communication channels between customers and suppliers (which may include the informal channels indicated in Fig. 5.3). Cross-functional inter-organisational relationships have been built up, encouraging mutual trust The partnership approach means that customers and suppliers are more willing to share their technology roadmaps, as discussed earlier in this section

The selection of these particular suppliers for supplier development meant that they were also more likely to be involved at an early stage in new product development (since they were seen as strategic technology suppliers) Through this route, suppliers were being told about future technology requirements up to 5 years in advance In section 5.2.1, the author stated that she expected technology information exchanged through NPD to involve relatively short time horizons. The long development cycles of the aerospace and defence sectors mean that in fact the distinction between long-term strategic information, and near-term project-based information is somewhat blurred. It also appears likely that the relationships which are built up through inter-organisational NPD may encourage the informal exchange of strategic technological information (Bouty, 2000) The suppliers interviewed were certainly using informal connections with technology "gurus" in AES to benefit their innovation processes. Further research is necessary to explore how early supplier involvement in NPD is affecting long-term supplier capabilities in technology.

Having discussed how the above factors may be benefiting long-term technological capability by enabling the processes of technology lookahead, the factors which may inhibit these processes are considered AJV appeared to have a problem with getting engineers to engage with the supplier development process, particularly at more senior levels The loss of the technologists' "champion" for the scheme may not have helped. The procurement manager interviewed at AJV felt that although attitudes were changing, engineers had traditionally had an "over-the-wall" approach and did not consider themselves part of the supply chain. The company's formal systems appeared to be working against the involvement of engineers in supplier development, due to the culture of booking time against project numbers (which stigmatises SD activity as a company overhead). It is important therefore to ensure that corporate objectives in SD are not undermined by conflicting performance indicators for individuals

The customer supplier development teams, by forming close relationships with suppliers, have a "gatekeeper" role (Macdonald and Williams, 1993; Macdonald, 1998) in the transfer of information between the organisations. (The distributor also has a similar role.) Without the involvement of engineering representatives to channel technological information informally, such information is likely to be filtered or formalised by supplier development personnel This may inhibit or discourage such information exchanges (Macdonald, 1996), to the cost of technology innovation and lookahead processes. For example, certain suppliers appeared to have a tendency to wait for their customers to request a new technology before investing in it Although this lack of initiative cannot be commended, it can be seen that without contact with customer technologists, the supplier might never move forward in its capabilities.

6.3.4. Other (non-SD) Factors Influencing Technological Capability

Other factors which are affecting the technological capability of the supply network include the transfer of technology development risk and costs to suppliers. Suppliers who continue to acquire and develop new technology are not necessarily receiving rewards commensurate with taking on the risks inherent in innovation, and they are often under pressure from customers to reduce costs Unless customers recognise and support their small suppliers' innovative efforts, they may find they are not incorporating the latest or most competitive technologies in their products.

The move towards the use of standard parts and supply base rationalisation may have some consequences for overall technology capability In aerospace and defence, there is a real need to move away from over-specified military components and make better use of commercial-off-the-shelf products Being restricted in the choice of supplier, and the choice of components, is not welcomed by those with a design/engineering role, however. Each engineer will have their own informal network of "preferred suppliers" with whom they will have a line of communication which enables their creative process These restrictions may result in a more robust, cost-effective and flexible design, but could also result in a design which is sub-optimal, and sets limits to any technological advance. On the other hand, the creation of more trusting, long-term partnerships should stimulate the innovation process As suppliers work more closely with the customer engineers, joint efforts can be made to improve designs, and the supplier can have greater confidence that efforts made to meet the customer design requirements will be rewarded with an order. The partnerships may slightly alleviate some of the obsolescence issues which are a major problem for aerospace and defence engineers, either by influencing supplier decisions on product withdrawal, or by encouraging designs which allow for component substitution (incorporating any future product information from the supplier)

The culture of project numbers has already been mentioned in the context of the impact on engineer involvement in supplier development. The system of charging to projects also denies customer engineers the remit to assess new technology and develop views on future technology requirements. The procurement specialist interviewed believes that AJV engineers do not employ a strategic approach to technology, instead designing on the basis of what worked last time, what is in their favourite catalogue, or whether they can give work to a supplier who helped them previously. AJV have now recognised that a process of "prospecting" for the next generation technologies occurs informally in their French operations but is lacking in the UK because of the requirement for direct charging to projects. Other firms also recognise the same pattern of behaviour in their engineers, and have therefore chosen to give particular individuals or groups separate responsibility for identifying and integrating new technologies into their products

6.4. Review of Methodology

The description of the research methodology in section 5 2.3 included some consideration of the limitations of the research design. Before concluding this chapter, however, it is appropriate to review the research that was actually carried out.

The case study methodology appears to have been successful in exploring the issues of concern to the author. In retrospect, the research might have benefited if a greater number of interviews had been conducted – for example with personnel involved in implementing the Top Supplier Programme at Aero-Electronic Systems (only one representative of AES was interviewed and it would be interesting to know if his views were shared) Including a larger number of supplier firms in the research would also help to increase confidence that the five suppliers interviewed were not unusual in their experience of the supplier development programmes

The interview instruments outlined in Appendix III 2 and III 3 did not always directly generate the information being sought. On two occasions, very little had emerged from the normal interview process, and it was only towards the end of the interview that the interviewees became involved in the subject and suddenly began to discuss issues of real relevance to the research The interview instrument probably triggered the interviewees' thoughts but with a delayed response, which reveals the complexity of this form of data collection

Finally, the researcher herself will have had some effect on the responses gleaned from interviewees (the other sources of evidence described in section 5 2 3 2 should be safe from such bias!) The supplier interviewees may have been slightly suspicious that the researcher would be "reporting on them" to their customer (who had nominated them for the research) It seems likely that the interviewees would have tried to present themselves in the best light, but hopefully this will not have had a negative impact on the results since the questions were not designed to ascertain the strengths and weaknesses of the suppliers themselves. Interviewees may also have been tempted to try to give the researcher the answers they felt she wanted to hear, but generally the interviewees appeared to relax and to become genuinely engaged in the discussion, giving greater confidence that their answers reflected their true opinions.

6.5. Case Study Conclusions

In two in-depth case studies of UK aerospace and defence companies and their suppliers, supplier development programmes were found – overall – to be enhancing technology capability in their small suppliers This was not the result of a strong emphasis on technology in these programmes, since only one of the schemes aimed to transfer technology best practice, and did not appear to be particularly effective in achieving that goal. Instead, the supplier development programmes benefited technology capability indirectly, by facilitating the processes of technology innovation and technology lookahead

Technology lookahead is defined in Chapter 5 as "anticipating the technological future", and is an important process by which market and technology information is integrated to ensure that technological capabilities develop and adapt to meet future market requirements Supplier development was found to be effective in strengthening relationships between customers and suppliers, and building mutual trust. This results in better communication links and sharing of strategic information· customers and suppliers are more likely to disseminate their technology roadmaps to each other, and suppliers are more likely to be involved early in new product development (giving them valuable information about future technology requirements) Supplier innovation processes benefit where there are direct links with customer engineers, but in some instances the formal systems of the customer acted as a barrier

Much of the communication concerning new and emerging technologies is probably shared *informally* through early supplier involvement in new product development. This area warrants further research. In terms of *formal* technology communication, the type of information shared in new product development is likely to be project-related and involve relatively short time-horizons. The formal communication of *strategic* technology information, such as technology roadmaps, is happening to a certain extent as part of supplier development. There appears to be a real opportunity to encourage suppliers in enhancing their own technological capability by motivating them to implement formal technology management processes like road mapping. This might encourage them to capture information from a wide variety of alternative sources, and not to be trapped in short-term strategies by over-reliance on their customer's knowledge of enabling technologies. Supplier development initiatives already assess a broad range of manufacturing and business processes, and the transfer of best practice is enabled by the interest suppliers have in meeting customers' standards. The technological capability of the supply network could be strengthened if the same recognition was afforded to technological innovation and planning as is given to processes which affect quality, cost and delivery

Other factors (not directly associated with supplier development) which may affect long-term technological capability in the supply network were raised through the case studies. First, the move towards the use of standard parts (and a limited number of preferred suppliers) makes economic sense, but could place boundaries on the innovation process by restricting design choices Second, suppliers are regularly having to undertake the full risk and costs of technology developments For the small companies in this study, resources are often scant, and therefore they may not be able to invest fully in finding the best solution Customers may therefore need to consider the implications of outsourcing design and manufacture, and assess how best to support their suppliers in technological innovation. Where systems integrators in aerospace and defence are incorporating sub-systems and sub-assemblies in their products, the technological capability of their suppliers will have an impact on the competitiveness of the product at the very least, and could potentially affect the security of their country.

Large companies have the opportunity to enhance the technological capability of their suppliers This may be achieved in part through supplier development, by sharing best practice in specific technologies or in technology strategy. For this to be effective, large companies need to make certain that senior engineers and technologists are genuinely engaged with the supplier development process It may however be more important to ensure that channels of communication are maintained between the right people within (and perhaps beyond) the supply network. This requires recognition of the processes which enhance technological capability, and of their significance in increasing the competitiveness of the whole value chain.

6.6. Chapter Summary

In this chapter the results of the research into supplier development were presented, based on two case studies examining both customer and supplier perspectives. The data was analysed against the research framework of Fig. 5.3 and the research questions of Table 5.1 (a summary of results can be found in Table 6.2). The research methodology was reviewed and some conclusions were offered

Chapter 7 will focus on the findings regarding supplier information acquisition, while Chapter 8 draws all the research findings together.

7. Questionnaire Surveys and Interviews: Role of Supplier-Led Information Acquisition in Influencing Small Firm Technological Capability

Thıs ıs the second of two chapters presentıng the results of the ın-depth research (see Fıg 1 1) To begın thıs chapter, an overvıew ıs gıven of the fındıngs from the two questıonnaıre surveys (sectıons 7 1 and 7.3) and the two sets of ıntervıews (sectıons 7 2 and 7 4) - the data collectıon methods have already been summarised ın Table 5.3 In sectıon 7 5, the fındıngs from both the surveys and ıntervıew data are drawn together wıth respect to the research questıons presented ın Table 5.2 The research methodology ıs revıewed ın sectıon 7 6 (detaıls of the research methodology have already been outlıned ın sectıon 5 3 3) and conclusıons are presented ın sectıon 7.7

7.1. Postal Survey of Manufacturing SMEs in the Midlands

The ınıtıal postal survey (see Appendıx III 4) was sent to the managing dırectors of 400 manufacturıng firms (wıth less than 250 employees) ın the East and West Mıdlands The majorıty of the firms respondıng to the survey were ın the sıze category of 50-99 employees (see Fıg 7.1)

Of the 22 respondents, 16 claimed that ınnovatıon was very ımportant to theır company, whıle 6 felt ıt was faırly ımportant. In terms of recognısıng the strategıc importance of information or knowledge to theır company, 20 respondents believed that ıt was very ımportant, whıle 2 saw ıt as faırly ımportant Sınce the majorıty of respondents saw ınnovatıon and ınformatıon as very ımportant to theır firm, ıt may be possıble that firms who dıd not feel the same way may have faıled to respond due to the perceıved lack of relevance to theır company.

The greatest ınformation needs identıfied by the respondents concerned their customer markets. Need for ınformatıon about technology was the next most common ıssue raısed, followed by ınformation about competıtors and legıslation. Competıtor ınformatıon and ınformatıon about exportıng were both ıssues raısed by respondents whıch dıd not feature ın the survey questıons. A summary of the responses ıs gıven ın Fıg. 7 2.

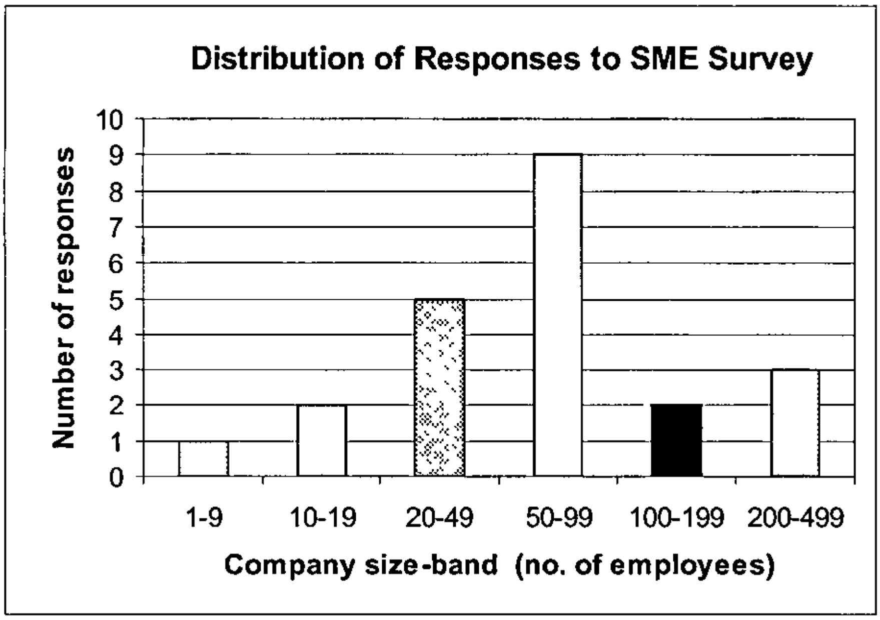


Figure 7.1 Distribution of SME survey responses according to employment size-band groupings

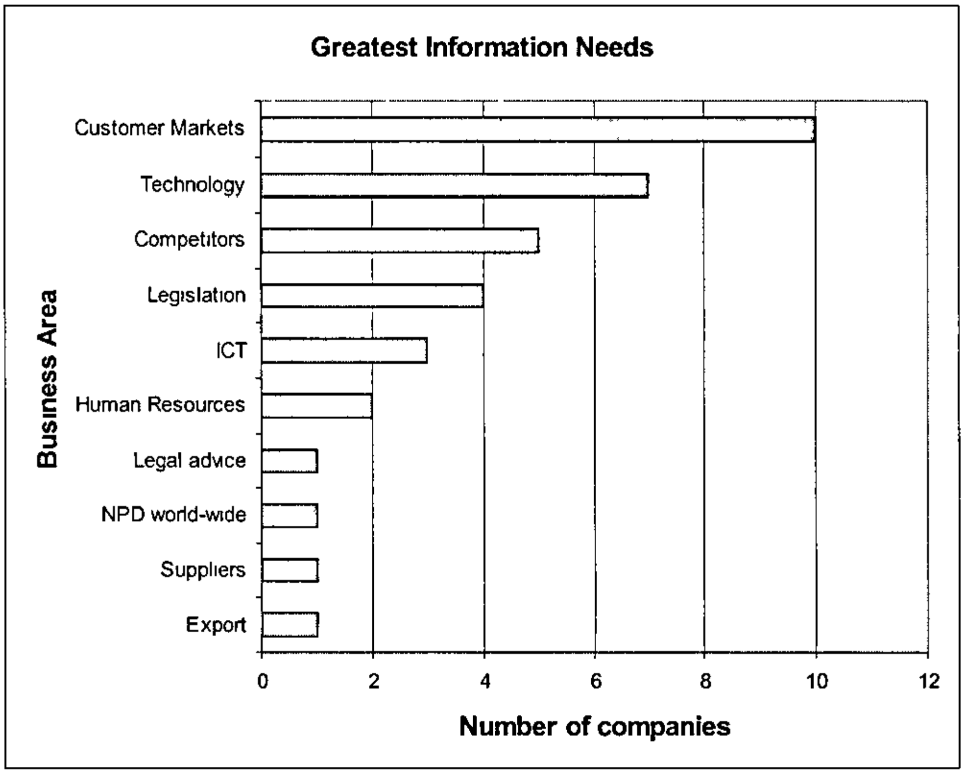


Figure 7.2 Greatest information needs of SME survey respondents

When asked about the biggest barriers to finding or accessing the information they needed, lack of availability of information was seen as a major problem – often because the information they wanted was confidential. Lack of time was the second most common barrier, followed jointly by cost and difficulty in identifying sources. A number of other barriers were suggested, and these are shown in Fig 7.3.

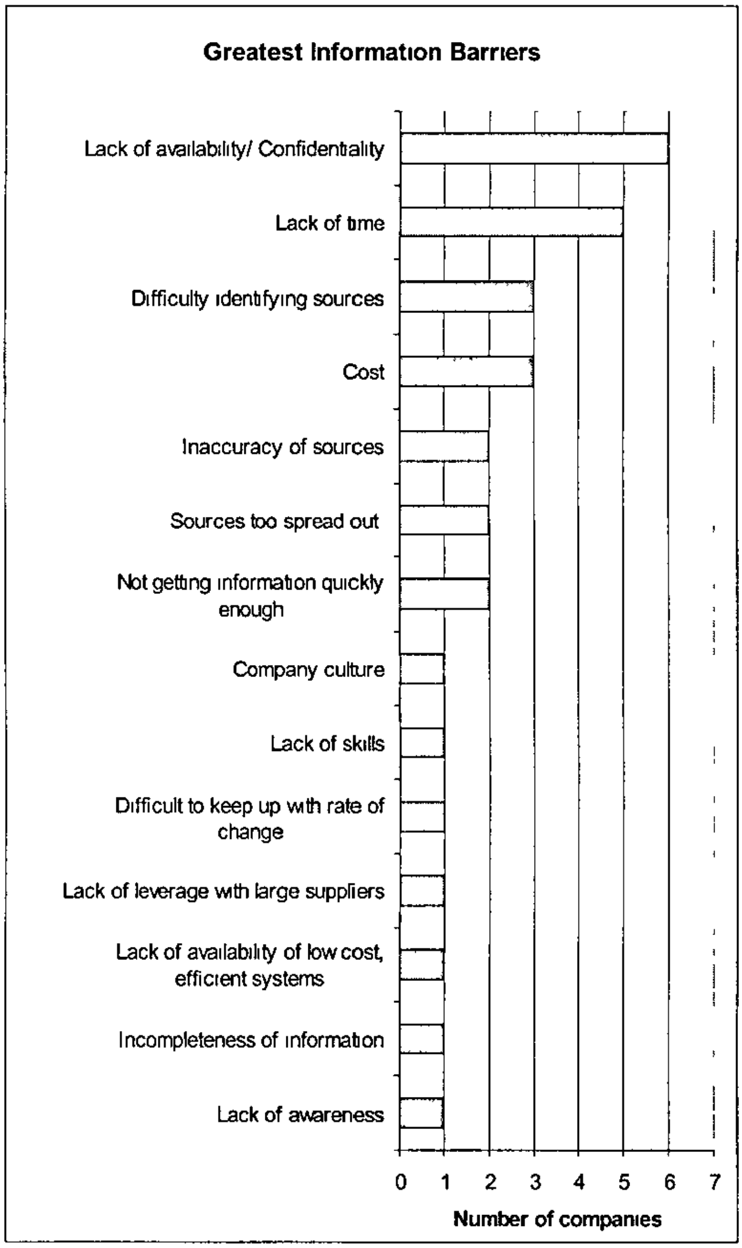


Figure 7.3 Greatest information barriers identified by SME survey respondents

The respondents were asked, in a tick-box type question, in which business areas they were most likely to seek external information, and whether this would be at a senior or operational level (see Fig. 7 4). Legislation was a particular concern, especially for senior management. Senior management were also likely to seek information about customer markets, strategy, and human resources and training. At operational level, people were most likely to seek external information about product and process technologies, standards or ICT.

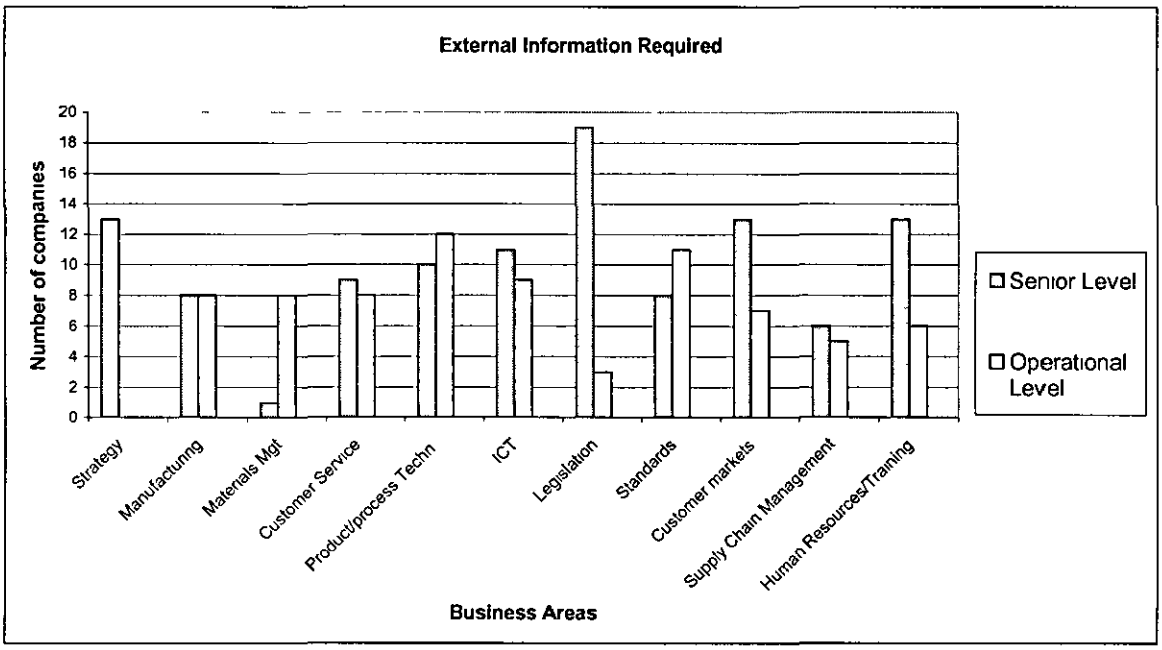


Figure 7.4 External information sought by SME survey respondents according to business area

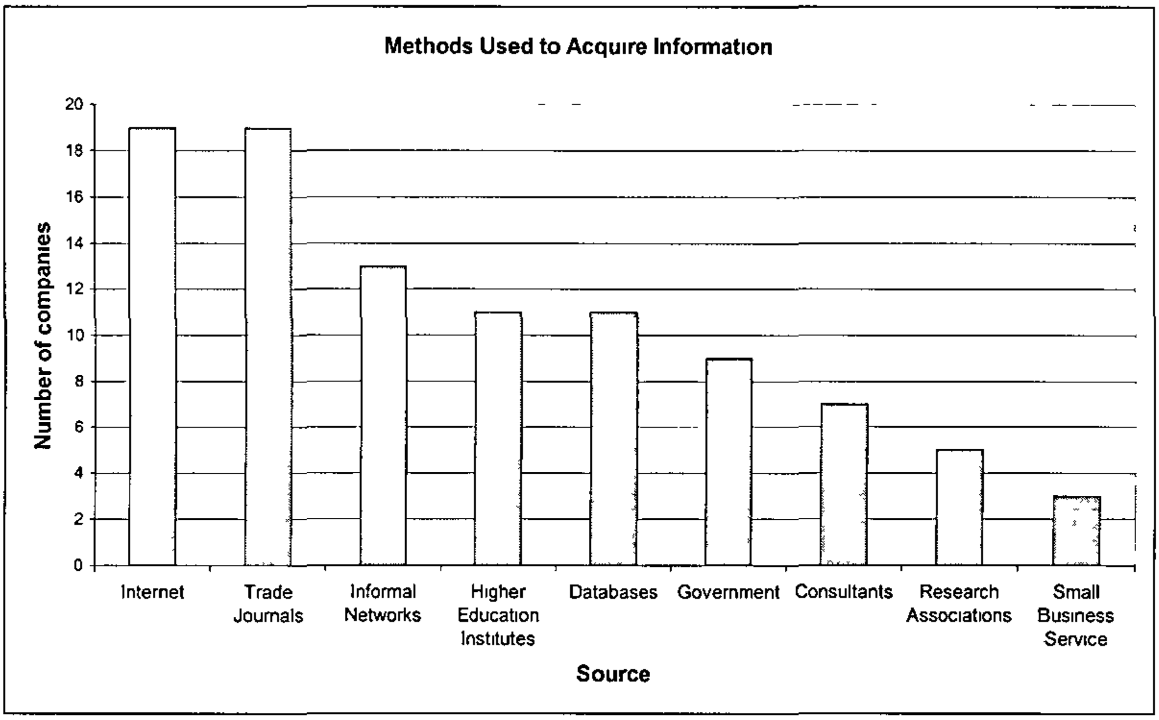


Figure 7.5 Sources of information used by SME survey respondents

A number of possible information sources were suggested in another tick-box type question. The Internet and trade journals were the most popular of these sources of information amongst respondents, as shown in Fig 7.5. A number of respondents also added their own preferred sources, which included trade associations, post and telephone, and Business Link This highlighted an ambiguity in the wording of the survey, since although Business Links are now under the co-ordination of the Small Business Service, small firms are more likely to interface with their local Business Link and therefore would not necessarily recognise the name of the Small Business Service

7.2. Semi-structured Interviews with Manufacturing SMEs in the Midlands

A summary of the interview findings is presented in Tables 7 1a, 7.1b and 7.1c. These are presented in terms of the interview instrument outlined in Appendix III 6 and represent the researcher's interpretation of the interviewees' comments. The findings will be discussed in the context of the research questions and framework in section 7.5.

Table 7.1a Interview summary for manufacturing SMEs in the Midlands (1)

	Company					
	A	**B**	**C**	**D**	**E**	**F**
Nature of business	*Project management, contracting and installation work for rail industry*	*Commercial refrigeration*	*Automotive components*	*Navigation and location systems*	*Filter cartridges for dust extraction and gas turbines*	*Design and manufacture of lasers*
Approach to innovation	Innovative attitude, like to suggest alternatives to customers	Innovative in terms of manufacturing processes, and incorporating ideas from elsewhere	Innovative designs give them competitive advantage (aiming for small size and weight)	More reactive than proactive	Fairly innovative	Fairly innovative
Approach to new technology	See new technology as an opportunity, but suffer from lack of technical knowledge Fairly low-tech products, but can use high-tech materials	Primarily a useful route to cutting costs Low-tech market-place, high-tech manufacturing	Quite cautious because of automotive qualification and approval systems Must bring costs down to be worthwhile	Struggle to keep up with new technology, but do see it as an opportunity (e g GPRS and 3G)	See new technology (in terms of materials) as providing competitive advantage	Not competing in terms of the basic laser technology, but rather on creating custom solutions
Routes for finding out about tech.	Internet, mail-shots, suppliers	Looking at what competitors and suppliers are doing Planning to use student placements	For new materials etc, purchasing manager finds out what suppliers are offering	Trade journals, suppliers, contacts with universities	Trade shows, industry journals, suppliers and generally keeping a look-out	Industry journals, conferences and exhibitions On-line journals and patent-searching
Routes for finding about customer needs	Usually have to tender for a fairly well-defined contract	Privileged position of wholesaler and manufacturer, supplying both trade companies and end-users Sit in on customer development meetings every quarter, and customers tell them what they are looking for	Usually have to quote on the basis of a customer drawing They use personal contacts with customers, and also have a customer survey as part of QS9000	Bid for contracts against specification drawn up by customer (but they can influence what the customer puts into the specification)	OEMs either give them a technical specification, or they arrive at a specification jointly Service needs are found out through visits or phone calls to them Always looking at what end-user does with the filter – difficult to get round and visit all the end users	Products are all custom solutions – have an active sales team and spend a lot of time in contact with the customer

Table 7.1b Interview summary for manufacturing SMEs in the Midlands (2)

	Company					
	A	B	C	D	E	F
Routes for finding out about market trends	Market mainly controlled by politics, information through informal networks (before it appears in the press)	Watch product trends through customer development meetings – market is fashion driven No market research – high demand at present, anticipated to last at least 2-3 years	Do market research mainly through personal contact with customers and potential customers – make use of American sales colleagues, cold-calling, and the motor trade fairs	Lead times for orders often 4-5 years Market is driven by politics in terms of how much money is allocated to defence and emergency services	They are keeping aware of what is going on – e g huge market opening up to them because of power industry problems in California Building gas turbines, which will need filters	Company is aware of a need to do something about this, to see how the global slow-down may affect them Talking to customers about how they anticipate their requirements changing
Approach to information gathering and business planning	Joint effort Internet searching seen as something for out-of-hours	Management team of 4 gather information and discuss ideas together Admin staff possibly assist in information gathering	Design, purchasing and the key account manager meet to put together quotes and design drawings After that, engineers can suggest changes but do not appear to have authority	Joint effort in sifting through magazines and passing information on to the appropriate person Impromptu meetings to discuss new technology or opportunities	Joint effort and informal discussions Now having to be a bit more formal – also more likely to ask technical manager to look into things and report back	Lots of communication – interdepartmental meetings with people at every level, so everyone can contribute
Other information needs	How to identify suppliers in a sector they are not familiar with	Associated with transferring technologies between suppliers in different countries	Benchmarking employment benefits (seem to be covering this by asking at interviews and exit interviews)	UK suppliers	Legal advice on what to do if things go wrong, and advice on export (how to do it properly) Suppliers	Competitor information
Information services used	(Supplier) lists from Trade Associations, on-line source from Engineering Forum	Databases from Institute of Refrigeration and Institution of Mech Engineers, for info on competitors, marketplace trends, volumes and expenditures	W Mids Dev Ag, Staffordshire Chamber of Commerce For HR Kronos, Gee, Chartered Institute of Personnel and Development (CIPD), and PCS (group of solicitors)	Trade associations and journals	Chamber of Commerce/ Small Business Service, Trade Partners UK (DTI), Combined Heat and Power Ass (Trade Ass), free trial of Mcilvaine (on-line market info Source)	HR Chamber of Commerce, Small Business Service, Learning and Skills Council, CIPD

Table 7.1c Interview summary for manufacturing SMEs in the Midlands (3)

	Company					
	A	B	C	D	E	F
Information barriers	Time Information not held in one place Technical knowledge not broad enough (also jargon used by trade associations) Problem of incomplete database classification of supplier activities	Time required to find relevant information due to poor sign-posting Info not specific enough to their sector	Interviewee has to read through all the information and apply it in the context of the company	Time-consuming reading through all those articles	Cost (not yet subscribing to Mcilvainc [see Table 7 1b] although lots of relevant info) Also cost of subcontracting testing to get technical information Getting the right keywords Accuracy	Some difficulties with internet because of different definitions and names are used for the same thing, and either too much or too little information is found Confidentiality issue
Features of a "fantasy" information service	Database of contractors/ suppliers with particular skills and infinite capacity Speed is important	Just wants to have to say which sector, and what info is required, and then receive regular updates Every 6 or 12 months, should have opportunity to update what info is required Particularly wants to know how big the overall market is, and whether it is growing or stagnant	Database of perfect employees Also, database of machinery with all specifications and costs provided On HR side, could do with something which could interpret the laws into working practices appropriate for the individual firm	Something for engineers to swap ideas	Accurate contact information for potential customers, including what equipment they have got (e g turbines) Who can they go to for technical products (link to web-sites or product brochures)? Who can take a container from Tilbury to Antwerp for them?	(No suggestions)
Key message	Difficult to ask the right questions if you do not have a broad enough understanding of different technical areas	Information needs can be very specific to particular niche market – information provision is often too general	Automotive industry a relatively small world – everyone seems to know what everyone else is doing by word of mouth	"Know it when you see it" approach to information searching may be difficult to convert to asking the right questions	Difficult to get sector-specific information (problem choosing right keywords) Classified ads as important as articles in trade journals?	Difficult knowing where to start if you want to be more proactive rather than reactive towards market trends

7.3. Postal and Telephone Survey of UK-based RTO members

The second survey was posted to users of a UK-based membership RTO, and was also administered by telephone to people designated as the "main contact" for the RTO within member companies The survey was primarily designed to provide the RTO with information about the requirements of members using their enquiry service, but a subset of the questions were either designed for this research project or are helpful to consider in this context (see Appendix III 5)

The survey data has been analysed by breaking the responses down according to the employment size-band of the responding firms. The five size-bands under consideration are 1-49 employees, 50-249, 250-499, 500-999 and over 1000 employees Since only 10 responses were received from firms in the 1-49 size-band, the comparisons made between size-bands should be treated with some degree of caution. Fig 7 6 depicts the distribution of responses from each size-band.

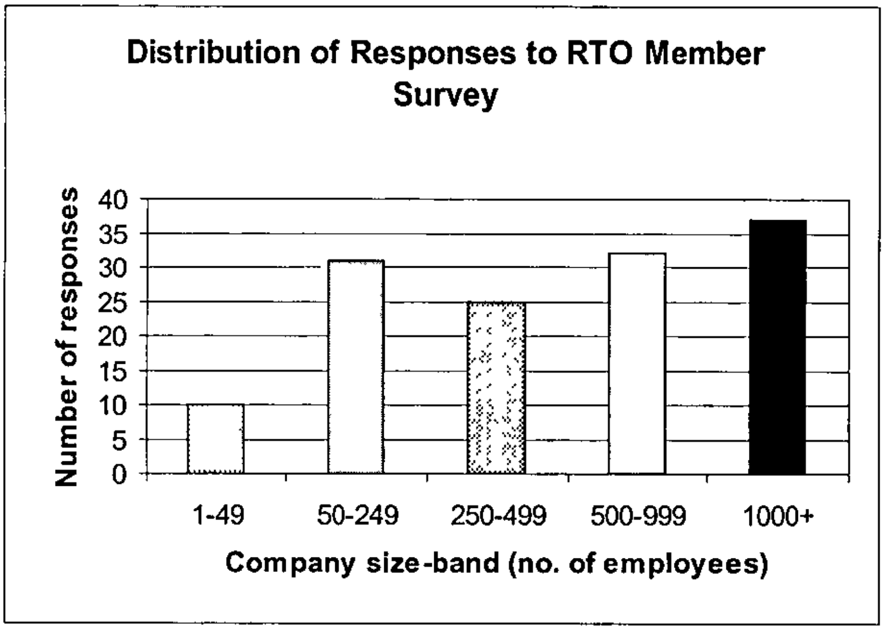


Figure 7.6 Distribution of RTO member survey responses according to employment size-band groupings

The members of the RTO were asked to tick which information sources they used regularly. A similar question was asked in the SME survey, but in this survey different categories were offered which focus on codified rather than tacit information sources, and reflect what the RTO perceived as their competition. The results for the different employment size-bands are presented in Fig. 7.7, along with a line indicating the "overall" average across all size-bands From this chart it can be seen that a higher than average percentage of the smallest companies (with between 1 and 49 employees) use all of the sources regularly. This size-band is in fact more likely to use most of the information sources listed than any other size-band. The very largest companies (with over 1000 employees) are the second most aggressive information seekers, using clippings/abstract services and other external enquiry services even more than the smallest size-band Meanwhile, the medium sized companies with 250-499 employees or 500-999 employees tend to use these sources less than the average (in some cases claiming to use none of these sources at all).

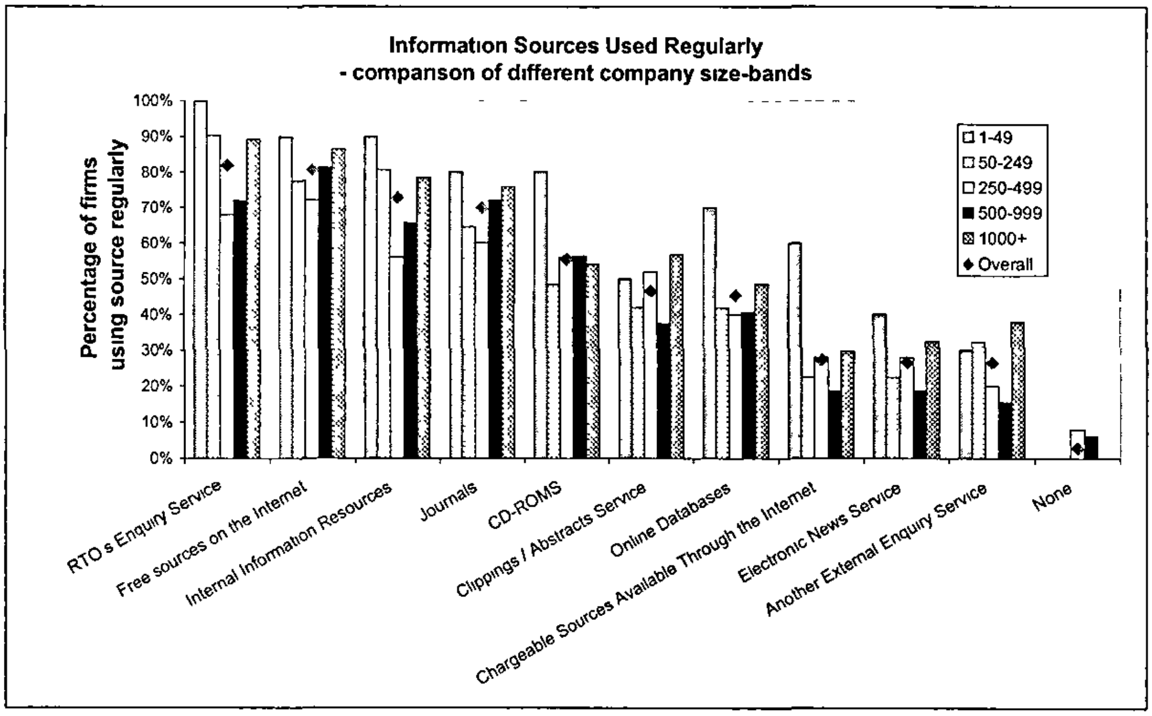


Figure 7.7 Information sources used regularly by respondents

It is interesting to consider why the respondents choose to use the RTO's enquiry service. A number of possible reasons were suggested, and the respondents were asked to rate the reasons from 1 to 4, where 1=never true, 2=occasionally true, 3=quite often true and 4=frequently true These ratings have been combined to form an average rating for each employment size-band as shown in Figs 7.8a and 7.8b The overall average across all size-bands is indicated by a diamond-shaped marker.

The small companies with 50-249 employees were most likely to turn to the RTO because they did not know where else to get the information (see Fig. 7.8a) This might suggest that they do not have a good awareness of the other information sources available to them (particularly as this group were also least likely to identify with the reason "when my preferred sources have drawn a blank") Two suggested reasons related to speed and urgency, and these were of concern to the smallest companies with 1-49 employees and to those with 250-499 employees - but not for the 50-249 size-band. As might be expected, the respondents were more likely to seek information in the early phases of a project or problem-solving activity than in the later stages. Greater concern over the reliability of information was indicated by the very smallest and very largest companies than by those in between

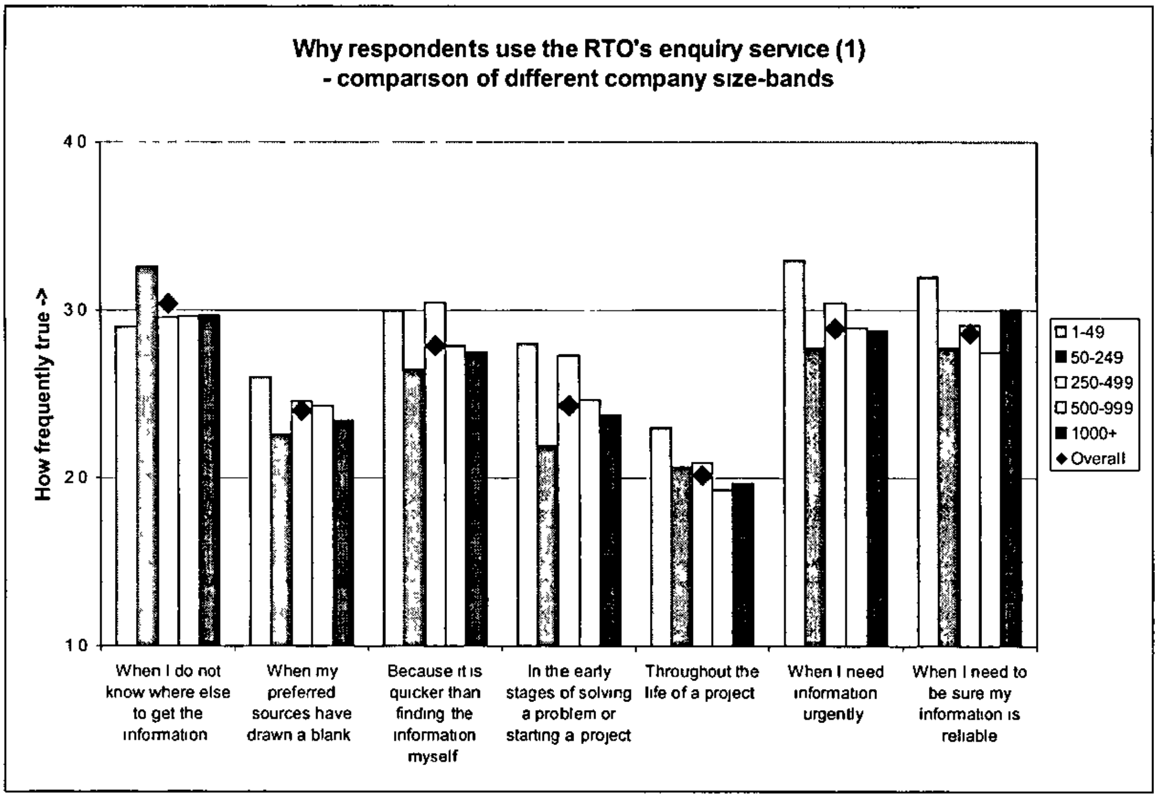


Figure 7.8a Reasons why respondents use RTO's enquiry service

Fig. 7.8b focuses more on reasons which relate to expertise. The smallest firms with 1-49 employees were most likely to identify with every reason suggested here except the frequency of looking for technical information - which was slightly more of interest to the 250-499 employment size-band. The smallest firms were significantly more likely than other groups to use the RTO to get access to database information, to be looking for information in their own area of expertise, to want analysis rather than simple data, and to be looking for business information In general, respondents were more likely to use the RTO's enquiry service when they were working outside their own area of expertise than when dealing with something familiar. This is not surprising, since in their own field they would be more likely to be knowledgeable concerning where to find the necessary information. For the smallest firms the limitations of an individual's knowledge may be reached more quickly, particularly since there is less likely to be anyone else in-house with similar expertise. Given the RTO's historical background as a manufacturing centre, the emphasis on technical information rather than business information is not altogether surprising, despite the RTO's efforts to build up its business expertise The use of the RTO's service for business information by the smallest firms perhaps reveals their need for efficiency in not having to deal with too many different information providers.

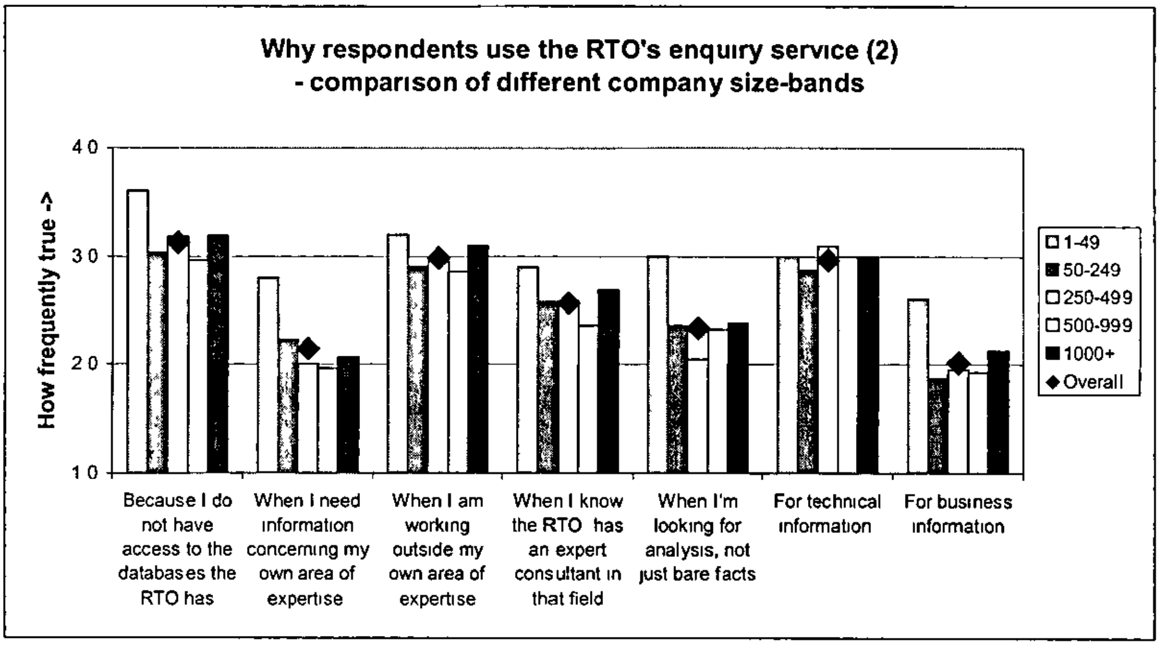


Figure 7.8b More reasons why respondents use RTO's enquiry service

Other survey questions dealt with the RTO's recently introduced on-line information service Firms in the largest size group (>1000 employees) and the 50-249 employees size group were the most likely to have used the on-line service Paradoxically both the smallest and largest firms were most likely to want specific information sent to them in paper format, and least likely to want it simply made available to them on the web-site (E-mail was the preferred format to all sizes of firm, but the smallest firms with 1-49 employees were unusual in only having a marginal preference for e-mail over paper format). The importance of the medium through which information is transferred will be discussed further later in this chapter.

7.4. Semi-structured Interviews with UK-based RTO members

The findings from this phase of data collection will be discussed in section 7.5 (N B the interview instrument is given in Appendix III 7) A summary of the results is presented in Tables 7.2a, 7 2b and 7.2c, which as before represent the researcher's interpretation of the interviewees' comments It was not always appropriate to ask all the questions of each company (for example the technical librarian in Company P was dealing with information needs right across the company and was not asked to define which was the "greatest" need). On other occasions the interviewee did not respond to certain questions There are therefore some gaps in Tables 7.2b and Table 7.2c.

Table 7.2a Interview summary for UK RTO members (1)

	Company			
	G	**H**	**I**	**J**
Nature of business	*Project management, contracting and installation (marine)*	*Central heating pumps*	*Fire protection systems*	*Security equipment and systems*
Current greatest information needs	Market intelligence – early awareness of emerging opportunities	Design and development issues (e g heat transfer)	Getting up to speed on a new market area	Which materials to use
Other information needs	Technical background information for developing bids Competitor financial information	Suppliers, legislation and standards, specific technical design issues	Short-term engineering problems	Suppliers with specific technical process capability
Nature of activities that stimulate information-seeking	Analysing competitor activity for 5 year strategic plan	Cost-cutting Need to change things after a competitor found out too much during a failed takeover bid	Supplier problems, obsolescence of components Cost-cutting	Obsolescence of components
Greatest barriers to finding/accessing information	Competitor secrecy Difficulty in framing questions clearly when approaching external sources	Time – individuals have too much to do to spend much time searching for information	Time and initiative to do the necessary searches (too busy dealing with day-to-day) Knowing if they are using the right sources of information	Knowing where to look Lack of expertise in materials to understand specifications
Sources used	Shipping journals, internet, RTO, commercial databases, Business Shop	Suppliers, flyers, internet, e-zines, journals, external motor design "guru", patents	Internet, RTOs, personal networks, patents, trade journals, professional institutions, internal research department	Sales team, insurance companies, trade journals, internet, suppliers, CD-ROM catalogues
How information is valued	Saving time by outsourcing search important Easy access to databases valued	Personal touch important, and speed of response	Sources that keep them up-to-date with market valued most Complementary sources to in-house knowledge important	External expertise valued, saving time by outsourcing search important
Any changes in way information is needed, sought or used	People are more likely to search because they know the answer is probably out there	Since MBO, decisions are taken quickly and informally so less information required to write reports to convince board	Information searching now more focused because of mass availability of info via Internet	More up-to-date component catalogues available via internet

Table 7.2b Interview summary for UK RTO members (2)

	Company			
	K	L	M	N
Nature of business	*Lawnmowers*	*Optical components*	*Games and toys*	*Drinks dispensers*
Current greatest information needs	Metal finishing processes (in relation to a supply problem)	Materials and processes for design and development	Suppliers of new materials	How to overcome particular design problem
Other information needs	Manufacturing methodologies	Suppliers with specific technical process capability	-	-
Nature of activities that stimulate information-seeking	Solving design problems	Project-related (18 month timescale) not for strategic planning Choosing between alternative designs	Short-term technical problem solving Also design definition	Design and development
Greatest barriers to finding/accessing information	-	Information not easy to find Need info very quickly but hard to find external expertise	Not always sure where to look	Technologies needed may not even exist Framing question correctly can also be a problem
Sources used	Dealers and distributors, suppliers, trade organisations, internet, specialist consultants, commercial databases	In-house sources, RTOs, trade journals, e-zines, suppliers, technical journals	Sourcing agent, journals, in-house sources, internet	Patents, in-house sources, journals, internet, e-zines
How information is valued	External specialist expertise valued	Ability to get quickly up to speed in new areas is valued	Important to be able to trust sources	Saving time by outsourcing search important Speed of response important
Any changes in way information is needed, sought or used	People are now more likely to consider looking outside their own industry More information is used because more available	Since info can be easily accessed, people are less likely to spend time reading to become experts in particular areas	No	Internet means that people can spend a lot of unproductive time trawling through info and "looking busy"

Table 7.2c Interview summary for UK RTO members (3)

	Company			
	O	P	Q	R
Nature of business	*Pharmaceutical devices*	*Metrology*	*Defence*	*Automotive systems*
Current greatest information needs	-	-	Benchmarking manufacturing activity and how to create an innovative culture	Keeping track of how environmental legislation is being implemented across Europe
Other information needs	Proprietary materials, low level technical answers	Technical and market information	Health and safety	Market information
Nature of activities that stimulate information-seeking	Validating decisions	Project activities, problem solving (Not strategic)	Problem-solving	Answering ad-hoc requests from other parts of the company
Greatest barriers to finding/accessing information	-	-	Lack of awareness of potential sources	Insufficient network of contacts
Sources used	Network contacts used for market information Internal sources, technology scouts, Internet, patent literature	Journals, books, commercial databases, RTOs, in-house library, professional institutions	In-house sources, professional institutions, internet, commercial databases	Commercial databases, in-house sources, internet, customers
How information is valued	Value external subject-area expertise and quality control on information	Company has its own library	Browsable sources that generate ideas valued Extra resource from external sources important	Reliability of sources important Market information sources valued highly
Any changes in way information is needed, sought or used	Greater need for knowledge management	Information resources have been centralised within the company (possibly due to capability of librarian rather than need)	No change in what is required, but internet has made it much easier to access information	-

7.5. Data Analysis

The data is analysed in the light of the framework presented in Fig. 5.5b. Section 7 5 1 addresses information needs, while section 7.5.2 considers the attributes of those needs. Section 7 5.3 looks at sources of information and section 7.5.4 considers attributes of those sources. Section 7 5.5 analyses the barriers and enablers to information flow

In terms of the research questions presented in Table 5.2, sections 7.5.1 to 7 5.4 tackle question C regarding how small firms perceive their own information needs and the potential sources of information available to them. Question D is addressed in section 7.5.5 and is developed further in section 7.7, where the factors that enable or inhibit the process of information acquisition and technology lookahead are considered. Table 7 3 provides a summary of the findings as they relate to the research questions and the framework in Fig. 5 5b

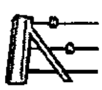
7.5.1. Information Needs

The companies were asked what they saw as their current greatest information need, in order to gain an impression of the "burning issues" facing the respondents. As seen in section 7.1, the small manufacturers identified customer markets, technology, competitors and legislation as important areas. Many of these issues could have an impact on strategic technology choices within the firms When the RTO members were asked a similar question in interviews, a number of companies (both large and small) identified that they needed technical information to solve particular design problems. One small firm had an unreliable subcontractor and needed to find an alternative process or supplier. Two smaller companies needed market intelligence – one in order to move into a completely new market The very largest firms were more concerned with top level needs such as: how to create a more innovative culture; benchmarking manufacturing capabilities; and how new environmental regulations were being implemented in different EU countries. Therefore the RTO members were concerned about a mixture of strategic and short-term issues.

The technological information sought by the smaller firms tended to be information that they would not regard as being specific to their industry. There were exceptions, such as Company H needing information about motor windings and Company J needing information about white light filtering relating to security applications. Mostly however the information requirements related to manufacturing more generally. Companies I and L talked about using well-known technologies and applications-engineering them to suit their particular niche, which would sometimes demand non-standard information about components and materials.

When it came to market information, however, the small firms were definitely looking for very specific, detailed information, since they were operating in niche markets. The very smallest firms in the RTO survey (with less than 50 employees) were much more active than any other size grouping in seeking business information from external sources, although the firms with between 50 and 249 employees were actually the least interested in seeking business information in the survey. The interview with Company D, in the lower end of that size-band, contradicted this with their keen interest in finding out the potential size of their segment of the market and their current market share

Table 7.3 Summary of research findings from surveys and interviews

Research Questions		**Findings from surveys and interviews**	
C How do the small firms studied perceive their own information needs and the potential sources of information available to them?	C(i) Needs 	<u>Subject areas</u> • Markets • Technologies • Materials • Suppliers • Competitors • Patents • Standards • Legislation • Validation • Testing	<u>Attributes</u> • No formal technology lookahead • Occasionally strategic • Dependent on nature of decision-making • Usually problem-solving • Scoping out alternative designs • Ironing out manufacturing problems • Cutting costs • Dealing with obsolescence • Variable urgency • Working outside own area of expertise • Reassurance within own area of expertise
	C(ii) Sources 	<u>Type of source</u> • Internet • Trade journals • Electronic news services • Commercial databases • CD-ROMS • Internal sources • Informal networks • External enquiry services • Flyers and mail-shots	<u>Attributes</u> • Personal or impersonal/inanimate • Browsable or searchable • Medium (paper, electronic) • Level of familiarity • Ease of access • Level of control
D What factors enable or inhibit the process of technology lookahead in the context of supplier information acquisition?	D(i) Enablers 	• Trust - Familiarity - Credibility • Perception of value • Easily accessible • Doing something new	
	D(ii) Inhibitors 	• Lack of time • Lack of availability • Not knowing where to go • Not understanding jargon • Difficulty in finding keywords • Poor quality of information • High cost • Sources too spread out • Organisational culture	

More generally, firms recognised their need for information concerning materials, technologies, markets, suppliers, competitors, patents, standards, legislation, validation and testing (See Table 7 3) Many of these areas would provide technology lookahead and influence technological innovation within the firm, as well as any informal technology strategy. The next section considers the attributes of this external information-seeking

7.5.2. Attributes of Information Needs

In the previous section, the focus was on "what" information was sought. Here the concern is more with questions relating to "how" and "why" information is sought and "what for".

The focus of this research is on information acquisition relating to technological innovation and technology strategy. None of the interviewees knew of any formal process to review such technology management issues within their firms, although Companies G, K and L acknowledged having some sort of business plan and review of company strategy. Of those three companies, only Company G was actively acquiring information as part of this process, to find out about competitor activity. The other firms did not recognise an external information input to the process, seeing it instead as relying on the knowledge of their employees. This knowledge would probably be kept up-to-date by the employees making use of a variety of information sources in the course of their work For the small manufacturing companies, much of the technology planning activity concentrated almost exclusively on large capital equipment acquisitions Assessment of the need for such equipment was based on customer requirements, and the equipment was selected based on the information provided by a number of known potential suppliers of the equipment.

The perception of the need for an information-gathering process was influenced strongly by the interviewee's position within the firm and the nature of decision-making in the company or group For example, Company H was a management buy-out from a large group, now a fully independent SME. Whereas before they were required to write reports to support their decisions and plans, now these decisions and plans were made on a much more informal, gut-feel basis (requiring less formal information-gathering to back them up) Company O was amongst the largest of the companies interviewed (although it had only reached that size through recent rapid expansion), but the interviewee was at a senior level where decisions had to be made very rapidly to respond to changes in the market Therefore decisions were again made on the basis of gut-feel, and information-gathering was used to validate decisions almost after the event.

The predominant reason for seeking external information (for all sizes of firms interviewed) was in order to solve a particular problem. Typically this meant they had thought of a particular way of manufacturing a product, but either did not know if a process existed to achieve this or did not know of a supplier who could do this for them. For companies involved in design, this meant that information was usually needed in the early stages of new product development, when scoping out alternatives. The survey of RTO members showed that companies with between 50 and 249 employees were less likely to see themselves as seeking information at the start of a project, perhaps reflecting an outlook more concerned with manufacturing than with design. Once firms were committed to a particular product design, there was often a second phase of information seeking, directed towards ironing out unforeseen manufacturing problems Sometimes there were issues with cost, and alternative suppliers were needed in order to cut the costs of products Companies I and J were also sometimes faced with the problem of parts becoming obsolete, and having to find alternative solutions or alternative suppliers. This fire-fighting activity in the smaller firms was blamed for limiting the time they had available to concentrate on more strategic activities. Although these companies were often aware of needing information to expand into a new market or to kick off a new product development, they felt they had not yet had a chance to start looking at these areas. In a way this reveals the low level of priority given to information acquisition in this context, since if it had been considered important enough, other activities would have been neglected instead

The urgency of information requirements varied – in the survey of RTO members, the firms with less than 50 employees were most likely to look to external sources when they needed information urgently. In contrast, the companies with between 50 and 249 employees appeared much less concerned about finding information quickly than any other size group Company K talked about having a supplier problem for a number of years, but only began to look for a solution when it 'really started to hurt [them]'. In terms of solving design problems, it appeared that when the companies interviewed looked for external information, they were usually content to wait for a few days but tended to want an answer within a week (whether project timescales were measured in years or in months). The interviewee in Company H, however, commented that although he might not need an answer immediately, he needed to know that his request was progressing, which suggested that he was not particularly comfortable the loss of control inherent in delegating or outsourcing his information needs. In contrast, Company R, one of the large companies, was happy to wait up to a month for information to build up their knowledge in a new area of strategic importance to them.

Often the survey respondents and interviewees were particularly conscious of needing information when they were working outside their own area of expertise. The survey of RTO members found that both the very smallest firms (<50 employees) and the very largest (>1000 employees) identified very strongly with this need for external information outside their own area of specialism Employees in the smallest firms, however, also recognized their need for more information concerning their own area of expertise (sometimes simply to reassure them they were doing the right thing), but as firm size increased, people were less likely to recognise such a need. From the interviews, it was clear that for larger firms, there were often other people in-house with the necessary knowledge and skills who could be called upon to help tackle a particular issue. For employees of small firms, it was less likely that there would be someone else with similar or complementary subject area knowledge, heightening the need to seek external information Large firms were not immune to this problem, and in Company Q there was only one person responsible for health and safety This person therefore had to turn to external sources of information for support in how to implement new legislation This example reinforces the argument, since a small firm would be unlikely to have even one person dedicated solely to health and safety, and would be in even greater need of external support. Another factor relating to expertise was that in a number of the small firms, the interviewees were acting in a number of roles all at once The production engineering manager at Company H was also responsible for maintenance and for building refurbishment The HR manager at Company F also had a wide range of other responsibilities, from PA to the managing director, to competitor analysis and site facilities management Where people have multiple roles, the depth of expertise that they can bring to each role will often be limited. This can limit their ability to absorb the information they need, including strategic technological information (the literature points to the importance of "absorptive capacity" for innovation and learning (Cohen and Levinthal, 1990; Dankbaar, 1998))

7.5.3. Information Sources

The survey of RTO members suggested that the smallest companies (with less than 50 employees) made the most active use of information sources, regularly using the Internet to access both free and chargeable data sources, reading journals, making use of electronic news services, CD-ROMs, internal sources and external enquiry services The very largest companies, with over 1000 employees, were the second biggest users of most information sources, although they were the most likely to use a service to provide clippings or abstracts Meanwhile, the companies with 250-499 employees and 500-999 employees tended to be the least likely to make use of the various information sources. In terms of reasons for seeking information from the RTO, firms with between 50 and 249 employees were most likely to seek information from that source because they did not know where else to find it.

The preferred methods used to acquire information by the manufacturing SMEs surveyed were trade journals and the Internet (both cited by over 80% of the respondents), followed by informal networks. This finding was very much backed up by both sets of interviews. Companies A, C, E and G all subscribed to journals which they felt provided them with critical information regarding their own market place – the larger companies did not show such enthusiasm for specific publications, perhaps because their interests were slightly broader. Journals and magazines linked into trade associations were also very popular, particularly amongst the small firms (Companies C and K talked of circulating these within the office). While some publications kept the companies up-to-date with developments in the market they were selling into, other publications were more concerned with the basic technologies behind the products. Part of the attraction with this latter type of trade publication seemed to be the classified advertisements (Companies A, B and H also cited flyers and mail-shots from potential suppliers as valuable sources of information) The author gained the impression that the technology-based publications did not elicit such strong enthusiasm from interviewees as the market-based publications, because firms often seemed to feel that they understood the technology fairly well already while market news was fresher. (One can however imagine that there are other firms who are very well tuned into their market, for whom market-based publications might not bring anything new – but instead, technology-based publications could do.) The Internet was used by most of the interviewees, often to get background information when tackling a new area, and also to find suppliers (although Company N commented that many of the firms they worked with still did not have web-sites) and datasheets There was sometimes less interest in this medium at managing director level. this could be partly due to the age of those interviewees (they were more comfortable and familiar with printed publications), and partly because they had less time available to trawl through the mixed-quality information brought up by Internet searches.

The small firms did not have access to the wealth of information resources available to the larger firms Amongst the large firms, Companies O and P both had library functions, while Company R had a small department dedicated to answering enquiries Companies O and Q also spoke of having active intranets – for Company Q, that also included the benefit of being able to fire off a question to all the technical experts within the company worldwide. The large companies also tended to have direct access to chargeable database sources which were not available to the small firms except through intermediaries such as business support organisations

7.5.4. Attributes of Sources

The sources described above (and used by the firms in this study) all have particular characteristics and attributes which shape how they are perceived and valued (see Table 7.3). These attributes are now discussed

Many of the preferred sources of information were people – suppliers, consultants or technical "gurus" who could be easily contacted by telephone or e-mail. Two of the small firms interviewed were willing to pay thousands of pounds to access the technical expertise of particular individuals. This is likely to be because it is much quicker and easier to extract information by talking to an expert than by trying to read up on the subject oneself (Julien, 1995).

The firms perceived the difference between browsing and focused searching for specific answers. Browsing is usually associated with published material whilst searching is associated with external enquiry services, CD-ROMS and commercial databases. The Internet can fall into either category (Company G talked of searching for a supplier on the Internet, and through that accidentally discovering that a firm they had approached was closely linked with a competitor) The small firms appeared more at ease with a browsing approach, preferring to wait for inspiration from trade magazines rather than to proactively search Information found by browsing could be valued more highly than that found by searching, because of the individual's delight or relief in finding out something they had not known to look for. In contrast, the results of searching were much less likely to be able to exceed expectations in that way

The media through which information was presented played a part in how sources were perceived For example, the RTO used to provide its members with a paper bulletin containing abstracts of technical and business articles. This facility was replaced by an on-line searchable database, but the loss of the paper bulletin emerged as a real problem to a number of the firms interviewed, since it was no longer a publication that could be quickly scanned to keep them up-to-date with developments in manufacturing technology and methodology They were much less likely to remember to visit the on-line database Interviews revealed that many people really wanted a paper edition, even though the same people had requested an e-mail bulletin in the RTO survey. Whether sent electronically or through the post, it was clear that this type of information source lent itself more to browsing rather than searching

Another attribute that tended to affect how information sources were perceived and valued was to do with familiarity. In most cases, sources in the "comfort zone" of the interviewees were valued highly, being sources that they knew well and turned to regularly Where sources were unfamiliar, they were not usually seen as valuable There was one exception to this where the interviewee in Company H who was not familiar with using database sources had rather unrealistic expectations of what such sources could offer him, and therefore valued them highly. Since that firm could not afford direct access to the database sources, it requested the information via an intermediary, but when the information received was found to be inaccurate, Company H attributed the problem to the intermediary rather than the database source.

When asked which three sources of information they would pay for if all their existing sources were taken away from them, most firms said they would choose to pay for the Internet above all other sources. (It seems that the companies did not think of personal sources in the context of that question.) In firms where there are a reasonable number of qualified engineers, people have become accustomed to searching for themselves, and they value having control over the search process and being able to find enough information by trial and error to gain an overview of a topic which might be new to them The availability of the Internet has in some cases prompted people to look for answers where in the past they might have struggled on without the information, thus in some senses raising the perceived value of the information. The true value of the Internet to a firm is however affected by the relative skills of its employees in finding information, the time required to extract it, and the reliability of the information obtained. The time-consuming nature of Internet searching and the lack of quality control of the content were attributes that were only identified by a small number of interviewees. The majority of firms did not make a considered decision about the efficiency of using the Internet as an information source

7.5.5. Information Barriers and Enablers

In Table 5 2, research question D focussed on the factors which inhibit and enable the processes of technology lookahead in the context of information acquisition Since technology lookahead requires information acquisition, barriers to information acquisition are likely also to form barriers to technology lookahead, and similarly those factors that enable the process are also likely to enable technology lookahead (see Table 7 3).

When asked about the greatest barriers they faced in acquiring the information they required, the biggest issue (for a large number of the SMEs interviewed and surveyed) was finding the time to do the research they needed. People were overstretched, and information searching would impact too much on their other activities. In Company B, information searching via the Internet was something to be done in one's own time, in the evening after dinner – in Company H the favoured method was flicking through trade magazines while eating a sandwich at lunchtime Again, the fact that information acquisition is viewed almost as a "hobby activity" raises questions about whether enough priority is given to this process.

Another major barrier was that much of the information needed was not available in the public domain. This was either because the information was confidential, or simply because it was not written down anywhere. Company R talked about their networks in Europe not being extensive enough to be able to access the type of first-hand information they required – as they are a global company, it suggests that small firms would have even more difficulties obtaining that sort of information. Published information was usually not specific enough to the niche requirements of the small firms in this study Linked to the issue of availability, many of the small firms had problems identifying which sources to go to for various types of information, and knowing whether the sources they were using were the right ones. The survey of manufacturing SMEs revealed that many respondents were unclear about what a database was, which suggests that they would be unlikely to understand how to make the best use of database sources.

There were also difficulties in obtaining information especially in other industry sectors due to the technical jargon used by sources such as trade associations. Identifying the most appropriate keywords for searching was another problem for those without in-depth knowledge of a subject. This difficulty was particularly acute for small firm employees having to undertake a number of roles for which they had not been trained.

The cost of information was a barrier mentioned by 3 of the companies in the SME survey It did not appear to be a major issue for the RTO members (beyond a slight concern about whether they were getting value for money from the RTO's information service), and was only raised implicitly in one of the Phase 1 interviews: Company E appeared to have found a good on-line source of market information, but despite a successful free trial they were not ready to subscribe to the service.

The SME survey respondents complained about problems getting accurate, up-to-date information, and about sources being too spread out – one firm was concerned that by only getting fragments of the information they required, the real picture was being distorted. The culture of the organisation was held to be the biggest barrier to information in a number of instances, but for one survey respondent the real issue was that they did not always realise when they should have been looking for information – they had not been aware of a change in legislation, and so had failed to investigate it.

In terms of factors which enabled and encouraged information acquisition, the ability to trust the source was important. For example, information from trade journals appeared to be favoured by the firms studied, partly because their own sector trade associations were seen as familiar, trustworthy and relevant sources Trust is also a key factor in the reliance on people as a source of information, based on the credibility of the individuals concerned For small companies to be willing to spend thousands of pounds to acquire technical information from the "gurus" described in the previous sections, the belief in these individuals must have a very positive influence This also suggests that perceiving an information source as high-value is an important enabler to information acquisition.

Another enabling factor appears to be where information is easily accessible. This was true of both trade journals and the Internet, which were preferred sources in this study.

In section 7 5.2, it was seen that external information was often sought when companies were involved in a new development, or when people were doing something outside of their "comfort zone" of expertise This implies that innovation may actually be an enabler of information acquisition. This will be discussed further in section 7.7 after a brief review of the research methodology.

7.6. Review of Research Methodology

Before concluding this results chapter, the methodology is reviewed (in the same way as presented in section 6 4 for the previous results chapter).

The limitations of the research design have already been discussed in section 5 3.3 where the low response rate for the survey of manufacturing SMEs in the Midlands was raised as a concern. Since the survey of RTO members was dominated by market research questions, neither of the questionnaire surveys proved ideal as a research tool, although they were helpful in identifying companies for interview.

The interviews themselves were an appropriate means of exploring the research questions Information acquisition is however a difficult concept to capture, since it is so much part of everyday life that it becomes a subconscious activity The responses elicited from the interviewees will certainly have been affected by how questions were asked, and there are probably many different ways of looking at the same issues. For example, the importance of informal networks as a source of information did not emerge from the interviews, although they did feature in the survey results - and previous research suggests they play a significant role. The way the research agenda was presented may have constrained the interviewees thinking to sources which they see as "work-related"

The interviewee responses from the RTO members may also have been affected by the ambiguous status of the researcher, who was certainly seen by some companies as representing the RTO (despite her efforts to explain the visit in terms of university research) Taking the view that the researcher was selling or endorsing a particular information service may have coloured the responses of some interviewees when describing their information needs and acquisition processes. The presence of a second researcher for more of the interviews might have helped in the process of identifying such factors

7.7. Information Acquisition Conclusions

The research described in this chapter was encouraging in so far as it indicated that the smallest firms were often as active as the largest firms in seeking external information. While they did not always have access to the breadth of sources available to the larger firms, this was balanced by the ease of communicating information within the firm and the lack of bureaucracy in decision-making This type of environment makes it easier to harness information to help with technological innovation and strategy formulation.

The awareness of information needs within the firms did not always extend to strategic issues, and even where it did, information acquisition was given relatively low priority None of the firms described having any formal processes for seeking future technology information. In some of the small firms however, information was sought regarding future markets, which would then have an impact on their technological choices Given that most of the companies studied appeared to be reasonably innovative and willing to adapt technologically, technology lookahead is likely to have been taking place even if it could not be identified as a strategic search for technological information It seems that perhaps the distinction made by the researcher between strategic information acquisition and information acquisition to support everyday operational activities is a false one Instead it is possible that where firms are actually seeking technical information to solve a particular design problem, they may simultaneously be absorbing information about possible alternatives which may stimulate ideas for future technological innovation. Similarly, the more mundane searches for information concerning materials, suppliers, competitors, patents and legislation may have a similar indirect effect in providing technology lookahead. This justifies the approach taken by the researcher in investigating information acquisition across a broader range of subjects than simply strategic technology information

At the end of the previous section, it was observed that innovation could be an enabler of information acquisition. This implies a "virtuous circle", where doing something new necessitates a search for information, which in turn kindles more new innovative ideas This "virtuous circle" will not necessarily always continue, particularly if companies have difficulty accessing and obtaining the information they require. Where disruptive technologies are impacting upon an industry, or when firms want to move into completely new markets or take up a technology previously unfamiliar to them, companies face much greater challenges in finding the information they need. Identifying sources and interpreting the jargon surrounding a new area is difficult and time-consuming for a small firm working alone In more familiar, stable industry settings, small firms are able to utilise their trade associations for strategic technology information Opportunities to get involved in industry road-mapping can sometimes arise through such trade networks, which can assist companies in formulating their own technology strategy

Returning to small firms operating outside their own "comfort zone", there remains a serious challenge The Internet may appear the cheapest route to find out about something new, but a great deal of time may be required to trawl through information where the right keywords are not known (The ability to absorb information without the necessary background understanding is particularly critical in small firms where employees are often asked to turn their hands to unfamiliar things.) The quality and reliability of information on the Internet may also be difficult to verify Chargeable on-line sources could be appropriate if it meant that the company could be sure of receiving accurate, reliable, complete and up-to-date information. To meet the needs of small firms through a chargeable on-line service would however demand a significant investment in the user interface, in order to give clear signposting (Vos et al , 1998), avoid jargon, and help the small companies to refine their search – almost performing an educational role in some ways It would still fall to the small firms themselves to make the leap to understand the significance of a new technology or market development to their own future business

It may be more efficient and more desirable to turn to a trusted person who understands both the new area and the needs of the company. For something which is genuinely outside the ordinary for a firm, however, there may not be a suitable contact in their personal network. The alternative is to turn to a consultant or professional information service to provide a bridge to the new area of interest and translate the required information to the individual circumstances of the firm. Yet such a personalised service is likely to appear expensive to a small firm.

Although most of the small firms in this study did consider knowledge of their markets and specialist technologies to be important, they did not fully appreciate the value of information. They did not always recognise the importance or even the existence of their own information gathering processes, nor the need to be aware of future challenges and opportunities. By taking a more considered approach to information acquisition, smaller firms would be better able to advance their technological capability to meet future market needs

7.8. Chapter Summary

In this chapter the results of the research into supplier information acquisition were presented The findings were broken down according to the data collection method, and then reviewed against the research framework of Fig. 5.5b and the research questions of Table 5 2 (the results are summarised in Table 7.3). The research methodology was re-assessed and a number of conclusions were drawn

Chapter 8 will present a discussion drawing together the research findings of both Chapters 6 and 7 (see Fig. 1.1), before summarising the main findings and original contribution of this research

8. Discussion and Conclusions

This chapter takes a top level view of the issues and themes which have emerged during this research The context of the research is revisited in section 8 1, and the findings from the previous two chapters are drawn together in section 8 2 Section 8 2 1 provides a review of possible tools and techniques for technology lookahead by way of exploring the practical options open to small firms In section 8 3, the key themes from the research are drawn out Section 8 4 summarises the key contributions of this research in the context of the existing literature, while section 8 5 re-states the limitations of the research A list of further research opportunities is presented in section 8 6, before the chapter is summarised in section 8 7

8.1. Re-statement of problem

Before reviewing the research findings, the issues that stimulated the research at the outset are revisited The main concern was for small manufacturing firms who increasingly need to develop their technological capability in response to the demands of large systems integration companies (particularly in mature industries such as the aerospace industry). Greater outsourcing of sub-system design and manufacture by the former OEMs suggests that these larger companies are unlikely to dedicate much resource to R&D in the enabling technologies that underpin such products. Instead, their smaller suppliers are expected to take on the risks of technology development as they provide products with greater added-value Two main drivers are working against small firms as they try to meet this challenge – firstly the business environment and secondly the technological environment.

In terms of the business environment in the UK, small manufacturers are facing a very difficult time economically, with the global downturn and the relative strength of sterling. Cost-down pressures are transmitted through the supply chain, leaving small firms with little resource to fund any longer term developments. At the same time, it is vitally important for firms to develop technological strengths as they are increasingly exposed to global competition and supply base rationalisation.

The technological environment is also rather challenging for small firms: more than ever before, there is a need to combine and integrate different technologies in order to meet market needs for smaller, lighter, cheaper but functionally enhanced products. The pace of technological change is also continuing to increase, and it is difficult for small firms to maintain the necessary level and breadth of expertise in-house. Design cycles and product lifecycles are being compressed, which adds to the pressure on small firms to bring products to market quickly, and maximise their profit while they can

Developing appropriate technological capability to meet market need is therefore a significant challenge for small manufacturers. This is an important issue not only for the firms themselves, but also for the long-term competitiveness of the value chains in which they operate

The research considered the mechanisms by which technology capability might be developed, focussing chiefly on "technology lookahead" – the means by which companies make themselves aware of the particular technologies which they will need in order to be able to compete in the future. Without this awareness and understanding of emerging technological requirements, firms are very unlikely to be able to develop suitable capabilities The next section considers how small firms can use sources of information for technology lookahead.

8.2. Innovation Environment of Small Manufacturers

Small manufacturing firms cannot gain understanding of future technology requirements in isolation. The research presented in this thesis has been based on a concept of information flows – that by accessing the relevant sources of information, a small company should be able to build up a reasonable picture of where the best opportunities lie, and which technologies will enable them to innovate to capitalise on those opportunities There are issues about whether a small firm will necessarily recognise the significance and relevance of information, especially when it deals with an unfamiliar subject, but this will be discussed later

A draft framework of the innovation environment was presented in Fig 3 4 During the course of the research, many of the links between the small manufacturer and the elements in the innovation environment were explored. The link between small firms and their customers provides a good flow of information to feed the innovation process. As part of their daily environment, customers are easily accessible as a source of information, and their advice is valued highly because following it may lead to future orders. While much of the information from customers is market-orientated, some customers are able to provide technical guidance to their suppliers. For instance, many of the former OEMs retain a certain amount of technical expertise from the days before outsourcing, often through the tacit knowledge of employees now operating in completely different roles The scoping study, however, highlighted a potential danger. that the strong influence of customers could trap firms into short-term technology strategies Most of the information from customers was concerned with the next potential order, and not with longer-term industry or technology trends. The customer could lead the supplier down a technological "blind alley" if they both failed to identify the emergence of a rival technology. This can happen when the supplier is only concerned with providing what the customer asks for, but the customer only asks for what it knows about (Macdonald, 1995) Even where the customer is an OEM that has had relevant technical expertise in the past, their knowledge will soon become out-of-date, and the unstated assumption is that the supplier should be the one to suggest new alternatives. In the course of this research, however, some frustration was expressed over the conservative approach taken by a number of suppliers. This might be due to those suppliers being unwilling or unable to take risks, or could reflect a lack of awareness of technological and market changes

Chapter 6 considered how customer influence could be used to best advantage to further supplier technological capability through supplier development schemes. In some cases it may be appropriate for customers to directly transfer technological best practice to their suppliers, but it is not often that they will be in a position to do this. Taking best practice from one supplier and presenting it to other suppliers could undermine the competitive advantage of the originating firm It is also becoming less likely that the customer firm will retain their own technological expertise which they could then pass onto their suppliers. A more generally useful approach would be for customers to actively encourage their suppliers to develop their own technology management processes. Many business processes are inspected as part of the supplier development process, and subjecting it to regular scrutiny would underline the importance of developing technological capability to fit the emerging market and technological requirements By recommending that a broad range of information sources is used, customers could also help suppliers not to fall into the trap of over-dependence on themselves, the customers, for information

The research suggested that although customers were seen as an important source of information, their suppliers were not always able to speak to the right people within the customer firm. Engineers were failing to get involved with supplier development due to organisational pressures, which meant that the lines of communication between customer and suppliers were not as beneficial as they might have been. This is an area where large firms could act to improve the situation. The ability to talk to customer "technical gurus" was very useful in one case – while that supplier saw it as an opportunity to show off their own technology, it seems likely that there was a two-way flow of information and that the supplier benefited from the "gurus'" extensive knowledge of world-wide technological developments.

The importance of customers as a source of information is partly due to the fact that they are part of the daily environment of a firm. They are known and therefore trusted to a certain extent. The same is true of suppliers, although for many of the firms studied during the course of this research, suppliers were not seen as playing a significant part in the innovation process. The suppliers of these companies were often large multinational providers of materials and equipment, and they did not have enough leverage with their suppliers to receive much support or help from them Other suppliers were small local concerns who were not credited with much input to the innovation process. One of the firms described in Chapter 7 did seem quite successful at learning from suppliers and potential suppliers, by collecting flyers and phoning round a number of companies. This was not recognised as an input to their innovation process, however The respondents to the innovation surveys described in Chapter 2 were generally better at recognising the role played by suppliers in their innovation process, so perhaps the sample of companies used in this research was atypical in this respect Regardless of whether suppliers are viewed as important to innovation, relying too much on suppliers as a source of information must carry the same "health warnings" as relying on customers – over-dependence on suppliers can blind a company to alternative approaches and technologies arising out of completely different industry sectors.

In this particular study, suppliers often appeared to stimulate change which was perceived in a negative way by their customers – through the obsolescence of components and processes Many firms seemed unprepared for having to redesign their products to cope with obsolescence There may be a role for technology lookahead not only in being prepared for new technology as it emerges, but also in anticipating the demise of current technologies.

Beyond the supply chain, there are many other potential sources of information which can spark technological innovation in small manufacturing firms. Out of all the other elements in the innovation environment put forward in Fig. 3 4, the two most significant to small firms in this research were trade associations, and reading matter such as the Internet and trade journals. It is likely that informal networks were also very important, but it is hard for people to identify the contribution made via casual conversations with friends and associates. The research methods used were not particularly well suited to unlocking the intricacies of such informal mechanisms, since they were directed mainly towards finding out how the interviewees understood things Unless interviewees had actually spent some time analysing the role played by their own networks, their thoughts would naturally tend towards information sources that they see as work-related.

Sources such as trade journals and magazines came easily to mind for the small firm interviewees, and were seen as very useful. The important role of these publications is in stimulating new ideas – alerting the reader to new market opportunities or inspiring new product or process ideas Often inspiration seemed to strike when interviewees were just browsing or looking for something else, and in a way these ideas were valued more because they were unexpected Many interviewees were also very enthusiastic about the Internet and the easy access to information that it provides, without appearing to consider the cost in time and effort required by searching A key benefit of the Internet was in giving people a handle on unfamiliar subjects (although this was heavily dependent on the skill and understanding of the searcher). With very little knowledge of a topic or the correct keywords, it is possible for someone to gain a significant amount of background knowledge from the Internet through trial and error, perhaps opening up to them the potential of new technologies and techniques from outside their industry.

The need to be open to new possibilities from outside the firm's "comfort zone" was highlighted by the status of trade associations as a favoured source of information within the innovation environment The companies in this study tended to be very familiar with their trade associations, and as such they were a trusted and easily accessible source of information Often these associations would provide firms with networking opportunities through seminars and exhibitions, putting people in contact with each other and allowing the opportunity to access information directly from people (the information source most likely to inspire confidence). The use of trade associations for information is ideal for companies who find themselves in a stable industry with few external drivers of change Where an industry is changing rapidly, however, the trade associations are unlikely to be able to flag up every potentially significant new technology and market trend. Even when more permanent changes occur, it can be difficult for trade organisations to respond quickly enough (it has been commented that trade associations are often structured in a way that reflects the shape of the industry 10 years previously) Also, for companies seeking information from other industries, the information provided by external trade associations can be confusing and full of jargon that is not easily understood by outsiders.

Returning to Fig 3 4, there are strong information links between small firms and the elements in their innovation environment when these sources are either seen as easily accessible, highly valuable, or trusted as a result of their familiarity or perceived credibility The barriers to companies in accessing sources are more general in nature, such as lack of time and lack of awareness of where to go for particular types of information. The sources which are used most commonly by small companies are also those which may be least likely to challenge them in the "status quo", and therefore it may be worth considering formal tools and techniques for technology lookahead

8.2.1. Review: Tools and Techniques for Technology Lookahead

There are a variety of tools and techniques described in the literature which are designed to help firms gain awareness of future technology requirements, and to assist in the technology planning process. Most of these techniques have been developed with large companies in mind, and there is little empirical evidence to support their use in small firms There may nevertheless be some benefit for small firms in using some of the techniques, particularly to help surmount the danger of over-dependence on the supply chain for information

It is relatively rare for small firms to engage in formal technology lookahead processes The literature makes it clear that small firms are not very comfortable with any form of strategic planning, and there was only one small firm in this research sample (out of a total of 21 small firms interviewed) that appeared to have a formal approach to technology lookahead As a result it was not practical to try to assess best practice empirically, and instead, a literature review is presented in Appendix IV which considers the suitability of various techniques for small firms, based on the understanding of small firms gained through this research In this section, a brief summary of Appendix IV is presented. The aim is to highlight the practical alternatives for small firms in addressing the issues raised by this research.

The first technique suggested is monitoring and scanning the technological environment This is something which all firms do anyway, but often it is done subconsciously and without any recognition of its significance It involves utilising the sources of information in the innovation environment that have been discussed already in this chapter There may however be some benefits in taking a conscious and systematic approach to information gathering This makes it clear to everyone involved that it is a strategically important activity, and helps to ensure it is not overlooked The approach should be tailored to suit the relative stability or turbulence of the industry environment (Raymond et al., 2001) The development of specific technologies can be regularly monitored in detail where appropriate, but it also worth scanning the environment in a broad but less detailed way, in order to be aware of developments emerging from unexpected quarters such as other industries.

While monitoring and scanning can give indications of the future direction of technology, they are mainly concerned with what is happening in the present. There are a number of techniques which are designed either to forecast the future of particular technologies, or to generate a number of potential future scenarios. In the electronics industries, technological progress has often followed a clear trend-line (such as Moore's Law (Palmer et al , 1999)). By plotting technology trend curves, a firm can in theory predict the future performance of a technology. This is useful when competitive advantage is based on a single technological parameter – for instance microprocessor clock speeds – but does not predict if or when customers might become more interested in (for example) price rather than speed. Most small firms would not have the necessary knowledge to develop their own technology trend curves, and the benefits in doing so are limited for most companies where products are often based on a combination of technologies with many different performance parameters Instead, it is sometimes possible to access technology trends published by industry associations Otherwise, the main point for small firms to understand is that technological progress tends to follow an S-shaped curve over time, rather than a straight line. Although progress may be slow in the early days of a new technology, it is likely to accelerate – and conversely fast rates of development in more mature technologies are unlikely to be sustainable.

Technology trends based on technological parameters may be restricted in their usefulness to sectors like the electronics industry where incremental innovation tends to play a significant role. A more generic approach to technology trends comes from bibliometrics, a technique for counting patents and publications. For example, a sudden explosion in the number of patents concerning a particular technology would imply that this technology might have a significant economic impact in the future. As discussed in Appendix IV, however, patenting activity varies from country to country and from industry to industry, and the timing of any increase cannot be used to accurately predict the uptake of a technology This technique is therefore unlikely to be of any great use to small firms in planning their technology investments

An alternative approach to obtaining a future view of technology is to gather expert opinion on the subject. Small firms are rarely in a position to be able to commission major surveys of expert opinion, but they can make use of the published findings from government- and industry-sponsored studies. These findings are usually at a fairly broad level, and will need to be interpreted for the particular circumstances of the company. In the UK and elsewhere, national Foresight exercises have been conducted (Foresight Website) which are described in Appendix IV. In the UK, a variety of different programmes have been undertaken, focussing on different sectors and themes. The aim has been to draw together stakeholders from across the community to discuss what might be expected in the future, and what can be done to bring about a desirable future. Small firms can use the outputs of this process to give them background information about unfamiliar market sectors, and to gain credibility and funding for technology developments in areas that have been identified as strategically important through Foresight (Reid, 1996). It appears at present that the Foresight process in the UK is being scaled down, so companies may have to look to studies at the European level for similar information in the future.

Industry roadmaps provide another means of accessing expert opinion on the future of a particular industry sector These tend to be sponsored either by governments (where an industry is believed to be critical to national interests) or by industry associations. The roadmaps capture the consensus of opinion on the future direction of the industry, and sometimes highlight the key technological challenges which may need to be overcome to achieve this In the electronics industry, industry roadmaps are strongly linked to technology trends such as Moore's Law, and are no doubt instrumental in ensuring that the trends are continued. Industry roadmaps are shaped to a certain extent by key players within that industry, and can therefore be a useful guide for smaller firms who are interested in the direction industry leaders are likely to take.

Having discussed means of obtaining technology lookahead information above, some of the tools and techniques for technology planning are now considered. The timing of investment in new technology (either by acquiring it or developing it) can be very difficult for small firms to judge, since there can be market share advantages in adopting early, but there can also be higher costs with an unproven technology. Economists have attempted to model technology adoption decisions, and this literature is also reviewed in Appendix IV The main conclusion from this however is that the complexities of the real world make it very difficult for economists to apply these models, and they are extremely unlikely to be of any practical use to a small company manager. Perhaps of more relevance are the trends of technology substitution and market diffusion. There are models which can be used to predict the cumulative take-up of new technologies over time, which follow an S-curve similar to that of technological progress against time. Unfortunately the predictive power of the S-curve is dependent on an accurate estimate of the market saturation level, which is difficult to achieve. Market consultants may be able to assist in this process, but can at best provide a good guess. Market diffusion or lifecycle models are helpful in identifying the likely pattern of sales over time and in anticipating obsolescence. They also draw attention to the fact that different types of customers adopt technologies at different stages of the lifecycle, and that correspondingly, different features will be important at different stages in the lifecycle One final issue to do with timing is the overall state of the industry. Industries, as well as markets, follow a lifecycle curve This curve does not lend itself well to being plotted with real data, but is useful as a conceptual tool. Technological performance tends to be critical in the early phases of the life of an industry, while cost becomes dominant as the industry matures – this can mean that product innovation is important early on, while process innovation is more significant in the later stages If a firm is able to judge the state of the industry, then their efforts can be focussed towards performance enhancement or cost reduction.

In Appendix IV, two planning frameworks are described which can be used to help make decisions about how and when to acquire or develop new technology. These frameworks draw together all the business and technological issues such as customer expectations, external environmental factors and adoption timing factors such as technological risk and likely competitor actions. The first framework is scenario planning, which typically focuses on a time frame of 5-20 years (where uncertainty becomes much greater) Having defined the scope and time frame of the study, the key stakeholders within the company should be identified, and then the key drivers and uncertainties that are likely to affect the issues under question. Through the process of generating a range of potential outcomes, it is possible to identify some of the important factors which are likely to affect the business and to be more prepared for change (technological or otherwise)

The second framework is generating product-technology roadmaps at company level. There are a wide variety of roadmaps in use, but often they involve mapping external events, technology developments and product developments against a time axis, and looking at the interactions between these elements. The time frame varies from firm to firm, but usually starts with the present (unlike scenario planning) Company roadmaps have typically been used by large companies rather than small companies, but there is evidence that they are a useful communication tool for aligning business and technology strategies, and for demonstrating to potential customers that the company is technologically ready for the future Using roadmaps, customers and suppliers can align their technology strategies where there is mutual benefit in doing so Another benefit of using either scenario planning or roadmapping comes from the discipline of preparing detailed documents, which requires the participants to consider the issues properly.

As indicated above, not all of the toolkit of possible techniques described here will be appropriate for individual small firms Indeed, for some firms it may be enough if they simply develop a forward- and outward-looking attitude which allows them to make good use of the information sources in their daily environment Other firms will however benefit from using some of the techniques to formalise the process of technology lookahead and therefore give priority to their future technological capability.

8.3. Overarching Themes

From the research presented in this thesis, it appears that a low priority is given to technology strategy by the majority of the small firms and by those in the larger firms responsible for supplier development Although this was often attributed to lack of time, it reveals the lack of importance attached to technology lookahead activities Information acquisition in two of the companies was seen as a lunchtime or after-dinner activity – something to be done as a hobby, rather than something with serious business implications

Technology lookahead was however almost certainly taking place to a greater or lesser degree, since the majority of the firms interviewed were reasonably innovative The firms clearly did not recognise the processes by which this was occurring, and the author is now of the opinion that these strategic activities must happen alongside the more mundane, day-to-day activities. As suggested in Chapter 7, companies may for example be picking up strategically important information at the same time as finding information to resolve a technical problem that has just come up. In Chapter 6, concurrent engineering involving suppliers was identified as a route through which strategic technology information might be communicated, even though that type of collaboration only concerns a current project with a relatively near time horizon. Further research would be needed to explore these hypotheses, which would probably have to be conducted through participant observation since there is no guarantee that those involved in the process would recognise the strategic dimension to their activity. One of the dangers of failing to recognise these strategic processes is that they can easily be blocked or damaged accidentally, by changes in the way things are done or changes in personnel. If a single individual is acting as a conduit for strategic technological information and that is not recognised, the process is very vulnerable

The research revealed the need for small firms to look beyond their familiar environment – beyond their customers, suppliers and trade associations The supply chain and trade associations can of course be vital sources of information and should by no means be ignored, but it is too easy to become complacent in a closed environment, and unaware of disruptive technologies which may transform or even destroy an industry. As discussed in Chapter 2, firms need to be embedded in a variety of networks in order to capture relevant information It has however been suggested that it is not always the strong ties, such as those with customers and suppliers, that stimulate innovation, but weak ties with companies and individuals from different backgrounds that challenge the status quo (Granovetter, 1982; Bryson and Daniels, 1998).

Another way in which small companies are challenged to consider new ideas is through browsing sources such as journals and the Internet While the author would recommend formal processes for technology lookahead such as systematic monitoring and scanning, there is a place for serendipity and letting the ideas present themselves This does require a "prepared mind", so browsing and formal searching are complementary activities.

It can be difficult for small firms to step outside their comfort zone and investigate unfamiliar technologies There are a number of reasons for this: firstly, they may not know where to look for the information they need. Secondly, they may not know the right keywords with which to search, or may not understand the technical jargon used, particularly if the technology is associated with a different industry sector. Thirdly, they may be limited by their own level of knowledge as to whether they can grasp the potential significance of the technology to their business. In larger firms, there tend to be more subject specialists employed, and so it is more likely that there will be someone else who can help to make sense of the information. In contrast, those in small firms often have to take on multiple roles for which they have had no formal training or education, and so it is much harder for them to absorb information concerning unfamiliar topics and then transform that into product or process innovation (Cohen and Levinthal, 1990). This relates back to the second point again – understanding jargon and identifying keywords depends on the ability and experience of the searcher. Some of those interviewed during the course of the research clearly found themselves out of their depth when trying to investigate alternative markets and alternative technologies. Others were able to get a long way using the Internet, and through trial and error were able to home in on what they needed to know This type of skill and experience can be found in small companies as well as in large, but it did appear to be lacking in the less innovative small firms

For companies with less skill and breadth of experience available to them, it can be a very time-consuming business to find and digest relevant information about potential new technologies Even though there is much "free" information available via the Internet, the cost of spending days sifting through it is quite significant. There may be a role for small business support organisations or consultants to assist small firms in this process of investigating alternative technologies, if this could be done relatively quickly and cheaply. The challenge would be for the external agent to understand both the technology under question and the nature of the small firm's business, in order to assess the suitability of the technology for that firm. This process of translation is very important, since it is of little use to a company for someone to tell them all about a new technology if they are left none the wiser as to how they could use it Another possibility (as outlined in Chapter 7) might emerge as Internet technology develops, which could avoid the cost of the personal service suggested above An on-line service with a highly developed user interface might be able to assist those with very little knowledge of how to search for such information, although it would not be able to provide any recommendations regarding the suitability of technology adoption for any one firm.

These issues are not simply the problem of small companies struggling to develop their own technological capability – they affect the value chains in which those small firms operate If large systems integration companies want their small suppliers to continue to provide technologically advanced sub-systems, they may need to consider further how they can support their suppliers in identifying, acquiring and developing new technologies It is in the interest of the systems integrators to ensure that their suppliers are updated on developments from other industries and that they are able to look beyond the technology requirements of the next order. This may require them to provide seminars or other means of disseminating technological information, or to make their technology specialists available to suppliers. (It also suggests that it may be important for systems integrators to continue to maintain technology specialists or "gurus" within their organisations, for the sake of their own technology lookahead as well as that of their suppliers)

Part of the reason large firms have not given this type of support to their suppliers appears to be faith in market forces: that if their suppliers are not able to meet their requirements for high technology at a low cost, then someone else will. There appears to be little recognition that by outsourcing design and manufacture, they have outsourced most of the costs of technology lookahead and the risks of technological innovation to firms with fewer resources. This may not be sustainable in the long term, and the market may not always provide. It is possible that large international technology-based firms may step in to fill the gap if small UK manufacturers are unable to compete, and further research would be necessary to identify whether industry dynamics are changing in this way For the aerospace and defence industry, however, it is possible that the volumes would not be high enough to interest larger firms, and there may also be security issues if key technologies are not available from UK firms. Supporting the existing suppliers in developing their technological capability may be the best option.

Technology lookahead is simply a first step towards developing technological capability, and there are particular challenges for companies trying to integrate technologies where they may not traditionally have had the skills and expertise to do this. Further research is needed to investigate how firms can develop or acquire the necessary expertise – whether through technological alliances with other small firms, or by recruitment or training. That first step of gaining awareness of future technology needs and opportunities is nonetheless vital, and deserves greater recognition from large and small companies alike

8.4. Summary of Research Findings and Statement of Contribution

The aim of the research presented in this thesis was to identify and evaluate mechanisms for maintaining and developing technological capability in small manufacturing suppliers. Through a scoping study based on interviews with small firm managers, "technology lookahead" (the process of anticipating the technological future) was selected as an important mechanism to be investigated. This research investigates how small manufacturers interact with the innovation environment around them in order to obtain the information they need to foster technological capabilities appropriate to future market requirements. This question has not hitherto been directly addressed in the academic literature and therefore the research presented in this thesis provides a unique perspective.

The literature review and the scoping study identified customers as a dominant influence for small firms in technological innovation, but also revealed that over-reliance on customers left their suppliers committed to short-term technology strategies that might not benefit them beyond the next order The in-depth research into technology lookahead was therefore divided into two parts. first to explore the impact of customer-led supplier development programmes through case study research; and then to evaluate the suppliers' own information acquisition processes (in looking outside the value chain) via surveys and interviews

The study of supplier development programmes addressed a number of gaps in the literature·

- by identifying technological development as a supply chain management issue
- by approaching supplier development from an engineering perspective rather than from a procurement perspective
- by directing research effort towards studying the development of technological capabilities rather than dwelling on quality, cost and delivery performance
- by exploring how suppliers perceive supplier development programmes instead of focussing exclusively on the buyers' perspective (Krause, 1997; Krause et al., 2000)

It was found that the supplier development programmes studied did little to address technological issues directly, which is consistent with the priorities identified in previous research (Krause and Handfield, 1999, Watts and Hahn, 1993) They did however appear to facilitate technology lookahead indirectly, by building up relationships of trust between customer and supplier firms which were more conducive to the transfer of strategic technology information. The involvement of engineers in the supplier development process was identified as an important part of this process but was not always achieved

The contribution of the information acquisition research was in addressing the following gaps in the literature·

- by studying how small firms *perceive* their own information needs (which may drive them to seek technological information)
- by looking for evidence concerning how small firms acquire strategic technology information

The research also built upon the existing literature in developing the understanding of information acquisition processes.

The small firms studied were found to make active use of a wide variety of information sources beyond the supply chain (consistent with previous research e.g. (Lambert and Barber, 1998)), but were generally not consciously seeking strategic technology information Instead, it is probable that technology lookahead was occurring naturally alongside information-seeking conducted for more routine, operational purposes Innovative activity appeared to stimulate the companies to seek more external information (thereby laying the foundations for future innovation), but acquiring information about unfamiliar technologies or markets sometimes presented difficulties such as identifying suitable sources, ascertaining the right keywords and having adequate background knowledge to be able to understand the information (cf. (Vos et al , 1998; Cohen and Levinthal, 1990))

8.5. Limitations of Research

The limitations of the research have been addressed in previous chapters and are summarised below. firstly the limitations of the research methodology, and secondly the limitations in terms of generalising the research findings.

8.5.1. Limitations of Research Methodology

The overall sampling strategy could have benefited from greater consistency in targeting companies in the aerospace and defence sector. Broader criteria were used to select firms for the scoping study and for the information acquisition research, on the basis that the processes of interest could be seen in any small traditional UK manufacturing company The sample selection for the supplier development research could have been improved by including a larger number of supplier firms in the study, and if the suppliers had not all been nominated by the customer The selection of suppliers for interview is likely to have biased the results towards those companies where the customer believed supplier development was working well – but might therefore have provided a showcase for the processes of interest to the research.

In terms of data collection, it would have been desirable to conduct a greater number of interviews as part of the first supplier development case study, particularly to access the views of members of a supplier development team. For the first information acquisition survey, the response rate was disappointing and may have been improved by administering the survey by telephone rather than by post. The results of that survey and the consequent selection of companies for interview are not representative of small manufacturing firms in the Midlands. Instead they are likely to be biased towards firms which are perhaps more interested in utilising external sources of information and more likely to be involved in technology lookahead The second survey and selection of firms are also likely to be biased in the same way since the sample was drawn from an RTO membership base

The final factor which will have influenced the research findings is interviewer bias. A second researcher was involved with many of the interviews to help avoid this, but it was not possible for all of the interviews concerning information acquisition. The use of other sources of evidence such as surveys and corporate material will have helped to mitigate against this bias.

8.5.2. Limitations of Generalisability

The research presented in this thesis was targeted towards small, fairly traditional manufacturing suppliers operating within the UK supply chains of mature industries such as aerospace, producing niche products in low volumes. The findings are therefore limited in terms of their applicability in other types of companies, other industry sectors and other locations.

Part of the research dealt exclusively with two aerospace and defence companies and their suppliers, and it would certainly not be appropriate to generalise the descriptions of the supplier development programmes, since the nature of such programmes will vary from firm to firm and also from country to country. Nevertheless, the finding that the development of technological capabilities is given little emphasis in these particular cases appears to be consistent with the existing supplier development literature. The selection of case studies was deliberately targeted towards firms where supplier technological capability was likely to be a priority, so the author's expectation is that supplier development programmes in other companies or industries would be rather less likely to focus on developing technological capability. The finding that the case supplier development programmes helped to build relationships of trust between the buying firms and their suppliers (thus facilitating technology lookahead indirectly) cannot be generalised to all supplier development programmes, since it depends on the nature of the programme and how it is administered.

The part of the research concerned with information acquisition and information flows is likely to be more broadly applicable in its findings than the supplier development research. This is reflected in the sample of companies used, which was not limited to the aerospace and defence sector (although it was centred on traditional UK manufacturing firms) There is no single approach to information gathering, and the research findings do not provide a complete picture of information acquisition even within one of the sample companies. The findings do however give an indication that in

UK manufacturing at least, technology lookahead does not tend to be a conscious process.

8.6. Areas for Further Research

A number of opportunities for further research were identified through the literature review in Chapter 2, and during the active phase of the research:

- Industry dynamics within UK manufacturing merit further research.
    - to establish whether the trend of outsourcing is continuing, or whether there is a return to some form of vertical integration
    - to determine whether the trend is for systems integrators to outsource more sub-systems and sub-assemblies to their traditional small suppliers or instead to large international technology-based firms
- Existing research suggests that small innovating firms are no more profitable or productive than non-innovating small firms, nor more likely to grow in terms of sales or employment (Freel, 2000; Souder and Song, 1997) There is a need to discover why small firms do not appear to accrue benefits from innovation in the same way that large firms do
- The development of small firm technological capability is influenced by many external and internal factors, and this research has only investigated the links between small firms and their innovation environment, and flows of information. There is an opportunity for further research into the effects of:
    - Current economic climate (e g. funds available for technological development and recruitment)
    - Government policies (e.g availability of R&D tax credits or training and education policies)
    - Legislation (e g product end-of-life issues)
    - Top management (e.g. attitudes towards innovation, risk and strategic technology planning)
    - Employee skills (e.g. education and training)
- There are specific challenges for firms which need to integrate new, unfamiliar technology into their products alongside their existing technology. There are research opportunities to explore how the necessary expertise can best be developed or acquired (e.g. through technological alliances with other firms, by recruitment or by training existing personnel).

- Strategic technology management in small firms has not been directly studied, since it is unusual for small firms to take such an approach The best opportunity to address this gap in the literature might be to conduct a programme of action research This would require researchers to stimulate technology management activity within small firms, acting as participant observers
- The process of technological innovation tends to be examined at the level of the individual firm in the literature. While the research presented in this thesis has begun to address technological development as a supply chain issue, there is a real opportunity for researchers to develop this further and take a systems approach to technology in the supply chain.
- Early supplier involvement in new product development may have an influence on the supplier's long-term technological capability. This influence merits further exploration and may arise through the informal exchange of strategic (longer-term) technological information during discussions focussed on the current project. Those involved in the new product development might not even be conscious of the strategic aspects of their dialogue and participant observation would probably be necessary to identify such influences
- Further research using participant observation could also be used to establish whether companies acquire strategic technology information alongside the short-term information they need to solve problems on a routine day-to-day basis.
- Supplier development programmes have established routes for improving quality, cost and delivery, because the business processes involved are reasonably well understood There may be an opportunity to develop a business process model which encompasses longer-term activities such as technological innovation and planning, which could then provide guidance in improving these activities.

8.7. Chapter Summary

This chapter began by reminding the reader of the context of the research, in terms of the business and technological drivers which make it so important for firms to be able to develop appropriate technological capability Next, the role of the innovation environment in providing technology lookahead information was discussed by drawing together the research findings from Chapters 6 and 7.

A review of tools and techniques for technology lookahead was then presented in order to highlight some of the practical options available to small firms in tackling the concerns raised by this research. Next a number of key themes from the research were identified, followed by a summary of the overall research findings and original contribution. The limitations of the research were revisited and finally a number of opportunities for further research were identified.

Reference List

Foresight Websıte (2002) [On-lıne] Avaılable. http://www.foresıght gov.uk/

TEMAGUIDE (1998) [On-line] Avaılable.
http.//www centnm bus bton ac.uk/ajar/club/TEMAGUID/ENGL/RHS1 HTM

What ıs Foresıght? (2000) [On-lıne] Prevıously avaılable·
http //www.foresıght org uk/forum/whatısforesıght.htm

Abernathy, W J and Utterback, J M (1975) 'A dynamıc model of process and product ınnovatıon', *Omega,* **3**, (6), pp 639-656.

Acha, V and Von Tunzelmann, N. (2000) 'Innovatıon Metncs and Corporate Strategy· the Majors ın the Upstream Petroleum Industry', *workıng paper from the Brıtısh Academy of Management Annual Conference (BAM 2000)*, 13 – 15 September 2000, Edınburgh

Acs, Z.J and Audretsch, D.B. (1990) *Innovation and Small Fırms*, Cambridge, MA: MIT Press

Acs, Z J and Audretsch, D.B. (1993) 'Innovatıon and firm sıze: the new learnıng', *Internatıonal Journal of Technology Management,* (November special edıtion), pp 23-35.

Agres, T (1998) 'Roadmap poınts to crucıal semıconductor needs', *Research & Development,* **40**, (2), p 23

Albnght, R.E (2000) 'Roadmaps and Roadmappıng. Linkıng Busıness Strategy and Technology Plannıng', *The Sıxth Annual Cambridge Technology Management Symposıum*, Cambndge, UK.

Andersen, B. (1999) 'The hunt for S-shaped growth paths ın technological innovatıon: a patent study', *Journal of Evolutionary Economıcs,* **9**, (4), pp.487-526.

Angell, C A , Collıns, G C.S., Jones, A D W. and Quınn, J.J. (1985) *Informatıon Transfer ın Engıneerıng and Scıence*, London: Technical Change Centre

Aram, J.D. and Cowen, S.S. (1990) 'Strategic-planning for increased profit in the small business', *Long Range Planning,* **23**, (6), pp 63-70.

Audretsch, D B (2001) 'Research Issues Relating to Structure, Competition, and Performance of Small Technology-Based Firms', *Small Business Economics,* **16**, (1 (Feb)), pp 37-51

Autio, E. and Klofsten, M. (1998) 'A Comparative Study of Two European Business Incubators', *Journal of Small Business Management,* **36**, (1), pp 30-43.

Autio, E. (1997a) '"Atomistic" and "systemic" approaches to research on new, technology-based firms. a literature study', *Small Business Economics,* **9**, (3), pp.195-209.

Autio, E. (1997b) 'New, technology-based firms in innovation networks symplectic and generative impacts', *Research Policy,* **26**, (3), pp 263-281.

Autio, E (1997c) 'Technological and Manufacturing Embeddedness among Traditional and High Technology Small and Medium Sized Enterprises' in Oakey, R. and Mukhtar, S.M. (eds) *New Technology-Based Firms in the 1990s Volume 3*, London· Paul Chapman Publishing Ltd, pp. 151-167.

Autio, E and Geust, N. (1996) 'New Technology-Based Firms in Paradigmatic and Industry-Specific Technological Systems' in Oakey, R (ed.) *New Technology-Based Firms in the 1990s Volume 2*, London: Paul Chapman Publishing Ltd, pp. 117-129.

Baldwin, J. and Gellatly, G. (1999) 'Developing High-Tech Classification Schemes: a Competency-Based Approach (Ch 13)' in Oakey, R., During, W and Mukhtar, S M (eds) *New Technology-Based Firms in the 1990s Volume 6*, Oxford· Pergamon, pp. 185-199.

Bardsley, J N (1998) 'National Technology Roadmap for Flat Panel Displays ', *Solid State Technology,* **41**, (1), p 47.

Barker, D. and Smith, D.J.H. (1995) 'Technology Foresight using Roadmaps', *Long Range Planning,* **28**, (2), pp.21-28.

Bass, F.M (1969) 'A New Product Growth Model for Consumer Durables', *Management Science,* **15**, ((January)), pp.215-227

Beath, J., Katsoulacos, Y. and Ulph, D. (1995) 'Game-Theoretic Approaches to the Modelling of Technological Change (Ch5)' in Stoneman, P. (ed.) *Handbook of the Economics of Innovation and Technical Change,* Oxford: Blackwell.

Belotti, C. and Tunalv, C (1999) 'Acquisition of technological knowledge in small and medium- sized manufacturing companies in Sweden', *International Journal of Technology Management,* **18**, (3-4), pp 353-371

Bergelt, K (2000) 'The "New Motorola": Developing a perspective on value, innovation, and strategic technology planning', *The 6th Annual Cambridge Technology Management Symposium (Future Technology - Future Markets· Linking technology to business planning),* Cambridge, UK

Bertodo, R. (2002) 'Some developing trends in manufacturer supplier relationships', *International Journal of Manufacturing Technology and Management,* **4**, (1/2),

Bessant, J. (1999) 'The rise and fall of `Supernet'· a case study of technology transfer policy for smaller firms', *Research Policy,* **28**, (6), pp 601-614

Bessant, J., Kaplinsky, R. and Lamming, R. (1999) 'Using supply chains to transfer learning about 'best practice' - a report to the Department of Trade and Industry'.

Bhattacharya, A K , Coleman, J.L. and Brace, G (1995) 'Re-positioning the supplier: an SME perspective', *Production Planning and Control,* **6**, (3), pp.218-226

Bidault, F., Despres, C and Butler, C. (1998a) 'The drivers of cooperation between buyers and suppliers for product innovation', *Research Policy,* **26**, (7-8), pp.719-732.

Bidault, F , Despres, C and Butler, C. (1998b) 'New product development and early supplier involvement (ESI)· the drivers of ESI adoption', *International Journal of Technology Management,* **15**, (1-2), pp 49-69.

Bırchall, D.W., Chanaron, J.J. and Soderquıst, K. (1996) 'Managıng ınnovation in SMEs· A companson of companıes ın the UK, France and Portugal', *Internatıonal Journal of Technology Management,* **12**, (3), pp.291-305.

Bouty, I. (2000) 'Interpersonal and ınteractıon ınfluences on ınformal resource exchanges between R&D researchers across organızatıonal boundaries', *Academy of Management Journal,* **43**, (1), pp 50-65.

Bower, D J and Keogh, W. (1997) 'Innovatıon Management in the Supply Chaın and the Lımıtatıons of Lean Supply' ın Oakey, R and Mukhtar, S.-M. (eds.) *New Technology-Based Fırms ın the 1990s Volume 3*, London Paul Chapman Publishıng Ltd, pp. 104-113.

Bower, J L and Chnstensen, C M. (1995) 'Dısruptive Technologıes: Catchıng the Wave', *Harvard Busıness Revıew,* **73**, (1), pp 43-53

Bracker, J. and Pearson, J (1986) 'Plannıng and Fınancıal Performance of Small Mature Fırms', *Strategıc Management Journal,* **7**, (6), pp.503-522.

Braun, E and Ellıot, D (1996) *Global Patterns ın Technologıcal Innovation,* Mılton Keynes, UK The Open Unıversıty

Breıner, S., Cuhls, K. and Grupp, H. (1994) 'Technology foresıght usıng a Delphi approach - a Japanese- German cooperation', *R & D Management,* **24**, (2), pp.141-153

Bridges, E., Coughlan, A T and Kalısh, S. (1991) 'New technology adoptıon ın an innovatıve marketplace - mıcrolevel and macrolevel decision-makıng models', *Internatıonal Journal of Forecastıng,* **7**, (3), pp 257-270.

Brock, Y. (2003) 'Explanatory Notes to the SBAC Annual Survey - 2002' [On-lıne] Avaılable· http //www sbac co.uk/pdfs/03-0078 pdf

Brouwer, M (1998) 'Fırm sıze and efficıency ın ınnovatıon· comment on van Dıjk et al ', *Small Busıness Economıcs,* **11**, (4), pp 391-393.

Bryson, J R and Danıels, P W (1998) 'Busıness Lınk, strong ties, and the walls of silence small and medıum-sızed enterprıses and external busıness-service expertıse', *Envıronment and Plannıng C-Government and Polıcy,* **16**, (3), pp.265-280.

Burggraaf, P (2000) 'New roadmap unveıled', *Solıd State Technology,* **43**, (1), p.31

Burrell, G. and Morgan, G. (1979) *Sociologıcal Paradıgms and Organısatıonal Analysıs elements ın the socıology of corporate life,* Aldershot, England. Arena.

Canez, L E , Platts, K.W. and Probert, D R (2000) 'Developing a Framework for Make-or-Buy Decısıons', *Internatıonal Journal of Operatıons & Production Management,* **20**, (11-12), pp 1313-1330

Carayannıs, E G and Roy, R I S (2000) 'Davids Vs Golıaths ın the Small Satellıte Industry the Role of Technological Innovatıon Dynamics in Fırm Competıtıveness', *Technovatıon,* **20**, (6), pp.287-297.

CBI (1995-1999) *CBI/NatWest Innovatıon trends survey 1995, 1996, 1997, 1998, 1999,* CBI.

CBI (1998) *CBI Innovatıon Trends Survey 1998,* CBI

CBI (1999) '3M-Natwest· 1998 and 1999 Innovatıon Trends Surveys' [On-lıne] Avaılable http·//www cbı org.uk/ınnovatıon/

CBI (2001) *CBI/3M and Desıgn Councıl Innovation Trends Survey 2001. A questıon of Culture? Collaboratıve Innovatıon ın UK busıness,* CBI.

CBI (2002) *Innovatıon potentıal. CBI/3M/Desıgn Councıl Survey 2002. Results and analysıs of the 2002 ınnovatıon survey,* CBI.

Chakravartı, A K , Vasanta, B., Krıshnan, A S A. and Dubash, R.K. (1998) 'Modified Delphi methodology for technology forecastıng - Case study of electronıcs and informatıon technology ın Indıa', *Technologıcal Forecastıng and Socıal Change,* **58**, (1-2), pp.155-165.

Chesbrough, H.W. and Teece, D J. (1996) 'When ıs vırtual vırtuous? Organızıng for innovatıon', *Harvard Busıness Revıew,* **74**, (1), p 65ff

Chılde, S.J. (1998) 'Extended enterprıse - a concept of co-operatıon', *Production Plannıng and Control,* **9**, (4), pp.320-327.

Chrıstensen, C M. (1997) *The Innovator's Dılemma When New Technologıes Cause Great Fırms to Faıl,* Boston, Massachusetts: Harvard Busıness School Press.

Chrıstensen, C.M., Suarez, F.F. and Utterback, J M (1998) 'Strategıes for survival in fast-changıng ındustrıes', *Management Scıence,* **44**, (12), p.S207-S220

Chrıstopher, M. (1998) *Logıstics and supply chaın management·strategıes for reducıng cost and ımprovıng servıce,* 2nd edn, London Pitman.

Clark, K B (1989) 'Project scope and project performance· the effects of parts strategy and supplıer ınvolvement on product development', *Management Scıence,* **35**, (10 (October)), pp 1247-1263

Clark, K B and Fujımoto, T. (1991) *Product development performance strategy, organızatıon, and management ın the world auto ındustry,* Boston, Mass.: Harvard Busıness School Press.

Cohen, W M. and Levınthal, D.A. (1990) 'Absorptıve-capacıty - a new perspective on learnıng and ınnovatıon', *Admınıstratıve Scıence Quarterly,* **35**, (1), pp.128-152.

Cooke, P , Uranga, M G. and Etxebarrıa, G. (1997) 'Regıonal ınnovatıon systems: Instıtutıonal and organısatıonal dımensıons', *Research Polıcy,* **26**, (4-5), pp 475-491

Cooke, P., Uranga, M G and Etxebarrıa, G. (1998) 'Regional systems of ınnovatıon· an evolutıonary perspectıve', *Envıronment and Plannıng A,* **30**, (9), pp 1563-1584.

Cooke, P. and Wılls, D. (1999) 'Small Fırms, Socıal Capıtal and the Enhancement of Busıness Performance through Innovatıon Programmes', *Small Busıness Economıcs,* **13**, (3), pp.219-234.

Coombs, R and Tomlinson, M. (1998) 'Patterns in UK company innovation styles: New evidence from the CBI innovation trends survey', *Technology Analysis & Strategic Management,* **10**, (3), pp 295-310.

Cosh, A.D and Hughes, A (1996) *The Changing State of British Enterprise: Growth, Innovation and Competitive Advantage in Small and Medium Sized Firms 1986-95*, Cambridge· ESRC Centre for Business Research, University of Cambridge.

Cosh, A.D. and Hughes, A. (1998) *Enterprise Britain: Growth, Innovation and Public Policy in the Small and Medium Sized Enterprise Sector 1994-1997*, Cambridge. ESRC Centre for Business Research, University of Cambridge.

Cosh, A.D and Hughes, A (2000) *British Enterprise in Transition Growth, Innovation and Public Policy in the Small and Medium Sized Enterprise Sector 1994-1999*, Cambridge: ESRC Centre for Business Research, University of Cambridge

Craggs, A. and Jones, P. (1998) 'UK results from the Community Innovation Survey', *Economic Trends,* **539**, pp 51-57

D'Aveni, R A (1999) 'Strategic Supremacy Through Disruption and Dominance', *Sloan Management Review,* **40**, (3 (Spring)), pp 127-137.

Dana, L.P. (2001) 'Networks, Internationalization & Policy', *Small Business Economics,* **16**, (2), pp 57-62.

Dankbaar, B. (1998) 'Technology management in technology-contingent SMEs', *International Journal of Technology Management,* **15** , (1/2), pp.70-81.

Denzin, N K. and Lincoln, Y S (1998) *Strategies of Qualitative Inquiry*, London. Sage Publications

Dodgson, M. (1993) 'Strategies for accumulating technology in small high-technology firms a learning approach and its public policy implications', *International Journal of Technology Management,* (special edition), pp 161-170.

Dowlatshahı, S (1998) 'Implementing early supplier involvement: a conceptual framework', *International Journal of Operations & Production Management,* **18**, (1-2), pp 143-167.

DTI (1998) 'The 1998 Competitiveness White Paper: Our Competitive Future' [On-line] Available: http://www dti gov uk/comp/competitive/

DTI (1999) 'Learning through Business Networks ' [On-line] Available: http //www dti gov uk/mbp/bpgt/busnetwork/busnetworks html

Durrani, T S , Forbes, S M. and Broadfoot, C (1999) 'An integrated approach to technology acquisition management', *International Journal of Technology Management,* **17**, (6), pp.597-21

Dwivedi, S.N , Sharan, R , Prassad, R and Garg, R. (1990) 'Concurrent Engineering - why and what?', *Proceedings AI, Simulation and Planning in High Autonomy Systems (IEEE Cat No 90TH0308-7)*, Tucson, AZ, USA. pp 142-148

Dyer, J H and Ouchi, W G. (1993) 'Japanese-style partnerships - giving companies a competitive edge', *Sloan Management Review,* **35**, (1), pp 51-63.

Easterby-Smith, M , Thorpe, R and Lowe, A. (1991) *Management Research An Introduction*, SAGE Publications Ltd.

Edquist, C. (1997) *Systems of innovation· technologies, institutions and organizations*, London: Frances Pinter.

EFQM (2000) 'EFQM Homepage' [On-line] Available http://www.efqm org/

Ehrnberg, E. and Jacobsson, S (1997) 'Indicators of discontinuous technological change: an exploratory study of two discontinuities in the machine tool industry', *R & D Management,* **27**, (2), pp 107-126

Eisenhardt, K M (1989) 'Building Theories from Case Study Research', *Academy of Management Review,* **14**, (4), pp 532-550.

Entrialgo, M , Fernandez, E and Vazquez, C J (2001) 'The Effect of the Organizational Context on SME's Entrepreneurship: Some Spanish Evidence', *Small Business Economics,* **16**, (3), pp 223-236.

Ettlinger, N. (1997) 'An Assessment of the Small-Firm Debate in the United States', *Environment and Planning A,* **29**, (3), pp.419-442

European Patent Office (2001) 'B1 - esp@cenet - your gateway to patents' [On-line] Available· http //ep espacenet com/

Farzin, Y H., Huisman, K J M and Kort, P.M (1998) 'Optimal timing of technology adoption', *Journal of Economic Dynamics & Control,* **22**, (5), pp 779-799

Fine, C.H (1999) *Clockspeed,* Little, Brown and Company (UK)

Fine, C.H. and Whitney, D.E (1996) 'Is the make-buy decision process a core competence?' [On-line] Available http //imvp mit.edu/impvfree/Fine/Make_Buy pdf

Fisher, J.C. and Pry, R H. (1971) 'A Simple Substitution Model of Technological Change', *Technological Forecasting and Social Change,* **3**, pp.75-88.

Fisher, J. (1995) 'Roadmapping Assembly Technology ', *Circuits Assembly,* **6**, (9), pp 66,68

Frederickson, J W and Mitchell, T.R (1984) 'Strategic Decision Processes: Comprehensiveness and Performance in an Industry with an Unstable Environment', *Academy of Management Journal,* **27**, (2), pp.399-423

Freel, M S (2000) 'Do small innovating firms outperform non-innovators?', *Small Business Economics,* **14**, (3), pp.195-210.

Freeman, C. (1995) 'The National System of Innovation in Historical-Perspective', *Cambridge Journal of Economics,* **19**, (1), pp.5-24.

Fuellhart, K (1999) 'Localization and the Use of Information Sources: the Case of the Carpet Industry', *European Urban and Regional Studies,* **6**, (1), pp.39-58.

Fuller, T. and LaRue, D. (2000) 'The Implementation of Foresight in Organisations, a Structural Issue?', *Working paper from the World Futures Studies Federation Workshop The Quest for the Futures*, Finland

Gagnon, S (1999) 'Strategic challenges in developing electric vehicles: a literature review', *International Journal of Vehicle Design,* **21**, (1), pp 89-109

Garcia, M L and Bray, O. H. (1999) 'Fundamentals of Technology Roadmapping' [On-line] Available. http.//www.sandia gov/Roadmap/home.htm

Georghiou, L. (1996) 'The UK technology foresight programme', *Futures,* **28**, (4), pp.359-377

Ghemawat, P. (1985) 'Building strategy on the experience curve', *Harvard Business Review,* **63**, (2), pp 143-149.

Gibbons, M , Limoges, C , Nowotny, H , Schwartzman, S , Scott, P and Trow, M. (1994) *The New Production of Knowledge the dynamics of science and research in contemporary societies*, London. Sage Publications

Gill, J. and Johnson, P (1997) *Research Methods for Managers*, 2nd, London: Paul Chapman Publishing Ltd.

Giunipero, L C. (1990) 'Motivating and monitoring JIT supplier performance', *Journal of Purchasing and Materials Management,* **26**, (3), pp.19-24.

Glaser, B G and Strauss, A L (1967) *The Discovery of Grounded Theory Strategies for Qualitative Research*, New York: Aldine de Gruyter

Godet, M (1986) 'Introduction to La Prospective - 7 key ideas and one scenario method', *Futures,* **18**, (2), pp 134-157

Godet, M and Roubelat, F. (1996) 'Creating the future: the use and misuse of scenarios', *Long Range Planning,* **29**, (2), pp 164-171

Granovetter, M (1982) 'The strength of weak ties· a network theory revisited' in Marsden, P.V. and Lin, N. (eds) *Social Structure and Network Analysis*, London: Sage, pp. 105-130

Gregory, M.J. (1995) 'Technology Management· a process approach', *Proceedings of the Institution of Mechanical Engineers*, **209**, pp 347-356.

Groenveld, P. (1997) 'Roadmapping integrates business and technology', *Research-Technology Management*, **40**, (5), pp.48-55.

Grupp, H. (1994) 'The dynamics of science-based innovations reconsidered: cognitive models and statistical findings' in Granstrand, O (ed.) *Economics of Technology*, Amsterdam North-Holland, pp 223-252

Grupp, H (1999) 'Foresight activities - introduction', *Technological Forecasting and Social Change*, **60**, (1), pp 1-3.

Grupp, H. and Linstone, H A (1999) 'National technology Foresight activities around the globe - resurrection and new paradigms ', *Technological Forecasting and Social Change*, **60**, (1), pp 85-94.

Haddad, C.J. (1996) 'Operationalizing the concept of concurrent engineering: A case study from the U S auto industry', *IEEE Transactions on Engineering Management*, **43**, (2), pp.124-132.

Hahn, C.K., Watts, C A and Kim, K.Y. (1990) 'The Supplier Development Program: A Conceptual Model ', *International Journal of Purchasing and Materials Management*, **26**, (2), pp 2-7

Hall, M , Oppenheim, C. and Sheen, M.R. (1999) 'Barriers to the use of patent information in UK SMEs: Questionnaire Survey', *Journal of Information Science*, **25**, (5), pp.335-350.

Hall, M., Oppenheim, C. and Sheen, M R (2000) 'Barriers to the use of patent information in UK Small and Medium Enterprises II· Results of in-depth interviews', *Journal of Information Science*, **26**, (2), pp 87-100.

Hamel, G. and Prahalad, C K (1994) *Competing for the Future*, Cambridge MA: Harvard Business School Press.

Handfield, R.B , Ragatz, G.L., Petersen, K J. and Monczka, R.M. (1999) 'Involving suppliers in new product development', *California Management Review*, **42**, (1), pp.59-82.

Handfield, R.B. (1994) 'Effects of concurrent engineering on make-to-order products', *IEEE Transactions on Engineering Management*, **41**, (4), pp 384-393.

Hanna, V and Walsh, K. (2000) 'Alliances: The Small Firm Perspective', *Proceedings of the Fourth International Conference on MANAGING INNOVATIVE MANUFACTURING (MIM 2000)*, Aston Business School, Aston University, Birmingham, UK.

Hartley, J.L. and Choi, T.Y. (1996) 'Supplier development: Customers as a catalyst of process change', *Business Horizons*, **39** , (4),

Hartley, J L. and Jones, G E. (1997) 'Process Oriented Supplier Development: Building the Capability for Change', *International Journal of Purchasing and Materials Management*, **33**, (3), pp.24-29

Hartley, J L , Meredith, J R , McCutcheon, D. and Kamath, R.R (1997) 'Suppliers' contributions to product development: An exploratory study', *IEEE Transactions on Engineering Management*, **44**, (3), pp.258-267.

Hill, T and Chambers, S. (1991) 'Flexibility - a manufacturing conundrum', *International Journal of Operations and Production Management*, **11**, (2), pp 5-13.

Hines, P (1994) *Creating World Class Suppliers· Unlocking Mutual Competitive Advantage*, London: Pitman Publishing

Hobday, M (1998) 'Product complexity, innovation and industrial organisation', *Research Policy*, **26**, (6), pp 689-710.

Hoppe, H C. (2000) 'Second-mover advantages in the strategic adoption of new technology under uncertainty', *International Journal of Industrial Organization*, **18**, (2), pp 315-338.

Institute for Scientific Information (2001a) 'Derwent Innovations Index' [On-line] Available http //www isinet com/isi/products/derwent/

Institute for Scientific Information (2001b) 'Science Citation Index' [On-line] Available: http://www isinet.com/isi/products/citation/sci

Institution of Electrical Engineers (2001) 'INSPEC Home Page' [On-line] Available: http://www iee org.uk/publish/inspec/

Jensen, R. (1992) 'Innovation adoption and welfare under uncertainty', *Journal of Industrial Economics*, **40**, (2), pp.173-180

Johnson, P. and Duberley, J (2000) *Understanding Management Research. an introduction to epistemology*, London. Sage Publications.

Julien, P.A. (1995) 'New Technologies and Technological Information in Small Businesses', *Journal of Business Venturing*, **10**, (6 (Nov)), pp.459-475.

Kalish, S. and Lilien, G L. (1986) 'A market entry timing model for new technologies', *Management Science*, **32**, (2), pp 194-205.

Kamath, R R and Liker, J.K. (1994) 'A 2nd look at Japanese product development', *Harvard Business Review*, **72**, (6), pp.154-170

Kappel, T.A. (2001) 'Perspectives on roadmaps· how organizations talk about the future', *Journal of Product Innovation Management*, **18**, (1), pp 39-50

Karshenas, M. and Stoneman, P. (1995) 'Technological Diffusion' in Stoneman, P. (ed.) *Handbook of the Economics of Innovation and Technical Change*, Oxford: Blackwell.

Kaufman, A , Wood, C.H and Theyel, G. (2000) 'Collaboration and technology linkages: a strategic supplier typology', *Strategic Management Journal*, **21**, (6), pp.649-663.

Kleinknecht, A and Reijnen, J O N (1991) 'More Evidence on the Undercounting of Small Firm Research-and- Development', *Research Policy,* **20**, (6 (Dec)), pp.579-587.

Kodama, F. (1992) 'Technology fusion and the new R&D', *Harvard Business Review,* **70**, (4), pp.70-78.

Krause, D.R. (1997) 'Supplier Development: Current Practices and Outcomes', *International Journal of Purchasing and Materials Management,* **33**, (2), pp.12-19.

Krause, D R. (1999) 'The antecedents of buying firms' efforts to increase suppliers' performance', *Journal of Operations Management,* **17**, (2), pp 205-224.

Krause, D R and Handfield, R B. (1999) Developing a World-Class Supply Base. Tempe, AZ Center for Advanced Purchasing Studies.

Krause, D R., Handfield, R B. and Scannell, T V (1998) 'An empirical investigation of supplier development: reactive and strategic processes', *Journal of Operations Management,* **17**, (1), pp.39-58

Krause, D.R., Scannell, T V and Calantone, R.J. (2000) 'A structural analysis of the effectiveness of buying firms' strategies to improve supplier performance', *Decision Sciences,* **31**, (1 (Winter)),

Kusiak, A and Belhe, U (1992) 'Concurrent Engineering· A design process perspective', *Proceedings of the American Society of Mechanical Engineers,* **59**, pp.387-401.

Kuwahara, T (1999) 'Technology forecasting activities in Japan', *Technological Forecasting and Social Change,* **60**, (1), pp.5-14.

Kwoka, J.E and White, L.J. (2001) 'The New Industrial Organization and Small Business', *Small Business Economics,* **16**, (1), pp 21-30.

Lambert, R. and Barber, J (1998) 'Technology Sources for SMEs' in Oakey, R. and During, W (eds.) *New Technology-Based Firms in the 1990s Vol 5* , London: Paul Chapman Publishing Ltd, pp. 122-137.

Lammıng, R. (1993) *Beyond Partnershıp Strategıes for Innovation and Lean Supply,* London Prentıce Hall Internatıonal (UK) Ltd

Lammıng, R. (1996) 'Squaring Lean Supply With Supply Chaın Management', *Internatıonal Journal of Operatıons & Productıon Management,* **16**, (2), pp.183-196.

Lammıng, R., Boden, G., Cherrett, K , Irwın, N., Houghton-Jones, H. and Luckhurst, M (1999) Japanese Supply Chaın Relatıonshıps ın a Recession: Report on a DTI Mıssıon to Japan ın March 1999 Partnershıp Sourcıng Ltd.

Lang, J R , Calantone, R J and Gudmundson, D. (1997) 'Small Fırm Information Seekıng as a Response to Envıronmental Threats and Opportunıties', *Journal of Small Busıness Management,* **35**, (1), pp 11-23

Lawton Smıth, H , Dıckson, K. and Smıth, S L. (1991) '"There are two sıdes to every story": Innovatıon and collaboratıon wıthın networks of large and small firms', *Research Polıcy,* **20**, pp 457-468.

Lefebvre, E., Lefebvre, L A. and Harvey, J   (1993) 'Competing Internationally Through Multıple Innovatıve Efforts', *R & D Management,* **23**, (3 (Jul)), pp 227-237

Leıfer, R., McDermott, C M., O' Connor, G C , Peters, L.S., Rıce, M and Veryzer, R.W. (2000) *Radıcal Innovatıon how mature companıes can outsmart upstarts,* Boston, Massachusetts· Harvard Busınesss School Press.

Lıeberman, M B and Montgomery, D.B. (1988) 'Fırst-mover advantages', *Strategıc Management Journal,* **9**, (Summer Specıal Issue), pp 41-58

Lıeberman, M B and Montgomery, D B. (1998) 'Fırst-Mover (Dis)advantages: Retrospectıve and Lınk wıth the Resource-Based Vıew ', *Strategic Management Journal,* **19**, pp 1111-1125

Lınt, O. and Pennıngs, E (1999) 'Fınance and strategy: Time-to-wait or time-to-market?', *Long Range Plannıng,* **32**, (5), pp 483-493.

Lipparini, A. and Sobrero, M (1994) 'The Glue and the Pieces - Entrepreneurship and Innovation in Small- Firm Networks', *Journal of Business Venturing,* **9**, (2), pp.125-140.

Liu, S.J. and Shyu, J. (1997) 'Strategic planning for technology development with patent analysis', *International Journal of Technology Management,* **13**, (5-6), pp.661-680.

Loch, C.H and Huberman, B.A. (1999) 'A punctuated-equilibrium model of technology diffusion', *Management Science,* **45**, (2), pp 160-177.

Locke, K.D (2000) *Grounded Theory in Management Research,* London: Sage Publications Ltd.

Macdonald, S (1995) 'Too Close for Comfort: The Strategic Implications in Getting Close to the Customer', *California Management Review,* **37**, (4), pp.8-27.

Macdonald, S. and Williams, C. (1993) 'Beyond the boundary - an information perspective on the role of the gatekeeper in the organization', *Journal of Product Innovation Management,* **10**, (5), pp 417-427.

Macdonald, S. (1996) 'Informal information flow and strategy in the international firm', *International Journal of Technology Management,* **11**, (1-2), pp 219-232

Macdonald, S (1998) *Information for Innovation Managing Change from an Information Perspective,* Oxford: Oxford University Press.

Macdonald, S. and Lefang, B. (1998) 'Patents and Policy in the Innovation of Small and Medium Enterprises. Building on Rothwell' in Oakey, R P and During, W. (eds.) *New Technology-Based Firms in the 1990s Volume 5,* London: Paul Chapman Publishing Ltd, pp. 185-208

MacDuffie, J.P and Helper, S. (1997) 'Creating lean suppliers: Diffusing lean production throughout the supply chain', *California Management Review,* **39**, (4), pp.118-151

Madu, C N , Kuei, C -H and Madu, A.N. (1991) 'Setting priorities for the IT industry in Taiwan - a Delphi study', *Long Range Planning,* **24**, (5), pp 105-118.

Mahajan, V , Muller, E and Bass, F M (1990) 'New product diffusion-models in marketing - a review and directions for research ', *Journal of Marketing,* **54**, (1), pp.1-26.

Major, E.J. and Cordey-Hayes, M (2000) 'Engaging the business support network to give SMEs the benefit of Foresight', *Technovation,* **20**, (11), pp.589-602.

Malecki, E J. and Tootle, D.M. (1996) 'The role of networks in small firm competitiveness', *International Journal of Technology Management,* **11**, (1-2), pp.43-57.

Mamer, J W and McCardle, K F. (1987) 'Uncertainty, competition, and the adoption of new technology', *Management Science,* **33**, (2), pp.161-177

Marsh, R (1996) 'Innovation in Small and Medium Sized Enterprises, 1995 survey', *Economic Trends,* **516**, pp 24-41

Marshall, S. (1999) 'Industry roadmap planned for microsystems technology', *Research & Development,* **41**, (8), pp 44-45

Martin, B.R. (1995) 'Foresight in science and technology', *Technology Analysis & Strategic Management,* **7**, (2), pp 139-168.

Martin, B.R. and Johnston, R (1999) 'Technology foresight for wiring up the national innovation system - experiences in Britain, Australia, and New Zealand', *Technological Forecasting and Social Change,* **60** , (1), pp 37-54.

Martino, J P. (1983) *Technological Forecasting for Decision Making,* 2nd, North-Holland.

McCardle, K.F. (1985) 'Information acquisition and the adoption of new technology', *Management Science,* **31**, (11), pp.1372-1389.

McCutcheon, D.M., Grant, R.A. and Hartley, J.L. (1997) 'Determinants of new product designers' satisfaction with suppliers' contributions', *Journal of Engineering and Technology Management,* **14**, (3,4), pp 273-290.

McKiernan, P and Morris, C. (1994) 'Strategic Planning and Financial Performance in UK SMEs: Does Formality Matter', *British Journal of Management,* **5**, (June Special Issue), p S31-S41

Menkveld, A.J. and Thurik, A R (1999) 'Firm Size and Efficiency in Innovation: Reply', *Small Business Economics,* **12**, (1), pp 97-101.

Mensch, G. (1979) *Stalemate in Technology· innovations overcome the Depression*, Cambridge, Mass · Ballinger

Miles, M B and Huberman, A.M. (1994) *Qualitative Data Analysis*, 2nd, London· Sage Publications

Miller, R and Blais, R A (1993) 'Modes of innovation in 6 industrial sectors', *IEEE Transactions on Engineering Management,* **40**, (3), pp 264-273.

MOD (2002) 'Future Offensive Air System (FOAS) ' [On-line] Available: http.//www mod uk/dpa/projects/foas.htm

Monczka, R M , Trent, R.J. and Callahan, T.J. (1993) 'Supply base strategies to maximise supplier performance', *International Journal of Physical Distribution and Logistics Management,* **23**, (4), pp 42-54

Moore, F. (1999) 'Disk subsystem functionality roadmap', *Computer Technology Review,* **19**, (12), p 52

Moore, G A (1991) *Crossing the Chasm*, New York: HarperCollins Publishers Inc

Morgan, J. (1993) 'Supplier programs take time to become world class', *Purchasing,* **115**, (2), pp 61-63

Nevins, J.L. and Whitney, D E (1989) *Concurrent Design of Products and Processes*, New York McGraw-Hill

Nooteboom, B. (1994) 'Innovation and Diffusion in Small Firms - Theory and Evidence', *Small Business Economics,* **6**, (5 (Oct)), pp 327-347.

North, D , Smallbone, D and Vickers, I (2001) 'Public sector support for innovating SMEs', *Small Business Economics,* **16**, (4), pp.303-317.

North, J., Blackburn, R. and Curran, J. (1997) 'Reaching Small Businesses? Delivering Advice and Support to Small Businesses through Trade Bodies' in Ram, M., Deakins, D. and Smallbone, D (eds.) *Small Firms Enterprising Futures*, London: Paul Chapman, pp. 90-101

O'Neill, M and Dale, I. (2001) 'The Small Business Service Omnibus Survey', *24th ISBA National Small Firms Policy and Research Conference· Exploring the Frontiers of Small Business*, Hinckley, Leicestershire. pp.697-708

O'Shea, A. and McBain, N (1999) 'The Process of Innovation in Small Manufacturing Firms', *International Journal of Technology Management,* **18**, (5-8), pp.610-626

Oakes, I K. and Lee, G.L. (1996) 'Approaches to innovation amongst component suppliers: some smaller firm perspectives', *International Journal of Technology Management,* **12**, (7-8), pp.808-819.

Oakey, R P and During, W. (1998) *New Technology-Based Firms in the 1990s Volume 5*, London: Paul Chapman Publishing Ltd

OECD (1997) National Innovation Systems OECD. [On-line].

Office for National Statistics (1985-1999) Business monitor PA1003. Size analysis of United Kingdom businesses. London: HMSO.

Palmer, P J. and Williams, D J (2000) 'An Analysis of Technology Trends with the Electonics Industry', *Microelectronics International,* **17**, (1), pp 13-16.

Palmer, P J., Williams, D J. and Hughes, C. (1999) 'Observations and models of technology trends within the electronics industry ', *IEE Engineering Science and Education Journal,* **8**, (5), pp 233-240.

Patton, M Q (1990) *Qualitative Evaluation and Research Methods*, 2nd, London: Sage Publications Ltd.

Pavitt, K., Robson, M. and Townsend, J. (1987) 'The Size Distribution Of Innovating Firms In The Uk - 1945-1983', *Journal of Industrial Economics,* **35**, (3), pp.297-316.

Pavitt, K. (1984) 'Sectoral Patterns Of Technical Change - Towards A Taxonomy And A Theory', *Research Policy,* **13**, (6), pp.343-373.

Pavitt, K. (1988) 'The Size And Structure Of British Technology Activities - What We Do And Do Not Know', *Scientometrics,* **14**, (3-4), pp.329-346.

Pavitt, K (1994) 'Key Characteristics of Large Innovating Firms' in Dodgson, M. and Rothwell, R. (eds) *The Handbook of Industrial Innovation,* Edward Elgar Publishing Ltd, pp. 357-366

Peel, M J. and Bridge, J (1998) 'How planning and capital budgeting improve SME performance', *Long Range Planning,* **31**, (6), pp 848-856

Phaal, R , Farrukh, C. and Probert, D. (2001) *T-Plan The Fast Start to Technology Roadmapping,* Cambridge, UK: Institute for Manufacturing, University of Cambridge

Phaal, R., Farrukh, C.J P. and Probert, D R. (2000) 'Fast-Start Technology Roadmapping', *9th International Conference on Management of Technology (IAMOT 2000),* 20 – 25 February 2000, Miami, Florida, USA.

Piest, B. (1994) 'Planning comprehensiveness and strategy in SMEs', *Small Business Economics,* **6**, (5), pp.387-395.

Porter, A.L., Jin, X.Y , Gilmour, J E , Cunningham, S., Xu, H.D., Stanard, C. and Wang, L. (1994) 'Technology opportunities analysis - integrating technology monitoring, forecasting, and assessment with strategic-planning', *SRA-Journal of the Society of Research Administrators,* **26**, (2), pp 21-31.

Porter, A L , Roper, A.T., Mason, T.W., Rossini, F A and Banks, J. (1991) *Forecasting and Management of Technology,* John Wiley & Sons, Inc.

Porter, M.E. (1985) 'Technology and Competitive Advantage (Ch. 5)' in Porter, M.E. (ed) *Competitive Advantage,* New York: The Free Press.

Prahalad, C.K and Hamel, G (1990) 'The core competence of the corporation', *Harvard Business Review,* **68**, (3), pp.79-91

Probert, D and Shehabuddeen, N (1999) 'Technology Road Mapping: the Issues of Managing Technology Change', *International Journal of Technology Management,* **17**, (6), pp 646-661.

Probert, D R , Farrukh, C J P., Gregory, M and Robinson, N. (1999) 'Linking Technology to Business Planning: Theory and Practice', *International Journal of Technology Management,* **18**, (1-2), pp.11-30

Quazzotti, S., Dubois, C , Dou, H , Rostaing, H , Escorsa, P. and Arnau, R. (1999) *Guide des Bonnes Pratiques en PME/PMI,* Commission Europeenne, Centre de Recherche Public Henri Tudor, Universite Aix-Marseille III, Universite Polytechnique de Catalogne, IMPIVA.

Quinn, J J. (1986) 'Monitoring the technological environment', *IEE Proceedings Part A,* **133**, (6), pp 361-364.

Ragatz, G.L , Handfield, R.B and Scannell, T V. (1997) 'Success factors for integrating suppliers into new product development', *Journal of Product Innovation Management,* **14**, (3), pp 190-202.

Rajagopalan, S (1999) 'Adoption timing of new equipment with another innovation anticipated', *IEEE Transactions on Engineering Management,* **46**, (1), pp.14-25.

Raymond, L., Julien, P -A. and Ramangalaby C. (2001) 'Technological Scanning by Small Canadian Manufacturers', *Journal of Small Business Management,* **39**, (2), pp 123-138.

Rea, D G , Brooks, H , Burger, R.M. and LaScala, R. (1997) 'The semiconductor industry - Model for industry/university/government cooperation', *Research-Technology Management,* **40**, (4), pp.46-54.

Reid, S. (1996) 'High-tech innovators and the Technology Foresight Programme', *Business, Growth and Profitability,* **2**, (3), pp 261-265.

Reijs, J. (1994) 'Foresight Studies Undertaken by the Ministry of Economic-Affairs in the Netherlands', *R & D Management*, **24**, (2), pp.167-174.

Reinganum, J F. (1981) 'On the diffusion of new technology - a game theoretic approach', *Review of Economic Studies*, **48**, (3), pp.395-405

Reinganum, J.F. (1983) 'Technology adoption under imperfect information', *Bell Journal of Economics*, **14**, (1), pp 57-69

Reinganum, J F (1989) 'The Timing of Innovation. Research, Development and Diffusion (Chapter 14)' in Schmalensee, R. and Willig, R D (eds.) *Handbook of Industrial Organization*, Amsterdam: Elsevier Science Publishers B.V., pp. 849-908

Richardson, W. (1995) 'In Defence of Business Planning: Why and how it still works for small firms and corporations of small business units', *Small Business and Enterprise Development*, **2**, (1), pp 41-57

Robinson, R B. (1982) 'The importance of outsiders in small firm strategic-planning', *Academy of Management Journal*, **25**, (1), pp.80-93.

Robinson, R B. and Pearce, J A. (1983) 'The impact of formalized strategic-planning on financial performance in small organizations', *Strategic Management Journal*, **4**, (3), pp.197-207.

Rogers, E M (1995) *The Diffusion of Innovations*, 4th, New York. Free Press.

Roper, S. (1999) 'Under-Reporting of R & D in Small Firms. the Impact on International R & D Comparisons', *Small Business Economics*, **12**, (2), pp.131-135

Rosenberg, N and Fritschtak, C. (1994) 'Technological Innovation and Long Waves' in Rosenberg, N. (ed) *Exploring the Black Box Technology, Economics and History*, Cambridge: Cambridge University Press

Rothwell, R. (1983) 'Innovation And Firm Size - A Case For Dynamic Complementarity - Or, Is Small Really So Beautiful', *Journal of General Management*, **8**, (3), pp.5-25

Rothwell, R. (1984) 'The role of small firms in the emergence of new technologies', *OMEGA - International Journal of Management Science,* **12**, (1), pp.19-29.

Rothwell, R. (1989) 'Small Firms, Innovation and Industrial Change', *Small Business Economics,* **1**, (1), pp.51-64

Rothwell, R. (1992) 'Successful Industrial-Innovation - Critical Factors For The 1990s', *R & D Management,* **22**, (3), pp.221-239.

Rothwell, R and Dodgson, M (1991) 'External Linkages And Innovation In Small And Medium-Sized Enterprises', *R & D Management,* **21**, (2), pp.125-137.

Rothwell, R. and Dodgson, M (1993) 'Technology-Based SMEs: Their Role in Industrial and Economic Change', *International Journal of Technology Management,* (special edition), pp 8-22.

Roy, R , Wield, D., Gardiner, P. and Potter, S. (1996) *Innovative Product Development*, Milton Keynes, UK: The Open University.

Russell, S. and Lunn, R (1999) 'Supplier Capability in Product Engineering' [On-line] Available· http·//www cranfield.ac.uk/sims/cim/events/aerospace_s21 htm

Sako, M. (1992) *Prices, Quality and Trust Interfirm relations in Britain and Japan*, Cambridge University Press.

Sako, M (1994) 'Supplier Relationships and Innovation' in Dodgson, M and Rothwell, R (eds) *The Handbook of Industrial Innovation*, Edward Elgar Publishing Ltd, pp. 268-274

SBAC (2000) 'UK Aerospace Facts and Figures 2000' [On-line] Available· http.//www sbac co uk/pdfs/stats2000 pdf

SBAC (2003) 'UK Aerospace Equipment Sector' [On-line] Available: http //www sbac co.uk/pdfs/SBAC Equip Sector pdf

Scannell, T V , Vickery, S K. and Droge, C.L. (2000) 'Upstream supply chain management and competitive performance in the automotive supply industry', *Journal of Business Logistics,* **21**, (1), pp 23-48.

Schoemaker, P J H (1991) 'When and how to use scenario planning - a heuristic approach with illustration', *Journal of Forecasting,* **10**, (6), pp 549-564.

Schoemaker, P J H. and Mavaddat, V.M. (2000) 'Scenario Planning for Disruptive Technologies (Chapter 10)' in Day, G and Schoemaker, P. (eds) *Wharton on Managing Emerging Technologies,* New York. John Wiley & Sons Inc , pp. 206-241

Schumpeter, J A (1934) *The theory of economic development:an inquiry into profits, capital, credit, interest and the business cycle* , Cambridge, MA: Harvard University Press.

Schumpeter, J.A. (1942) *Capitalism, Socialism and Democracy,* New York: Harper.

Small Business Research Centre (1992) *The State of British Enterprise· Growth, Innovation and Competitive Advantage in Small and Medium-sized Firms,* Cambridge University of Cambridge

Small Business Service (2001) 'SME Statistics for the UK' [On-line] Available: http·//www.sbs gov uk/statistics/smestats asp

Smart, P.K., Brookes, N J , Lettice, F E., Backhouse, C.J. and Burns, N.D. (2000) 'Structuring Product Development in the 21st Century: Boundary Management in the Motor Industry', *Proceedings of the 2000 IEEE International Conference on Managing Innovation and Technology (ICMIT 2000),* Singapore. pp.412-418

Souder, W E. and Song, X M (1997) 'Contingent Product Design and Marketing Strategies Influencing New Product Success and Failure in US and Japanese Electronics Firms', *Journal of Product Innovation Management,* **14**, (1), pp 21-34.

Souitaris, V (2002) 'Firm-Specific Competencies Determining Technological Innovation: a Survey in Greece', *R & D Management,* **32**, (1), pp 61-77

Stake, R E (1998) 'Case Studıes (Ch. 4)' in Denzın, N K. and Lincoln, Y.S. (eds.) *Strategıes of Qualıtatıve Inquıry*, London: Sage Publıcations

Stenbacka, R and Tombak, M.M. (1994) 'Strategıc tımıng of adoptıon of new technologıes under uncertaınty', *International Journal of Industrıal Organızatıon,* **12**, (3), pp 387-411

Stockdale, B. (2002) 'UK Innovatıon Survey 2001', *Economic Trends,* **580**, pp 36-43.

Storey, D.J. and Tether, B.S. (1998a) 'New technology-based firms ın the European unıon: an introductıon', *Research Polıcy,* **26** , (9), pp.933-946.

Storey, D.J. and Tether, B S. (1998b) 'Publıc polıcy measures to support new technology-based firms ın the European Unıon', *Research Polıcy,* **26**, (9), pp 1037-1057.

Stout, D (2000) 'The Uses of Scenarios' [On-lıne] Available: http //www dtı gov uk/future-unıt/scenarıos/ındex html

Strauss, A.L. and Corbin, J. (1998) *Basics of qualıtatıve research: techniques and procedures for developıng grounded theory* , Thousand Oaks, Calıfornıa· Sage.

Sugasawa, Y. and Lıyanage, S (1999) 'Technology and busıness opportunitıes for small and medıum enterprıses ın Japan· the role of research networks', *Internatıonal Journal of Technology Management,* **18**, (3-4), pp.308-325.

Swınk, M , Sandvig, J.C. and Mabert, V A (1996) 'Customızıng concurrent engineerıng processes Fıve case studıes', *Journal of Product Innovation Management,* **13**, (3), pp 229-244

Tan, K C., Handfield, R.B. and Krause, D R. (1998) 'Enhancıng the firm's performance through quality and supply base management: an empırıcal study', *Internatıonal Journal of Productıon Research,* **36**, (10), pp 2813-2837.

Technology Futures, I. (2000) 'Forecastıng Technıques' [On-lıne] Avaılable: http //www tfi com/rescon/TF_Technıques html

Tether, B.S. (1998) 'Small and large firms: sources of unequal innovations?', *Research Polıcy,* **27**, (7), pp 725-745

Tether, B.S , Smıth, I J and Thwaıtes, A.T. (1997) 'Smaller enterprıses and ınnovatıon ın the UK. the SPRU Innovatıons Database revısıted', *Research Policy,* **26**, pp.19-32.

Tether, B S. and Storey, D J. (1998) 'Smaller firms and Europe's high technology sectors· a framework for analysıs and some statıstıcal evıdence', *Research Policy,* **26**, (9), pp 947-971.

Turok, I. and Raco, M. (2000) 'Developing Expertise ın Small and Medıum-Sized Enterprıses. an Evaluatıon of Consultancy Support', *Envıronment and Plannıng C-Government and Polıcy,* **18**, (4), pp 409-427.

Twıss, B.C. (1992) *Forecastıng for Technologısts and Engıneers: A practical guide for better decısıons,* London Peter Peregrınus Ltd.

US Patent and Trademark Office (2001) 'USPTO Web Patent Databases' [On-lıne] Avaılable http://www.uspto gov/patft/

Ussman, A , Almeıda, A , Ferreıra, J , Mendes, L. and Franco, M. (2001) 'SMEs and ınnovatıon· Perceıved barrıers and behavıoural patterns', *Internatıonal Journal of Entrepreneurshıp and Innovatıon,* **2**, (2), pp.111-118

Van Wyk, R J (1997) 'Strategıc technology scannıng', *Technologıcal Forecasting and Socıal Change,* **55**, (1), pp 21-38.

Vandıȷk, B., Denhertog, R., Menkveld, B. and Thurık, R (1997) 'Some New Evidence on the Determınants of Large-and Small-Fırm Innovation', *Small Business Economıcs,* **9**, (4 (Aug)), pp.335-343.

Vıthlanı, H. (1995) 'An empırıcal study of the UK ınnovatıon system', DTI.

Vos, J.P , Keızer, J A. and Halman, J.I.M. (1998) 'Dıagnosing Constraınts ın Knowledge of SMEs', *Technologıcal Forecastıng and Socıal Change,* **58**, (3), pp.227-239.

Wasti, S N and Liker, J.K. (1999) 'Collaborating with suppliers in product development. A US and Japan comparative study', *IEEE Transactions on Engineering Management,* **46**, (4), pp 444-461.

Watts, C.A. and Hahn, C K. (1993) 'Supplier development programs: An empirical analysis', *International Journal of Purchasing and Materials Management,* **29**, (2), pp 11-17.

Watts, R J. and Porter, A L. (1997) 'Innovation forecasting', *Technological Forecasting and Social Change,* **56**, (1), pp 25-47

Weiss, A M. (1994) 'The effects of expectations on technology adoption - some empirical-evidence', *Journal of Industrial Economics,* **42**, (4), pp.341-20.

Willyard, C H and McClees, C.W. (1987) 'Motorola's Technology Roadmap Process', *Research Management,* **30**, (5), pp 13-19

Wilson, I. (2000) 'From scenario thinking to strategic action', *Technological Forecasting and Social Change,* **65**, (1), pp 23-29.

Yin, R.K. (1994) *Case study research· design and methods*, 2nd, London· Sage.

Appendix I.

Evidence for Downsizing

Research by Tether and Storey (Tether and Storey, 1998) suggests that during the 1980s large companies in high technology manufacturing were downsizing while more small firms emerged to supply the products and services that were formerly provided in-house The research identified a phenomenon where employment in a particular industry sector decreased but the number of business units increased, contrary to the normal lifecycle pattern for an industry. This phenomenon can be explained by a reduction in the number of large enterprises where employment is usually concentrated, alongside an increase in the number of micro and small enterprises.

Table AI.1 Change in number of enterprises in UK between 1985 and 1994

UK SIC (1980)/ NACE-70 Industry Division		Employment Size Group								
		1-9	10-19	20-49	50-99	100-199	200-499	500-999	1000+	Total
32	Mechanical Engineering	++	+	++	+	+	-		-	++
33	Office Machinery and Data Processing Equipment	+++	+++	++++	+++	++++	++++	++++	+++	+++
34	Electrical and Electronic Engineering	+++	+	+++	+++	+	+	--		++
35	Motor Vehicles and Parts	++	+	+	+	++	++	++	--	+
36	Other transport equipment (incl Aerospace)	++	--	+	+	+	++	++		++
37	Instrument Engineering	++	-	++	+++		-	+	+	++
21-49	All production	++		++	+				+	+

+ increase of 5% or more - decrease of 5% or more

++ increase of 20% or more -- decrease of 20% or more

+++ increase of 40% or more --- decrease of 40% or more

++++ increase of 100% or more ----decrease of 100% or more

The author has performed further analysis on UK manufacturing industry data (Office for National Statistics, 1985-1999), to try to establish whether this trend continued beyond the 1980s. Due to a change in the Standard Industrial Classification in the UK, the periods 1985 to 1994 and 1995 to 2002 are considered separately. Table AI 1 shows the change in the number of legal enterprises in some of the engineering-based sectors over the earlier period. It can be seen that between 1985 and 1994, there was an increase in the number of enterprises in all of the manufacturing divisions shown here It is also the case that apart from in SIC (1980) Divisions 33 and 37, the number of large companies (over 1000 employees) tended to fall or remain unchanged, but the number of micro-sized companies increased quite significantly. Companies with 20 to 100 employees also increased in numbers

Table AI.2 Change in number of enterprises in UK between 1995 and 2002

UK SIC (1992)/ NACE Rev 1 Industry Division		Employment Size Group								
		1-9	10-19	20-49	50-99	100-199	200-499	500-999	1000+	Total
28	Fabricated metal products			-	-	-	-	--	---	
29	Machinery	-		-	-	-	-	-	--	-
30	Office Machinery and Computers	--	--	---	--	-	-			--
31	Electrical Machinery	-	-	+	+		++		--	-
32	Radio, TV and communications equipment	-	-		-	+		++	++	-
33	Medical, precision, optical and timing instruments	-		-		-	--	++		-
34	Motor vehicles and trailers	+		+	+	+		++	+++	+
35	Other transport equipment (incl Aerospace)	--	-	-	-	+		++		--
36,37	Unclassified manufacturing		++	-		-	+	-	+++	
15-37	All manufacturing	-	-	-	-	-	-		-	-

+ increase of 5% or more - decrease of 5% or more

++ increase of 20% or more -- decrease of 20% or more

+++ increase of 40% or more --- decrease of 40% or more

Table AI 2 indicates that the increase in the number of enterprises was not sustained through the second period, from 1995 to 2002 Overall, the number of enterprises fell, and this was true in all industry divisions apart from in SIC (1992) Divisions 34 where numbers rose and Divisions 28 and 36/37 where the numbers remained at the same level. The overall reduction was by a similar proportion across each of the employment size groups, apart from the band with between 500 and 999 employees where numbers of firms were relatively unchanged

The reclassification makes it difficult to compare the two periods with a high degree of confidence. Nevertheless, comparing the number of manufacturing enterprises between 1985 till 1994 (using SIC (1980) Divisions 21-49), and between 1995 to 2002 (using SIC (1992) Divisions 15-37) suggests that there has overall been an increase in the numbers of small firms and a decrease in the numbers of large firms (see Table AI 3). This is not the result of a steady trend, as can be seen in Figs. AI.1 and AI.2 which show how the numbers of enterprises have varied for companies with between 1 and 49 employees, and those with over 1000 employees

Table AI.3 Change in number of enterprises in UK between 1985 and 2002

Employment Size Group	% increase (or decrease) in numbers of firms from 1985 to 2002
1-9	10
10-19	8
20-49	5
50-99	-5
100-199	-19
200-499	-24
500-999	-26
1000+	-28
All firms	7

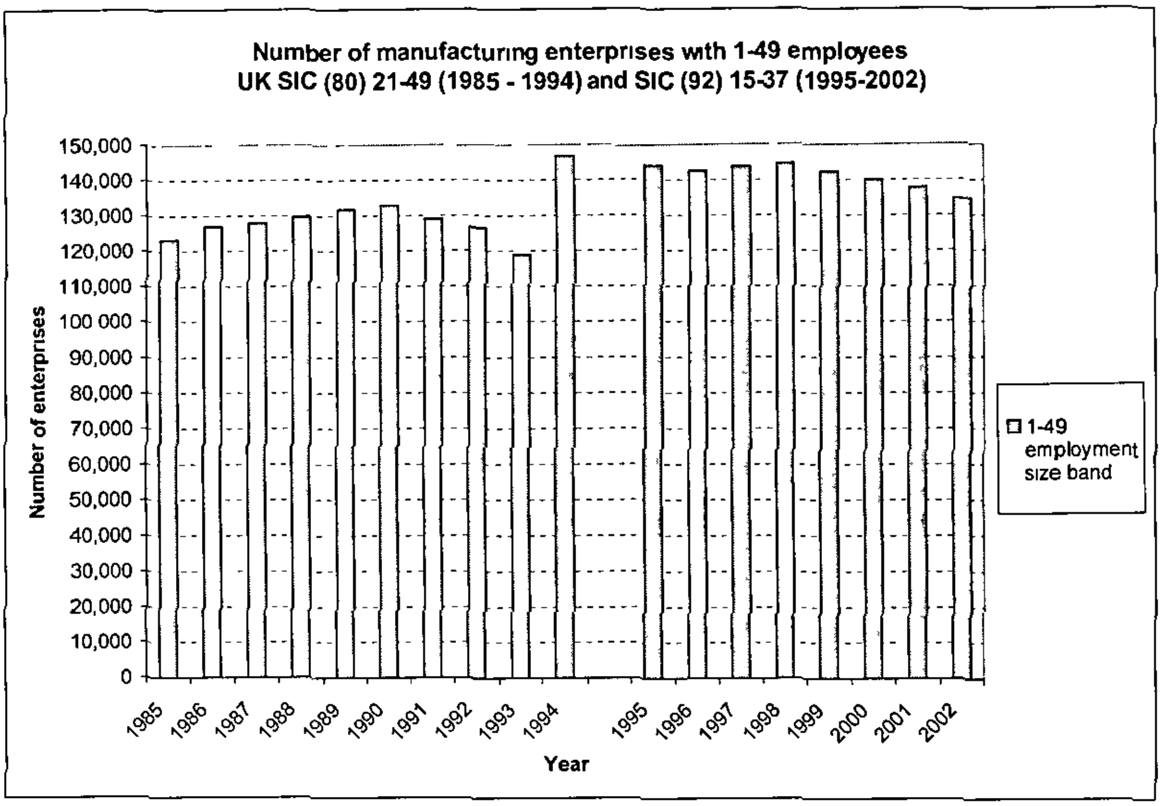


Figure AI.1 Variation in number of enterprises with 1-49 employees

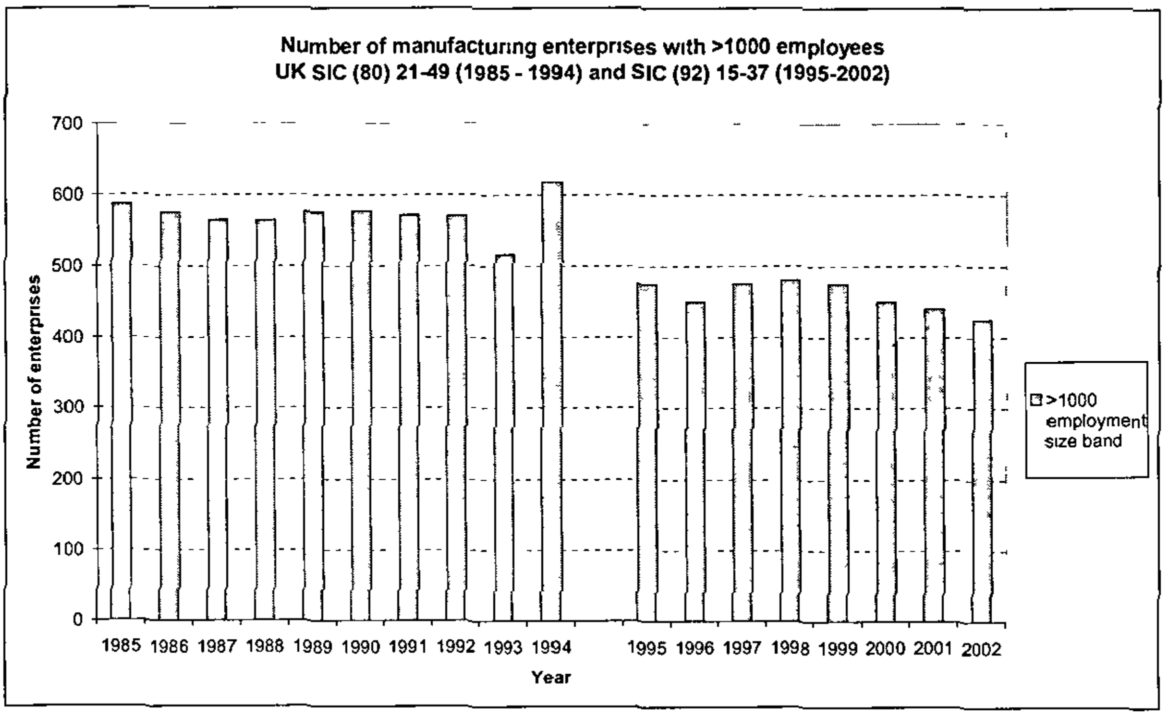


Figure AI.2 Variation in number of enterprises with >1000 employees

One classification which remained similar through both time periods was "manufacture of aircraft and spacecraft" [SIC (1980) 364 0 and SIC (1992) 35.30]. Fig. AI.3 shows that over both time periods, there was an overall increase in the numbers of smaller firms but a decrease in the number of large firms with over 1000 employees.

The industry dynamics in the aerospace sector cannot be generalised, and the number of enterprises in each sector will be influenced by the maturity of the industry cycle (in terms of growth or decline) and overall economic conditions such as interest rates and currency strength The classification system is also not particularly helpful in separating out the sectors where technological innovation is critical There may be an opportunity for research into the supply networks in different high technology manufacturing sectors, to map the size and numbers of firms at each level of the supply chain, and therefore to deepen the understanding of the interactions and contributions of each type of firm in innovation.

Certain conclusions can however be drawn from the analysis presented here and from the research of Tether and Storey (Tether and Storey, 1998). It is clear that during the 1980s and early 1990s, small companies began to play a more important role in high technology manufacturing This coincided with increased outsourcing by large companies and downsizing activity. During recent years, there appears to have been a slight reversal in the trends of company size, but this perhaps should not be interpreted as a reversal in the significance of smaller companies, but rather as a reflection of concerted efforts by large companies to rationalise their supply base, and of the overall economic conditions The importance of technological innovation for smaller companies has therefore increased throughout the 1980s and 1990s· firstly in undertaking more manufacture and design as it was outsourced by larger companies, and secondly in distinguishing themselves from their competitors in order to survive the rationalisation process

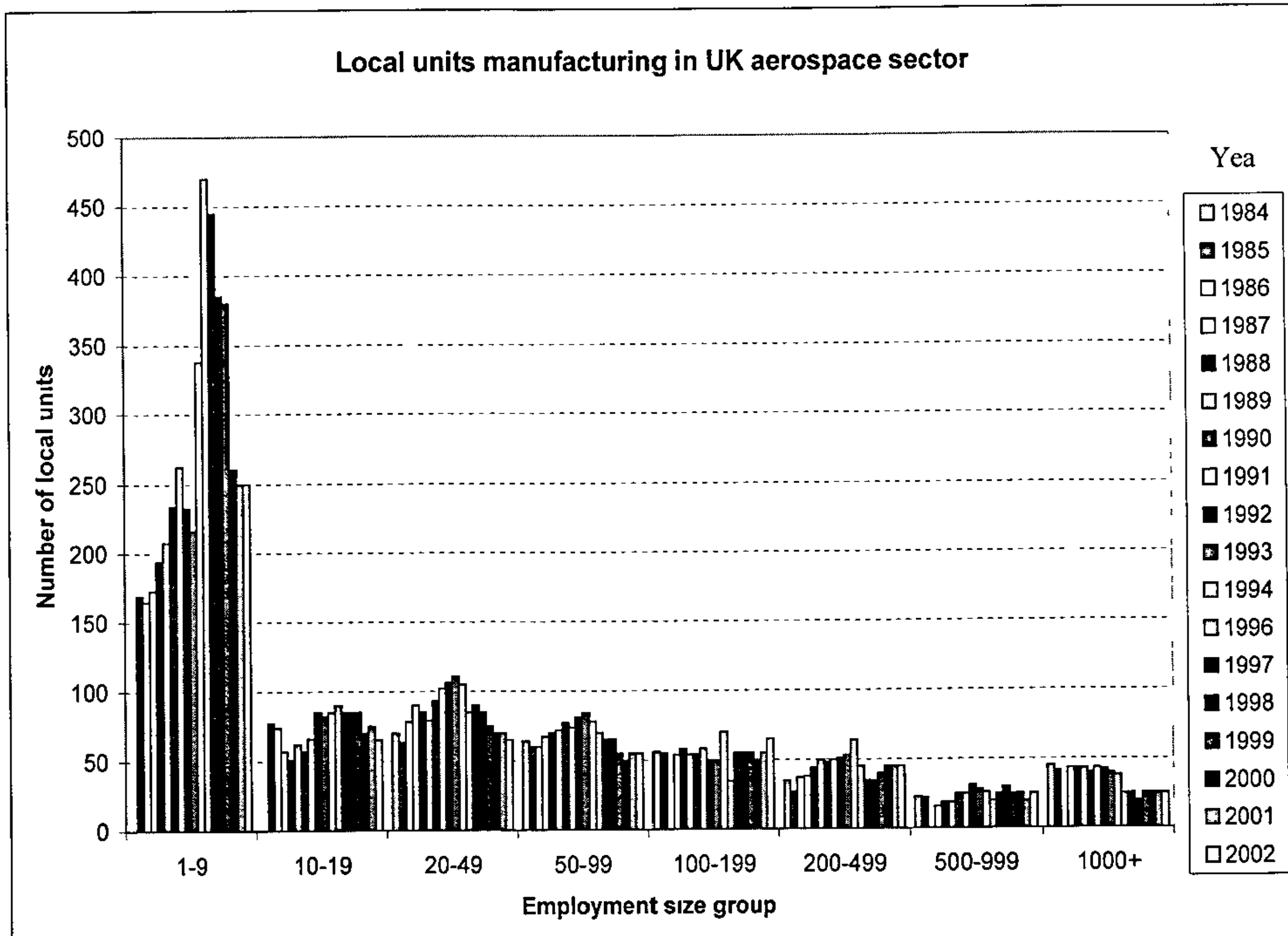


Figure AI.3 Number of local manufacturing units in UK aerospace sector, 1985 to 2002

Appendix II.

UK Aerospace and Defence Industry

This appendix outlines the structure of the UK aerospace and defence industry, in order to set the context for the case studies described in Chapters 5 and 6. The case studies concerned the supplier development programmes of two systems integration companies, "Aero-Electronic Systems" (AES) and "Aero-JV (UK)" (AJV). At the outset of the active research phase in December 1999, these two companies were completely independent. Not long afterwards, however, AES was involved in a merger with one of the parent companies which formed the joint venture AJV This is fairly typical for this complex and rapidly evolving industry, which has seen numerous consolidations in the last decade. It is therefore only possible to provide an indication of the industry and supply chain structure as it was at the time of the research. This analysis is based largely on data from the Society of British Aerospace Companies (SBAC) and on discussions with Sarah Greaves and Melvyn Greaves, both of Rolls Royce plc.

The aerospace and defence industry is commonly divided into three major industry sectors and three major product segments (Brock, 2003).
The industry sectors are:

1. **Systems and airframes** – complete systems of and/or airframes for aeroplanes, helicopters and gliders, missiles, space vehicles, satellites, launchers and ground installations etc , their subsystems and parts, spares and maintenance; service providers, consultants etc. for the above.
2. **Engines** – piston engines, turboprops, turbojets, jet engines, their subsystems and parts, spares and maintenance, for installation in aircraft systems; engines, their subsystems and parts, spares and maintenance, for installation in missile systems, propulsion devices, their subsystems and parts, spares and maintenance, for installation in space vehicles, satellites and launchers.
3. **Equipment** – finished products, subsystems and parts, spares and maintenance, also for test and ground-training equipment, for installation in aircraft systems, missile systems, space vehicles, satellites and launchers

The distinction between systems & airframes and equipment can seem rather blurred, but generally the first category focuses on the major structural elements of the aircraft, missile or spacecraft The majority of SMEs within the aerospace industry are equipment companies supplying to systems & airframes and engines manufacturers {SBAC 2000 #1850}. Equipment can be sub-divided into the following categories. airframe equipment, avionics, components & machining, computer systems & software, design & development, distributors, electrics & electronics, environmental control& life support, flight controls, fuel systems, furnishings & interior equipment, ground equipment & communications, landing gear, maintenance, repair & overhaul, powerplants, testing & certification and other services including general aviation services, consultancy services and training (SBAC, 2003)

The product segments are

1. **Aircraft** – aircraft systems and airframes, engines and equipment
2. **Missiles** – missile systems and airframes, engines and equipment
3. **Space** – space systems and airframes, engines and equipment

The position of the case study companies within the industry can therefore be located as shown in Table AII.1. As AES provides electronic systems, it falls within the equipment industry sector, as do its suppliers (referred to as AES-S1, AES-S2, and AES-S3). The chief product sector for AES is aircraft (although it is also involved in other defence systems such as naval defence which do not strictly fall within the aerospace industry)

AJV provides complete missile systems and therefore falls within the missiles product segment and the systems and airframes industry sector. Supplier AJV-S3 is directly involved in design, providing consultancy services and therefore may be considered to fall within the systems and airframes sector. The other two suppliers, AJV-S1 and AJV-S2, provide electronic components which fall within the equipment sector.

Since AES-S3 and AJV-S1 are actually the same company, it demonstrates the complexity of categorising the suppliers, since they can be part of a number of different supply chains. All of the suppliers involved in this research also had customers outside the aerospace and defence sector

Table AII.1 Location of case study companies within UK aerospace industry structure (table adapted from (SBAC, 2000))

		Industry Sector		
		Systems and Airframes	Engines	Equipment
Product Segment	Aircraft (civil, military and helicopters)			AES AES-S1 AES-S2 AES-S3
	Missiles	AJV AJV-S3		AJV- S1 AJV- S2
	Space			

Appendix III

Research Instruments

AIII.1

Interview Instrument for Scoping Study

1. Interview Information

Company Name

Date and Place of Interview Date Place

Name of Person Interviewed

- Position within Company

Interviewer

2. Company Contact Information

Postal Address

Telephone Number

Fax Number

E-mail Address

3. Background Information

Web Site

Number of Employees

Turnover

When was company established?

How was company established?

Is the company independent,
or part of a group?
Parent company name?

What kinds of people are
employed (in terms of
educational profile)?

Is any internal R&D
performed?
(Product or process)

- If so, what type and scale of
activity does this include?

4. Range of Products and Services

Description of product range

Describe typical product lifecycle

- Forward planning?

Any examples of new products, processes or technologies which the company have introduced?

What influences the decision to invest in a particular product, process or technology?

What strategies are used to implement the new product, process or technology?

What are the biggest technological challenges facing the company at the moment?

5. Relationships with Customers and Suppliers

Describe relationships/ interactions with customers

Describe relationships/ interactions with suppliers

Are customers predominantly large companies or small companies?

Where are they based geographically?

Does company do any design work for its customers?
Has it made changes to a product for a customer?

Has the company ever been encouraged to invest in new technology by customers?

Has the company had to change any business processes to be able to work with particular customers?

Are suppliers predominantly large companies or small companies?

Where are they based geographically?

Do any suppliers have to put in design effort to meet the company's requirements?

- If yes, does this mean they design to a set specification, or is a design team set up with engineers from both companies?

- If no, are they supplying standard parts, or does the company provide them with a design they can manufacture?

6. Sources of Information

What external sources of information are useful to the company in providing ideas for new products or processes?

What internal resources are important to the company for generating new product and process ideas?

What is the relative importance of internal and external resources in the innovation process?

6.1 External Organisations

	USEFULNESS			
	Generally	Innovation Ideas	Technology Lookahead	Making Contacts
Does the company belong to a Trade Association?	Y/N	Why?		
(Which?)				
Is the company involved with a Professional Institution?	Y/N	Why?		
(Which?)				
Is the company a member of a Chamber of Commerce?	Y/N	Why?		
Has the company had contacts with a Training and Enterprise Council?	Y/N	Why?		
Has the company had contacts with Business Links?	Y/N	Why?		
Has the company had contacts with an Innovation Relay Centre?	Y/N	Why?		

	USEFULNESS			
	Generally	Innovation Ideas	Technology Lookahead	Making Contacts
Has the company had contacts with a Business Innovation Centre?	Y/N	Why?		
Has the company had contacts with another enterprise or intermediary organisation? (Which?)	Y/N	Why?		
Does the company get advice from a bank e.g. through a small business advisor? (Which?)	Y/N	Why?		
Has the company used consultants to guide the direction of the business?	Y/N	Why?		

	USEFULNESS			
	Generally	Innovation Ideas	Technology Lookahead	Making Contacts
Is the company a member of a Research and Technology Organisation?	Y/N	Why?		
(Which?)				
What contacts has the company had with Universities and Colleges?		Why?		
		Which universities and colleges?		
- Research projects?	Y/N			
- Student placements?	Y/N			
- Teaching Company Scheme?	Y/N			
- Academic Consultants?	Y/N			
- Other?	Y/N			
Has the company ever been involved in a UK or European funded collaborative project?	Y/N	Why?		
(What?)				

	USEFULNESS			
	Generally	Innovation Ideas	Technology Lookahead	Making Contacts
Has the company ever been involved in any other form of collaboration or partnership?	Y/N	Why?		

Has the company received any particular awards or accreditations? Y/N

(Which?)

6.2 Other External Sources

Does the company use a patent searching service?

Has the company registered its own patents?

Has the company bought licences to use technology from other organisations?

Does the company license technology to other organisations?

Has the company ever made innovations in response to new legislation or product standards?

Do employees attend exhibitions or conferences?
- To pick up information?
- To present conference papers or seminars?
- To exhibit products and services on a display stand?

What is useful in terms of reading

- Web?
- Trade Magazines?
- Books?
- Journals?
- Mailshots?

7. Additional Information

AIII.2

Interview Instrument for Supplier Development Study - Systems Integrators

Interviewee Background

Description of career background; perception of current role

Perception of SD scheme

Open question about how the interviewee sees the scheme; what is its main function; what are the important elements in it; which suppliers are included (and what happens to the other suppliers), who does it benefit; who are the "champions" of the scheme; open question about whether the scheme is helping.

Background of SD scheme

Who initiated and initially drove scheme, has the focus of the scheme changed; are there any areas that cause conflict between different organizational functions when dealing with suppliers?

Technology elements of scheme

Ask for descriptions of particular elements/modules in the scheme relating to technology and transfer of technology best practice; how do these work in practice, does the interviewee see it as the supplier's responsibility to keep up-to-date or is it a joint responsibility – i e how far would they go in advising suppliers about which technologies to invest in; are engineers and technologists involved in supplier reviews; does the interviewee anticipate that suppliers will be able to keep up with technology requirements and is this seen as important?

Communication

Explore how many "lines of communication" are recognized between suppliers and different functional departments; whether communication is both formal and informal (i.e. does it take place outside of the processes of SD and will suppliers contact company technologists for information); do they have a formal technology planning process such as roadmapping (if so is this communicated to suppliers?)

AIII.3

Interview Instrument for Supplier Development Study – Suppliers

Company Background

No. of employees, turnover; product range; industry sectors served.

Interviewee Background

Description of career background; perception of current role.

Customer Expectations of Company

What is expected of them in terms of design, innovation, and new technology, are these expectations changing, what are project timescales and at what stage does the customer involve them?

Experience of SD scheme

Open question about how the interviewee sees the scheme (positive or negative), are they involved in any other company SD schemes; if so, are there any conflicts in meeting different customer requirements? What is their experience of (named) technology related SD modules (where interviews with customer indicates existence of such modules) and best practice transfer?

Expectations of own suppliers

What types of suppliers do they have (size and uniqueness); what do they expect of their suppliers in terms of design, innovation, new technology; are these expectations changing; what are project timescales and at what stage do they involve them; do they ever find suppliers unable to meet their technological needs?

Mechanisms for technology "lookahead"

What mechanisms do they use for technology forecasting/watching (or other informal means of capturing information about future technology requirements), do they make use of technology "gurus" in customer firms or elsewhere; do they have a long-term technology plan or roadmap (if so do they disseminate it to their customers or suppliers), do their customers disseminate technology roadmaps/"lookahead" information to them?

Communication

Do they have dealings with customer engineers/technologists (as part of SD or outside of it)?

AIII.4

Survey Instrument for Information Acquisition Study

- Midland Manufacturing SMEs

PERA
THE INNOVATION COMPANY

Loughborough University

Information for Innovation Study

Innovation is essential for firms that want to succeed in today's business environment. The need to improve products and services is widely recognised, but new ways of organising the business, new technology and new manufacturing processes may also bring advantage over competitors.

The aim of this study is to find out what information is needed by smaller-sized companies to help them in all types of innovation. It will also investigate what are the biggest barriers that companies face in finding this information. The research is funded by the Engineering and Physical Sciences Research Council, and is being undertaken by Loughborough University with the support of Pera.

I would be very grateful if you would take the time to complete this questionnaire and return it in the pre-paid envelope (alternatively fax back to 01664 501555)

SECTION 1 – Information Needs and Barriers

1. How important is innovation to your company?

☐ Very important ☐ Fairly Important ☐ Not important

2. Does your company regard information/knowledge as strategically important?

☐ Yes, very important ☐ Fairly Important ☐ No, not important

3. What are currently your greatest information needs?

4. What are the biggest barriers to finding or accessing the information you require?

5. **In which of the following business areas are you likely to seek external information?**

(Please indicate whether this is likely to be at senior management and/or operational level)

	Senior Management	Operational Level
Strategy and planning	☐	☐
Manufacturing	☐	☐
Materials management	☐	☐
Customer service	☐	☐
Product and process technologies	☐	☐
Information and communication technologies	☐	☐
Legislation	☐	☐
Standards	☐	☐
Customer markets	☐	☐
Supply chain management	☐	☐
Human resources and training	☐	☐
Other (please specify) ____________________	☐	☐

6. **What methods does your organisation use to acquire external information?**

- ☐ Internet
- ☐ Trade Journal Subscriptions
- ☐ Universities/Colleges
- ☐ Small Business Service
- ☐ Government (e g DTI, Regional Development Agency)
- ☐ Database Subscriptions
- ☐ Consultants
- ☐ Research Associations
- ☐ Informal Networks (word of mouth)
- ☐ Other (please specify)______________

SECTION 2 – Background Information

7. **How would you describe the nature of your business?**

8. **Number of employees:**

1-9	10-19	20-49	50-99	100-199	200-499	500-999	1000+
☐	☐	☐	☐	☐	☐	☐	☐

9. **What is your role or job function within the organisation?**

If you would be willing to discuss the information barriers and information needs for innovation within your company, please provide your contact details below (or attach a business card to this questionnaire).

Name ____________________ Company. ______________________________

Address ____

Telephone. ____________________ Email ______________________________

THANK YOU

AIII.5

Survey Instrument for Information Acquisition Study

- RTO Members

N B

Only questions 4, 7, 13 and 18 have been analysed as part of the research presented here.

PERA
THE INNOVATION COMPANY

Pera Member Survey

Pera is committed to continuous improvement of the services we provide. To ensure that we deliver valuable support to your organisation, we need to have your input. Please take a few minutes to complete this questionnaire and return by Friday 30th November 2001.

SECTION 1 – Background

Name ____

Job title ____

Company ____

Email ____

SECTION 2 – Perceptions of Pera

1. What terms do you associate with the name "Pera"? Please tick all the terms you feel are relevant:

a) Production Engineering ☐
b) Materials Engineering ☐
c) Manufacturing Processes ☐
d) Technology Development ☐
e) Innovation ☐
f) Information ☐
g) Knowledge ☐
h) Manufacturing Consulting ☐
i) Management Consulting ☐
j) Training ☐
k) Research ☐

Others (please specify)

____

2. **Please advise which of the following Pera services that you are currently aware of, and any that you currently use. Please let us know if you would like information to be sent to you, on a particular service by ticking the 'tell me more' box.**

	Aware of	Use	Tell me more
a) Enquiry Service	☐	☐	☐
b) Pera Express	☐	☐	☐
c) Technical translation	☐	☐	☐
d) askpera com	☐	☐	☐
e) Seminars and Open Days	☐	☐	☐
f) Manufacturing Training	☐	☐	☐
g) Quality Training	☐	☐	☐
h) Leadership Development Training	☐	☐	☐
i) Six Sigma Training and Consulting	☐	☐	☐
j) Manufacturing Consulting	☐	☐	☐
k) Web Design Services	☐	☐	☐
l) Product Development	☐	☐	☐
m) Rapid Prototyping	☐	☐	☐
n) Environmental Consulting	☐	☐	☐
o) Food Process Engineering	☐	☐	☐
p) Meeting and Conference Facilities	☐	☐	☐

3. **For you, what are the most important reasons for being a Pera member? Please rate the following by assigning a score of 1 - 5.**

1. Not at all important
2. Slightly important
3. Important
4 Very important
5 Extremely important

	[Please circle one option]
Enquiry Service	1 2 3 4 5
Seminars and Briefings	1 2 3 4 5
askpera com	1 2 3 4 5
Abstracts Service	1 2 3 4 5
Discounted Rates for Training	1 2 3 4 5
Discounted Rates for Meeting and Conference Facilities	1 2 3 4 5
Access to Pera Technology	1 2 3 4 5
Access to Pera Consulting	1 2 3 4 5

3. Continued.......

Access to other Pera services (please specify) **(Please circle one option]**

______________________________ **1 2 3 4 5**

______________________________ **1 2 3 4 5**

SECTION 3 – Enquiry Service

4. What information sources do you regularly use? (please tick)

a) None ☐
b) Internal Information Resources ☐
c) Free sources on the Internet ☐
d) Chargeable Sources Available Through the Internet ☐
e) CDROMS ☐
f) Online Databases ☐
g) Journals ☐
h) Clippings / Abstracts Service ☐
i) Electronic News Service ☐
j) Pera's Enquiry Service ☐
k) Another External Enquiry Service ☐
l) Other (please specify) ☐

5. Have you used the enquiry service in the past 6 months? ☐ Yes ☐ No

If NO, please state any reasons why. (Please then go to question 9 next)

____

____

6. Are there occasions when you choose not to use us? ☐ Yes ☐ No

If YES, please give the reason.

____

____

7. To help us understand your requirements, please look at the following statements about why you use the enquiry service, and rate them as follows:

1. Never true
2 Occasionally true
3. Quite often true
4. Frequently true

I use the enquiry service.....	**[Please circle one option]**
a) When I do not know where else to get the information	**1 2 3 4**
b) Because it is quicker than finding the information myself	**1 2 3 4**
c) Because I do not have access to the databases that Pera has	**1 2 3 4**
d) When my preferred sources have drawn a blank	**1 2 3 4**
e) For technical information	**1 2 3 4**
f) For business information	**1 2 3 4**
g) When I need information concerning my own area of expertise	**1 2 3 4**
h) When I am working outside my own area of expertise	**1 2 3 4**
i) When I know Pera has an expert consultant in that field	**1 2 3 4**
j) In the early stages of solving a problem or starting a project	**1 2 3 4**
k) Throughout the life of a project	**1 2 3 4**
l) When I need information urgently	**1 2 3 4**
m) When I need to be sure my information is reliable	**1 2 3 4**
n) When I'm looking for analysis, not just bare facts	**1 2 3 4**

8. Please tick which attributes of the Enquiry Service are important to you, which you feel could be improved and where you feel we do not currently meet your needs.

	Important	**Could be improved**	**Do not meet your needs**
Reliability (consistency of reply and dependability)	☐	☐	☐
Responsiveness (willingness and timeliness)	☐	☐	☐
Competence (service has the required skills and knowledge)	☐	☐	☐
Ease of Access	☐	☐	☐
Courtesy of employees	☐	☐	☐
Communication (keeping you informed about your membership)	☐	☐	☐
Credibility (we have our members interests at heart)	☐	☐	☐
Security (confidentiality of the service)	☐	☐	☐
Good understanding of your needs	☐	☐	☐

9. **Currently enquiries are received by email, fax, or via our website. Would you like this extending so that enquiries are taken over the phone?** ☐ Yes ☐ No

10. **Which of the following areas of expertise covered by the Enquiry Service are you aware of? (please tick)**

a) Company Intelligence ☐
b) Intellectual Property Rights ☐
c) Supplier Sourcing ☐
d) Market Intelligence ☐
e) Business Environment Monitoring ☐
f) Promotion and Selling Methods ☐
g) Economic Information ☐
h) Management Theory ☐
i) Standards ☐
j) Health and Safety ☐
k) Environmental Issues ☐
l) IT Strategy ☐
m) Productivity Techniques ☐
n) Human Resource Management ☐
o) Quality Management ☐
p) Legislation ☐
q) Design Methods ☐
r) Design Engineering ☐
s) Materials Selection ☐
t) Metallurgy ☐
u) Electrical Engineering ☐
v) Manufacturing Technology ☐
w) Electronics ☐

SECTION 4 – Seminars, Open Days and Briefings

11. **Have you attended any of our open days or seminars in the last 6 months?** ☐ Yes ☐ No

If YES, how would you rate the event(s) on average:

☐ Excellent ☐ Good ☐ Average ☐ Poor

If NO, which of the following best describes your reasons?

☐ Wanted to attend, but the timing of the event prevented me

☐ Wanted to attend, but pressure of work prevented me

☐ None were of interest

☐ Was not aware of events

12. **What topics would you like to see addressed as part of our programme of seminars?**

____

SECTION 5 – askpera.com

13. **Have you used askpera.com?** ☐ Yes ☐ No

If NO, why not? (Please go to question 17 next)

____

____

If YES:

How relevant would you rate the content of askpera.com (on average):

☐ Very relevant ☐ Some useful content ☐ Not relevant

14. **Which features on askpera.com do you find useful? Please rate the following by assigning a score of 1 - 5.**

a. Have not used
b. Not at all useful
3 Slightly useful
4 Useful
5 Very useful

	[Please circle one option]
Abstracts	1 2 3 4 5
Downloadable Pera reports	1 2 3 4 5
Signposting of Pera expertise	1 2 3 4 5
Ability to submit on-line enquiries	1 2 3 4 5
Direct access to Dialog databases	1 2 3 4 5

15. **Have you set-up the administration function of askpera.com?** ☐ Yes ☐ No

If NO, Please state why not

____

____

If YES, please rate level of difficulty in doing this. Was it......

- Easy ☐
- Relatively Easy ☐
- Average ☐
- Difficult ☐
- Extremely Difficult ☐

16. How could askpera.com be improved to better meet your needs?

____

____

SECTION 6 – Abstracts

Abstracts is a service that we offer where short summaries of articles published in various journals are provided to you. You can request the full text of any that are of interest to you.

17. Would you find it helpful to receive bulletins of the latest Abstracts available? ☐ Yes ☐ No

If No – go to question 21

18. Which format would you prefer these bulletins in?

☐ Paper format ☐ E-mail ☐ Available on our website

19. How often would you like to receive the bulletins?

☐ Fortnightly ☐ Monthly ☐ Quarterly

20. What areas of coverage would you like to see the Abstracts covering: (please tick)

a) Technology related - broad coverage of topical subjects ☐

b) Business and Management related - broad coverage of topical subjects ☐

c) Technology related – in depth articles covering very specialist areas of technology ☐

d) Business and Management related – in depth articles covering very specialist areas ☐

SECTION 7 – Payment Mechanisms

21. Have you heard about Pera research units ☐ Yes ☐ No

If NO, please go to Question 25

22. Do you know what a Pera research unit is worth? ☐ Yes ☐ No

If YES, please indicate the value below.

____

23. Do you feel you understand how the unit system works? ☐ Yes ☐ No

24. Do you like the current units system? ☐ Yes ☐ No

If YES: Please state why?

____

25. Would you prefer?

(please tick your preferred option)

a) An 'open access' scheme, where an annual fee provides unlimited access to the enquiry service (no administrative barriers to accessing information) ☐

b) A unit system where a purchasing decision is made on each individual enquiry (improved control of costs) ☐

Other (please specify)

____

26. **How would you prefer to pay your membership fee?** **(please tick your preferred option)**

a) An annual subscription – payable in advance ☐

b) An annual agreed fee, paid monthly by direct debit. ☐

c) A floating fee, dependent on usage and invoiced monthly ☐

d) A combination of fixed fee offering restricted access to the Enquiry Service and a floating fee, dependent upon usage and invoiced monthly ☐

27. **As an alternative to membership, might you be interested in a <u>monthly</u> package of Pera services including free training and/or consultancy from across Pera divisions; full-text articles; seminars and briefings; and unlimited access to the enquiry service?** ☐ Yes ☐ No

SECTION 8 – Contacts

28. **To enable us to keep people in your organisation informed of membership services that may be of interest to them. Please provide the contact names, job titles and email addresses of the senior person responsible for the following job functions.**

Marketing: ______________________________

Purchasing: ______________________________

New Product Development: ______________________________

Competitor Analysis: ______________________________

THANKS FOR YOUR HELP!
Please return by fax to 01664 501555
Or post to:
Fiona Reed
Pera Knowledge
Pera Innovation Park
Melton Mowbray
Leics, LE13 OPB

AIII.6

Interview Instrument for Information Acquisition Study - Midland Manufacturing SMEs

Background

Company background how long established, no. employees, turnover. Interviewee's perception of role

Attitude to new technology

Perception of new technology as providing an opportunity to steal a march on the competition or to get access to new markets – or something which you have to cope with and struggle to keep up with?

If it's an opportunity.

> (Are you using an advanced technology process to serve a relatively low tech market, or is it the product which is high tech?)
>
> How do you go about finding out about new technology? (e g. those which are just emerging, or technologies which are well established in other industries but could perhaps be applied in your sector)?
>
> What processes do you use to get the information you need?
>
> How does that information feed into the business planning process?

If new technology is a threat, how do you use information to mitigate against it?

Information Needs

Do you think you have an understanding of your customer's customers?

How proactive are you in terms of finding out what your customers want – thinking of it in terms of three different levels.

> Do you "sense" what the market needs are?
>
> Do you actively ask your customers what they want?
>
> Or do you research the customer markets to try to anticipate their needs perhaps before they have even recognised it themselves?

What processes do you use to get the information you need?

How does that information feed into the product development process?

Information Use

How do you use the information they get? Who acquires the information and who acts on it?

Does anybody have a specific responsibility for getting hold of this type of information for e g. strategy meetings?

Information Barriers and Fantasy Information Service

What gets in the way of acquiring the information you need?

If those barriers were not there, and if you had enough resources, what would you like to do?

AIII.7

Interview Instrument for Information Acquisition Study - RTO Members

<u>Background</u>

Background of company, level of decision-making, interviewee's perception of role

<u>General information needs and barriers</u>

What are your greatest information needs at the moment?

What are the biggest barriers to finding or accessing the information you need?

Are those "greatest information needs" typical of the sort of information you tend to need?

<u>Enquiries</u>

Are you looking for particular nuggets of information, for advice or for specific expertise? Access to database sources?

Technical or business orientated?

Is there any pattern in when you tend to look for information?

Would you say you are usually trying to solve a problem that has come up, or do you sometimes look for information that would help in the long-term e.g. info about a new technology which would let you make a new kind of product, or a different way of manufacturing?

Some firms have a formal process for gathering information about new technologies, competitors, market changes – are you aware of anything like that in your company?

Do you think you approach information requirements differently according to whether you are in your "comfort zone" or not?

What sources are you are comfortable with in your own area?

<u>Examples</u>

Do you need to /How do you go about finding suppliers?

Do you need to/ How do you find out about British Standards?

Do you need to/ How do you find out about patents?

Do you need to /How do you find out about latest manufacturing technologies?

Do you need to / How do you go about researching new market sectors?

Do you need to / How do you go about researching using a new technology in a product?

Which information sources are they aware of, which they use and how those sources are valued.

Types of Information

Would you use different sources for different sorts of information – e.g. Pera if it was urgent, or browsing internet or journals for longer-term information?

Do you actively try to keep up-to-date – if so, how?

Do you have a good trade association?

Do you attend technical seminars and conferences or trade fairs?

Value of Information

How do you value information?

How important is quality of information?

How up-to-date does it need to be?

How specific is it to your company or your industry?

Do you value certain types of information above others – what sort of information would you pay for, and what wouldn't you value in that way?

Changes in Requirements

Have you or has the company changed the way you seek and use information, and do you feel there is a greater need for information?

Appendix IV.

Tools and Techniques for Technology Lookahead

This appendix presents a collation of the various tools and techniques described in the literature that may be useful for technology lookahead. The potential relevance of these tools and techniques to small manufacturing firms is discussed. A summary can be found in Chapter 8.

The technology lookahead techniques discussed in the following sections are perhaps most appropriate to manufacturing or manufacturing service companies, where technology plays a particularly important role in the business. Yet even a very low-technology company should benefit from making limited use of the principles of technology lookahead. Small companies with little resources will find that much of the information for technology lookahead is publicly available, and once the key technological influences and drivers have been identified it may not cost much in time or money to maintain enough awareness concerning the technological future to gain competitive advantage In the next two sections processes are described which can provide specific types of technology information, focussing on the potential which these techniques have for SMEs. Firstly, the ways to keep abreast of the state of the art in technology are discussed Secondly, the processes available for anticipating future developments in technology are described Finally some suggestions are made concerning technology planning, a process which should draw on both the current and future technology information

AIV.1. Monitoring and Scanning the Technological Environment

At its most basic level, keeping abreast of current technology simply involves general awareness, and having an outward-looking approach. For hard-pressed small firms, even this can be difficult, since the demands of the business may allow little time to consider events outside the company. It is however essential to be able to recognise and respond to external changes, not only in technology but in the market and in society - before those changes manifest themselves in the loss of orders.

For science and technology based firms, monitoring and scanning may be important enough to use a strategic technology scanning process similar to one suggested by Van

Wyk (Van Wyk, 1997) Strategic technology scanning is differentiated from technology scanning using a radar analogy it has a greater range, and is concerned with "looking ahead" rather than "keeping abreast". For this process, Van Wyk employs the analogy of the "technological landscape", and so the first step in the scanning process is to define the boundaries of the landscape to be scanned and set an agenda Scanners would then be recruited to read and review sources of information concerning technological advance, and from this landmark technologies would be identified. The company's technological base would then be reviewed against the impact of the landmark technologies, and the technologies which are strategically relevant would be identified. The result is that firm's strategic focus is improved – however, how to implement their strategy is not something which is addressed by Van Wyk.

Small companies might find it difficult to follow this process fully, because of the need to recruit specialist technology scanners - although it could be worthwhile for firms where the intellectual property portfolio is all important. Nevertheless, other systematic technology monitoring and scanning processes have been successfully tested in small firms under a European funded project (Quazzotti et al., 1999). This project summarised best practice for what is known as "technology watch" in ten steps (translated here from the French by this author).

1) Ensure commitment of senior management to technology watch
2) Analyse the standard of information practices in the firm
3) Analyse the mechanisms of diffusion of information in the firm
4) Define and formalise information needs
5) Raise personnel awareness of the value of information
6) Diversify sources of information
7) Exploit the formal sources of information systematically
8) Organise the collection of informal information in the company
9) Take care to protect your information
10) Consider calling on information professionals

In both of the formal scanning processes described above, importance is given to identifying the type of information needed in that particular firm, and to the communication of that information so that it is exploited properly in strategy formulation or elsewhere. There are many different potential sources of information, and decisions concerning what to monitor are very much company specific A few possibilities, drawn in part from a survey of British scientists and engineers (Angell et al., 1985) are listed in Table AIV.1.

Table AIV.1 Potential sources of technological information (adapted from (Angell et al., 1985))

Potential Sources of Technological Information
Customers
Suppliers
Meetings/ conferences/ exhibitions
Research associations
Consultants
Friends outside work
Technical journals
Trade magazines
Books
Popular science magazines
Standards/ specifications
Abstracts/ indexes
Official publications
Conference proceedings
Patents
Internet
E-mail/ web discussion groups
Newspapers
TV/ radio

Formal and informal personal networks are a rich source of information about current technology. Therefore activities which can build up these links should perhaps be recognised as worthwhile investments rather than time away from the job. This includes attendance at trade meetings and conferences, for example. Informal networks have been shown to play an important role in new product development (Smart et al., 2000), in strategy formation (Macdonald, 1996), innovation (Macdonald, 1998) and in R&D (Bouty, 2000). The communication of technological information is linked to all of these processes, and informal networks may therefore also be important in maintaining awareness of current technology.

The trade press and research journals also provide current technology information. As the number of publications increases each year, and there is almost unlimited information available through the Internet, the greatest challenge is to identify the most important and most relevant sources of information. In order to make the best use of time, it may be appropriate to formalise the information-gathering process - by identifying the most likely sources of relevant technology information, and then actively monitoring those sources It may also be appropriate to systematically scan a broader range of sources. Patent information can help to build a picture of the technological environment, although research has found that small companies do not rate patents highly as a source of technical information (in comparison with personal contacts, trade journals and talking to clients and suppliers) (Macdonald and Lefang, 1998; Hall et al , 1999; Hall et al., 2000).

There can be a role for consultants and intermediaries in monitoring technology information sources, particularly in areas such as patents and competitor activity. Belotti and Tunalv (Belotti and Tunalv, 1999) found that small companies in Sweden are more likely to use private consultants than other sources in the acquisition of technical knowledge, which implies that it may be appropriate for small firms to utilise consultants in technology lookahead. There is also evidence from the United States that it is beneficial for small firms to utilise consultants as part of the strategic planning process (Robinson, 1982), and this may also be true for technology strategy and planning. While paying consultants to take on monitoring and scanning activities can be more efficient for a company with few employees, it is vital that the consultants truly understand the firm's business. Otherwise, although they might find better information sources, their service may not be well targeted to the particular circumstances of the firm. All companies have a different mix of technologies, capabilities, products and customers. a technology which might have great potential for one firm will not be suitable for another. It would therefore not be possible to draw up a generic list of all the sources of information which should be monitored to keep abreast of current technology, since different sources will be more relevant for some technologies - and therefore for some firms - than for others.

Sometimes new technologies emerge in different industry sectors which have the potential to be successfully applied in a company's own sector. There may be significant competitive advantage for a company which identifies this possibility - or there may be a serious threat to a company whose only product line may be superseded as a result of new technology (Quinn, 1986). Sometimes a particular industry sector is well-known as a potential source of new technologies - for example the aerospace industry is very interested in learning from the mobile telecommunications industry because of their ability to manufacture quite complex products with minimum volume and weight On occasion a useful new technology may emerge from an unexpected sector, however, and having a broad but not necessarily detailed scanning process may be advantageous.

AIV.2. Technological Forecasting and Future View

For highly technology-based firms, it is extremely important to be prepared for external developments in technology, and also to develop their own technology to take full advantage of new market opportunities A clear vision of where things are likely to stand in the future is necessary for the company to plan how they can develop or acquire the technology, and also gain the skills and expertise required

The forecasting techniques described in the next two sections may be helpful to science and technology-based firms, but since they require a reasonable amount of resource, they are probably not well suited to other types of firm. Any small company should however be able to benefit from publicly available information sources described in section AIV 2 3 below Although public information is also available to competitors, the interpretation will not be the same for every small firm as there will be a unique course of action for each company according to their circumstances.

AIV.2.1. Technology Trends

By monitoring and scanning current technologies over an extended period, it should be possible to get a feel for the development of those technologies. It has however been observed that people tend to assume trends will follow a linear path against time, whereas technological performance generally follows an S-curve (or sigmoidal curve). The S-curve is shown in Fig. AIV.1 - it should be noted that it is only valid for a single technological parameter against time (or more correctly against effort and resource expended). In the early stages, the rate of technological progress is slow. As time goes on, the rate of progress rapidly increases (up to the point of inflection on the graph), and then begins to slacken. Eventually the technology will approach the hard physical limit for that parameter, and at this stage there are only very limited improvements A linear extrapolation can therefore be quite misleading, since at the early stages it would be easy to assume that progress would continue to be very slow, and the opposite (but equally false) conclusion could be reached if the rate of progress was extrapolated from the fast improvement phase

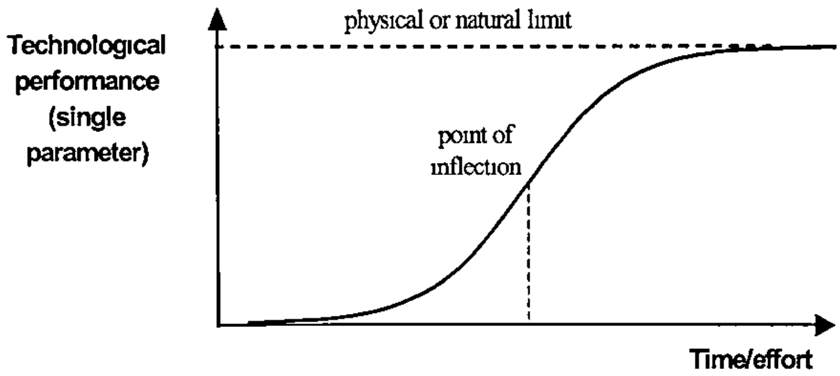


Figure AIV.1 The S-curve of technological progress (adapted from (Twiss, 1992)[p.80])

It is sometimes possible to stretch a technology through enhancements which raise the limit of technical performance (Fig AIV 2) This cannot be done indefinitely, and usually when the current technology approaches its physical limit, it is substituted by a new technology (Fig. AIV.3). The new technology may have existed for some time, but until the limitations of the current technology become an issue, there is little motivation to develop the new technology. Sometimes the existence of large legacy systems means that the old technology is stretched as far as possible, as in the case of copper technology for data communications. Optical fibre technology has greater capability in terms of data communication rates, but copper technology has continued to develop beyond expectations because of the huge investment required to replace copper with optical fibre (Palmer and Williams, 2000) In this example, the older technology is being substituted by the superior technology much slower than was expected, but sometimes technology substitution happens faster than expected. There can be a danger of failing to recognise the value of cheaper, lower-performance technologies (Bower and Christensen, 1995) – and even expensive technologies with the potential to out-perform existing technologies can be mistakenly disregarded because they appear inferior to current technologies in the early stages of the S-curve of performance.

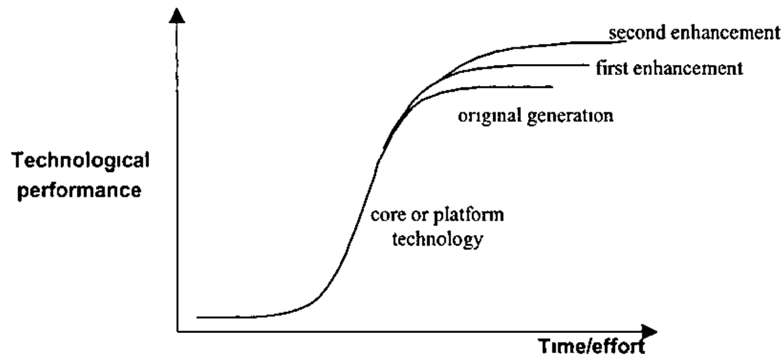


Figure AIV.2 The S-curve of technological progress with enhancements (Roy et al., 1996)

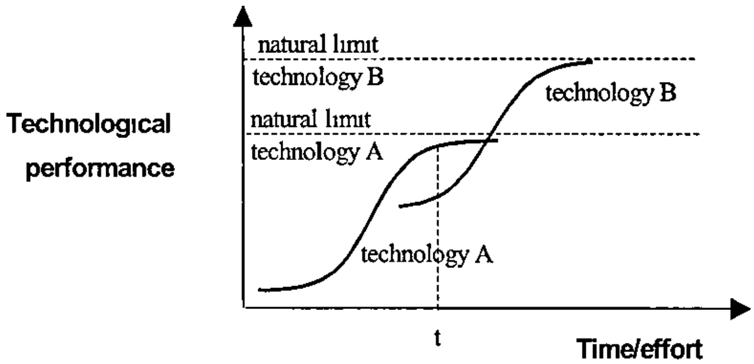


Figure AIV.3 Technology substitution (adapted from (Twiss, 1992) p 91)

There are a number of different forms of S-curve, including the logistic curve (equivalent to the Pearl curve), derived from biological population growth, and the Gompertz curve, which was originally used to describe the mortality rate of a population. The logistic or Pearl curve is symmetrical about the point of inflection, whereas the Gompertz curve is not. They can both be plotted as a straight line on a log-linear graph.

The formula for the logistic or Pearl curve (Twiss, 1992) is:

$$p = \frac{L}{1 + \alpha e^{-bt}}$$ ***Equation AIV.1***

where L = natural limit, t = time, α and b are constants

The S-curve can in theory be used as a forecasting tool in predicting the future performance of a technology The physical limit for the technological parameter must be known at the outset, however, unless the curve has already passed the point of inflection For a company which is reliant on the performance of a particular technology, it is worth gaining a good understanding of the likely trajectory of its S-curve. (At the same time, it is important not to become blinded to the possibility that the technological parameter which is valued by the customer at present may not be the parameter that will win them in the future.)

For other companies where their competitive advantage is not so closely linked to the performance of a single technology, it may not be worth trying to develop their own S-curves. This type of technology forecast may be available from e g industry associations instead, although Twiss found that these forecasts are not always consistent Plotting data from industry S-curves on a log/linear plot often exhibits an unexplained change in the slope of the graph between the recorded data-points and the predicted data-points, which suggests the forecast may not be reliable (Twiss, 1992)[p 90]. The technology trend-line should normally be a straight line, unless there is a sudden change in development activity.

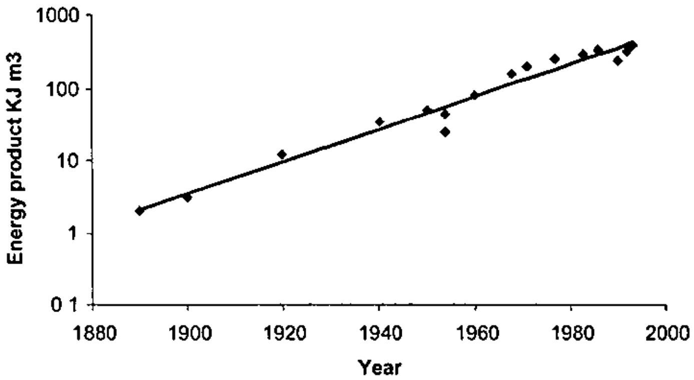


Figure AIV.4 Technology trend line for magnetic material development (Palmer and Williams, 2000)

Palmer et al. (Palmer et al , 1999) examine the usefulness of technology trends within the electronics industry, looking at Moore's law amongst others (which is usually cited as "the number of transistors in an integrated circuit will double every year to eighteen months") The argument that such trends are self-fulfilling promises is countered by the evidence that magnetic material capability has developed along a similar trend line over the span of more than a century (Fig. AIV.4).

Another type of technology trend which has some relevance in technology planning is the experience curve or learning curve (Willyard and McClees, 1987). This refers to the decreasing cost of production over time as more and more of a particular item are manufactured, which appears as a straight line on a log-log plot (Fig. AIV.5). This means that the experience curve can be used to set price targets for developing technologies (Technology Futures, 2000). Customers expect to see price reductions as a technology matures, so companies may need to take this into account when assessing how lucrative a technology may be for them - particularly since different technologies exhibit different experience curves (Ghemawat, 1985) (Twiss, 1992)[pp 176-178]. The experience curve has been used by Bell Laboratories (when part of Lucent) as an input to their roadmapping process (Albright, 2000).

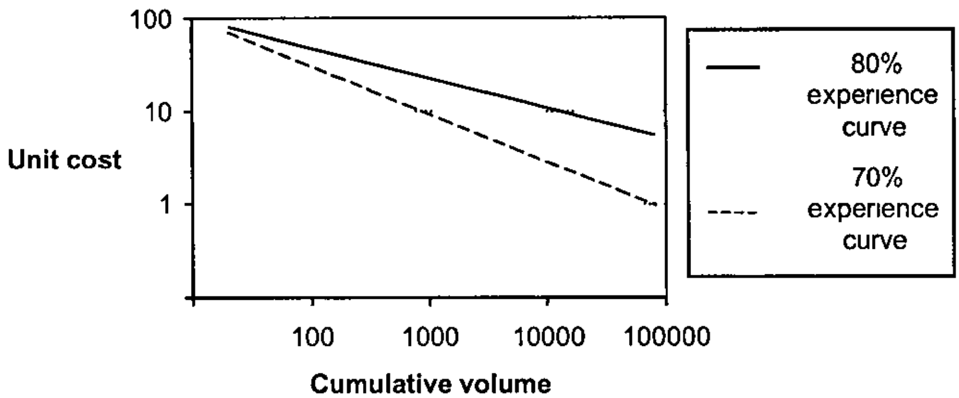


Figure AIV.5 Experience curve (adapted from (Twiss, 1992) [p 177]*)*

Technology trends do not appear to be widely recognised and applied beyond the electronics industry, and it is possible that there is something unusual in the nature of electronic technologies which allows trends to be useful for prediction there. Grupp and Linstone have observed that trend extrapolation is "*appropriate during any stable phase but inherently fails in chaotic phases*" (Grupp and Linstone, 1999). Those parts of the electronics industry where technology trends are helpful are those where the technology base is quite stable, and improvements are incremental rather than radical. Technological advantage there is associated with particular physical parameters such as clockspeed or feature size Where other industries also rely on the performance of very specific physical parameters, there may be trends which could be useful for small companies to monitor. The danger is that trends can inspire too much confidence because they are quantitative in nature (Kappel, 2001). If the technological base is constantly changing, the monitoring and scanning processes outlined in section AIV 1 will be of much greater benefit.

AIV.2.2. Bibliometrics

Whereas technology S-curves predict the performance of a particular technological parameter, it is possible to examine technology trends from other perspectives

For example, a surge in patenting activity surrounding a particular technology may indicate that this is a technology which is likely to be making an impact in the future The cumulative number of patents in any particular technology is also likely to follow an S-curve, albeit with an unpredictable cycle duration (Andersen, 1999) Research publications are another indicator of hot new technologies which may have major commercial applications The use of patent and publication counting is known as bibliometrics, and has been made significantly easier by the wide availability of searchable electronic databases such as those provided by the Patent Offices (European Patent Office, 2001; US Patent and Trademark Office, 2001) INSPEC (Institution of Electrical Engineers, 2001) and the Science Citation Index (Institute for Scientific Information, 2001b) The technique has limitations – partly because publishing and patenting policy varies widely between firms, industries and countries (Acha and Von Tunzelmann, 2000), and publication is biased towards the English language (Ehrnberg and Jacobsson, 1997). Often companies will opt for total secrecy if they are working on a technology they believe to have great commercial advantage, and so do not publish or patent. Sometimes publication by industrial researchers in academic journals is purely an indication that the technology was not successful enough to keep hidden from competitors Another limitation of bibliometrics is that there can be a significant time lag for research articles to be published and patents approved For very new technological areas, there is also a time lag before the patent classification system identifies the technology.

Despite the limitations, bibliometrics can provide useful information to show whether a technology is maturing – for example, the number of keywords associated with a technology will increase as it matures, as research will begin to focus in more detail on various aspects of the technology The co-location of keywords can reveal convergence of technologies, or new applications of technologies. Watts and Porter (Watts and Porter, 1997) have developed a detailed set of bibliometric measures for "innovation forecasting", and demonstrate the use of these measures to investigate the development of ceramic engine technologies Their approach appears to stem from a technique designed to ascertain the most fruitful research areas for an academic institution (Porter et al , 1994), and as such it may not be fully adapted to small industrial companies.

Other researchers have used patent and publication analysis to assess Light Emitting Diode (LED) material technology and Thin Film Transistor technology (Liu and Shyu, 1997) Using plots of cumulative patent and journal paper counts against time for three different types of LED material, they identify which material technology may be maturing, which is in growth and which is in the early phase of its lifecycle, based on the shallow slope of the graph for the maturing technology and the steep slope for the new technology They also suggest that once a technology moves from early development into industrial application, patents will begin to outnumber research papers - but in fact their data only supports this for the immature technology. Their data does show that growth in patent counts tends to precede growth in journal publication counts, which may be due to the slow peer review process. Patent analysis is also demonstrated as a technique for examining the relative strengths of the major players developing LED technology. Liu and Shyu present their research as evidence of the usefulness of patent analysis for technology planning and forecasting, but in fact they do not make a very strong case for the ability of this technique to predict future technological progress.

The technology-push linear model of innovation has been superseded by models which acknowledge the importance of market pull and inter-firm networking (Rothwell and Dodgson, 1991), and indeed the entire way in which scientific research and development is conducted has been challenged by "Mode 2" thinking (Gibbons et al , 1994) Under the old technology-push model, one would expect to see first a growth in academic publications concerning an emerging new technology, followed by a growth in patents This assumes that new technology starts with academic research, which is then commercialised and patented by industry. While accepting that the technology-push model is not a full picture of the innovation process, it is of interest to investigate whether any patterns can be identified using bibliometrics which could act as an "early warning system" for the rise of new technologies

This question has been studied by Ehrnberg and Jacobsson (Ehrnberg and Jacobsson, 1997), with case studies examining the transition from conventional to CNC machine tools, and the transition from CNC machine tools to flexible manufacturing systems. In addition to the use of patent and journal publication counts, other indicators were employed including the number of new entrants to an industry or technology and relative price changes of substitute technologies In the first case study, there was no warning of the technological change from the patent counts, which only increased as CNC machine tools were being taken up widely The publication counts actually rose later still, but the price and entrants indicators did move between 1-3 years before the change, and therefore could have acted as a warning In the second case, new entrants were the first indicator to rise 10 years before the technology took off, followed by publication counts 5 years before the technology was widely taken up In the case of the diffusion of CNC machine tools, the key innovation was the use of the microprocessor which was a new technology that came from outside the industry – so patent and publication searches concerning machine tools would not have shown up developments in microprocessor technology In the case of developments from within an industry, publication and patent counts might be expected to grow in anticipation of a new mass market Another factor identified by Ehrnberg and Jacobsson is that the machine tool industry is not heavily science-based, which they contrast with Grupp's findings on laser beam sources, where publication counts rose first, followed by patent counts, with market penetration occurring over a decade later (Grupp, 1994).

To test the usefulness of the technique to small companies, the author conducted a limited study into whether very simple bibliometrics could be used to demonstrate the development of process technologies in the electronics manufacturing industry. The preferred choice would have been to plot numbers of publications, numbers of patents and equipment sales against time Due to commercial sensitivities, however, it was not possible to access equipment sales data. The INSPEC database (Institution of Electrical Engineers, 2001) was used for publication counting since it yielded the most results, while the Derwent Innovations Index (Institute for Scientific Information, 2001a) was used to find patent information The results, as shown in Fig. AIV.6, were however as inconclusive as those of Ehrnberg and Jacobsson, although there may be some sort of pattern with the number of patents rising while publications drop in Figs. AIV 6 (a), (c) and (d). This could not be used to predict with any confidence when the process technology was about to be taken up widely, and therefore would not help a small company in making a major investment decision .

Simple patent and publication counting is therefore a technique which is unlikely to be of any direct use to small companies The detailed bibliometric process described by Watts and Porter (Watts and Porter, 1997) could provide useful information, but this information would need to be carefully interpreted, and as such it may be more appropriate for small companies to use experienced consultants if this data is believed to contain important technology trend information

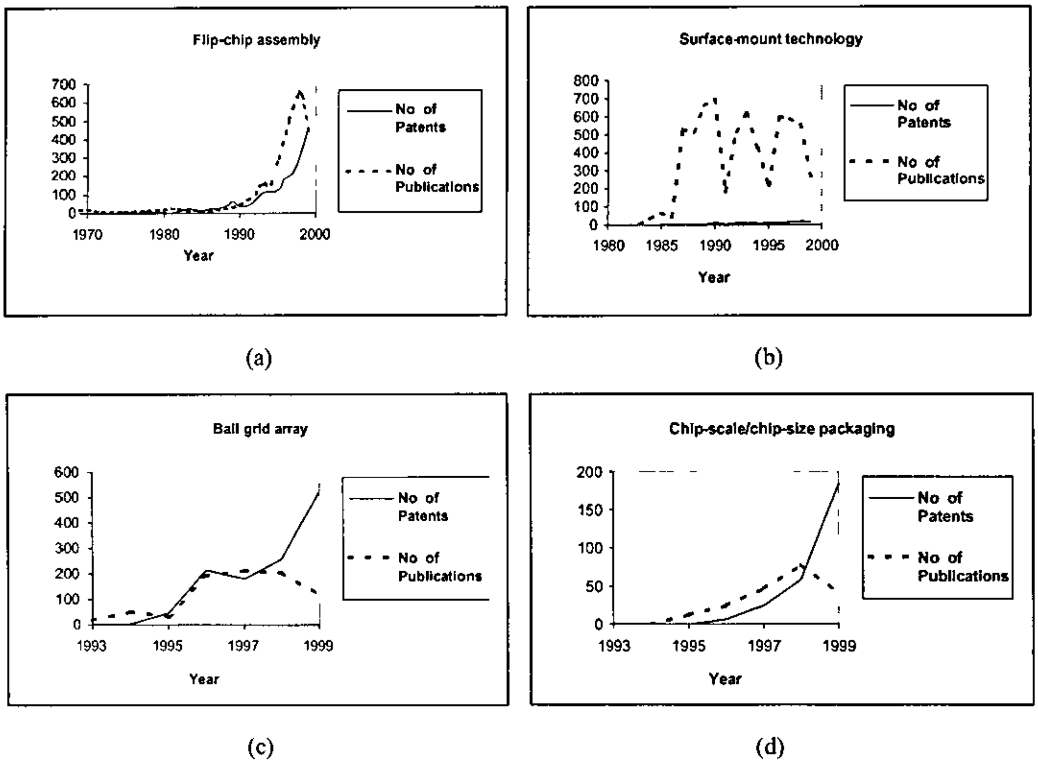


Figure AIV.6 Bibliometric trends for process technologies in the electronics manufacturing industry

AIV.2.3. Public Roadmaps and Foresight

Small companies cannot normally afford to bring together all the top experts in a particular industry to advise them on the future of various technologies. Expert opinion is however available in a more generalised form, as a result of government and industry initiatives to try to anticipate future developments There have been a number of national and regional Foresight exercises over recent years, and there has also been a growth in the number of industry sectors drawing up roadmaps. In some cases governments have initiated industry roadmaps where they believe that industry to be critical to national prosperity Delphi surveys form the basis of many of these exercises.

AIV 2 3 1 Delphi Forecasts

The Delphi technique is useful for longer term forecasting (20-30 years ahead), where expert opinion is the best (and usually the only) source of information available (Grupp and Linstone, 1999). Delphi surveys involve sending a questionnaire to a large panel of experts, then circulating the results and repeating the process a number of times to achieve convergence of opinion The experts are asked to identify possible technological developments, then estimate the probability of them occurring within a specific time frame e g. the next 10-20 years

The technique is helpful for distilling the judgement of a wide range of experts but it does have some disadvantages. It is essential that the questionnaire is worded very carefully to avoid ambiguity (Twiss, 1992)[p 108], and that the questions are appropriate and not biased by the mindset of those setting the questions To avoid this, the first round of the survey can be dedicated to generating or revising the set of questions (Grupp and Linstone, 1999) There is also a danger that members of the panel can feel compelled to agree with the majority even if they themselves might actually be better informed in that particular case The fact that the panel members do not meet face-to-face should however avoid individuals imposing their opinion on the group, and also allows panel members to revise their opinion without losing face (Martino, 1983). Another source of problems with Delphi surveys is the human impulse to think linearly (as described in section AIV.2.1) – technological progress is generally underestimated in the early stages of the lifecycle, and overestimated as maturity approaches (Twiss, 1992)[p 113].

Delphi was initially used for technology forecasting after World War 2, by the RAND corporation in the US, where "*the military confronted the combination of rapidly changing technology, long system lead times, and a perceived Cold War threat*" (Grupp and Linstone, 1999) In the 1970s, Japan adopted a Delphi process as part of their strategic effort to develop their science and technology, and have repeated their large scale study every 5 years (Kuwahara, 1999), while Taiwan has used the technique specifically to help develop their information technology industry (Madu et al , 1991). The fifth Japanese study was replicated in Germany using translations of the Japanese questions (Breiner et al , 1994), and since then Delphi has been one of the main methodologies used in various national Foresight exercises (as described in section AIV.2 3.2 below) (Grupp and Linstone, 1999).

While small firms are unlikely to commission large scale Delphi studies themselves, they may be able to use Delphi forecasts indirectly to access expert opinion. For instance, it may be possible that their large customers use this technique and are willing to pass the results to suppliers. Also, with an understanding of government priorities from national Delphi studies, small companies can choose to develop technological areas which are likely to benefit from positive conditions (such as government incentives).

AIV 2 3 2 Foresight

The definition of foresight which will be used here is "*a systematic attempt to look into the longer-term future of science, technology, the economy, the environment and society with a view to identifying the emerging generic technologies and the underpinning areas of strategic research likely to yield the greatest economic and social benefits*" (What is Foresight?2000). It is not advisable to consider technology in isolation, since the future direction of science, the economy, the environment and society will affect which technologies will be both possible and desirable in tomorrow's culture.

National technology foresight activities, in the form of Delphi forecasts, have been taking place for the last fifty years (see section AIV.2.3.1) There has recently (in the last 12 years) been new, more widespread interest in conducting national foresight exercises, starting in the Netherlands, with Germany, the UK and France following soon after (Grupp and Linstone, 1999) Foresight has also been taken up in many other countries in the past decade (Grupp, 1999). In the UK, the Technology Foresight programme was first launched in 1993, with the following aims: to increase UK competitiveness, to create partnerships between industry, the science base and government; to identify exploitable technologies over the next 10-20 years, and to make better use of the science base by focussing the attention of researchers on market opportunities (Martin and Johnston, 1999).

The second round of U K. Foresight began in 1999, divided into a number of different programmes: the thematic panels include "the ageing population", "crime prevention" and "Manufacturing 2020", while there are also sectoral panels such as "defence, aerospace and systems", "materials", "information, communications and media" (Foresight Website, 2002) The various programmes use a number of methodologies, particularly Delphi surveys (as described in earlier), consultation and scenario writing (described below)

Consultation in this context means seeking input from across the whole community, to consider the expected future, possible futures and preferred futures The expected future is drawn from extrapolating current trends and expert analysis, while the possible futures try to anticipate significant changes in the world. The aim was to draw up a strategy to reach the preferred future while coping with possible change, which meant identifying key issues and drivers for change (What is Foresight?2000).

Scenario writing is used to imagine what the future may be like It relies on having good quality information as an input to the process, and provides a mechanism for handling uncertainty (Stout, 2000) (The process is described in more detail in section AIV 3.2). The scenarios produced by government Foresight exercises are very unlikely to turn out to be an accurate prediction of the future. Small firms should not see them as a description of the future they should expect. There will however be useful messages for small companies in these scenarios - firstly in understanding that the future will not be like today, and secondly in becoming aware which industry, society or technology drivers may have a serious effect on their business

In the foresight studies conducted in the Netherlands, one of three key objectives was to provide SMEs with advance information about the possibilities for application of new technologies. Although the studies were able to provide this type of information, difficulties were encountered in diffusing the information into the SMEs and inspiring them into action. Intermediaries had an important role in overcoming this information bottleneck (Reijs, 1994) Meanwhile, in the UK, Reid (Reid, 1996) observed that resource constraints make it difficult for small firms to investigate and exploit the many public programmes and initiatives, and that the 10-20 year timescale of the Technology Foresight programme "*appears impossibly long for firms whose horizons are overwhelmingly short term*". Reid did however suggest four key benefits of the Technology Foresight programme for high-tech SMEs - in providing firstly, product and market information (particularly about less familiar sectors); secondly, access to government funds; thirdly, credibility in raising money for new projects; and fourthly, opportunities for strategic alliances with international companies to develop products identified as valuable

The first round of Technology Foresight in the UK was rather focussed on results - i.e. in trying to deliver "answers" about the future, for example by setting specific budgetary priorities for research (Martin and Johnston, 1999) In recent years attention has shifted to the process of Foresight, with the realisation that much of the benefit of undertaking Foresight studies comes from the greater understanding generated by going through the process (Martin, 1995) Martin and Johnston (Martin and Johnston, 1999) have observed that a major benefit of undertaking national foresight activities is that it "*wires up the national innovation system*" by involving people from government, industry, research, education, professional societies and community groups, and thus encouraging communication and shared decision-making. The creation of networks around critical technology areas was seen as a key objective in the foresight studies in the Netherlands (Reijs, 1994). By involving themselves in foresight networks and communities, small companies can access a wide pool of knowledge and keep up-to-date with developments, thus positioning themselves to exploit future technology and future opportunities.

The indications for the third round of Foresight in the UK (beginning in 2002) are however that the programme is being significantly scaled down, and that these opportunities for small firm involvement may be disappearing. The new approach is for short, task-based projects, with only a small number of projects underway at any one time – and therefore the chances of a small firm finding a Foresight project relevant to themselves will be reduced. The emphasis on stakeholder involvement is not very evident (to the author at least) in this round.

Some organisations have taken the original UK Technology Foresight programme as a benchmark for their own foresight activities (Georghiou, 1996), and the hope is that many companies, including small manufacturing firms, will adopt the process of foresight for their own benefit. Fuller and Larue have studied how foresight is implemented and embedded in UK organisations (Fuller and LaRue, 2000), and they found that significant problems were perceived regarding the ability of small firms to implement foresight processes. A small business owner was quoted as saying "*I find it hard enough to operate my business with hindsight let alone foresight*", while another respondent in the study noted that the agility of small firms allowed them to change when required, without the need for 20 years of time-consuming preparation. It was also felt that small firms, operating in a supply chain, would have little choice but to change with the supply chain, whether or not they anticipated the changes. These views came mainly from large organisations (including professional associations) concerning their experience with small firms, but Fuller and Larue countered these views with the observation that small firms often demonstrate their skill in anticipating the future through entrepreneurship.

AIV 2 3.3 Industry Roadmaps

A number of countries have created industry roadmaps - which are in effect very much like the Foresight exercises described above. The term "roadmap" is used simply to describe a plan of action, based on an understanding of the likely future of a technology or industry. Again this understanding is usually based on expert opinion, accessed using techniques such as Delphi

One example of a Delphi questionnaire-based industry roadmapping exercise was undertaken in India to examine the future of electronics and information technology in that country (Chakravarti et al, 1998) Their methodology also used inputs such as scenario writing and statistical analysis of the survey responses to create a fine tuned technology forecast and roadmap during a one-day seminar of experts, planners and administrators.

Industry associations also create roadmaps as a means of identifying key technological challenges and as an attempt to reach consensus on the future direction of the industry. One of the most well-known industry roadmaps is the one prepared by the Semiconductor Industry Association, based in California in the US - the National Technology Roadmap for Semiconductors (Agres, 1998; Rea et al., 1997; Burggraaf, 2000) This roadmap is a 15 year forecast of the technologies which will be required in the fabrication of CMOS (complementary metal-oxide semiconductor) integrated circuits, where the future requirements are based on extrapolating the historical technology trends such as Moore's law Roadmapping appears to be particularly popular in the electronics and related industries - industry roadmaps have been considered or created for electronic interconnection (Fisher, 1995), magnetic disk storage (Moore, 1999), flat panel displays (Bardsley, 1998) and microsystems technology (Marshall, 1999).

Industry roadmaps, whether created by governments or by industry associations, can be helpful to the small manufacturing company, since they can allow access to expert opinion on the future of technologies and industries. This may be especially useful for firms considering the adoption of a technology from outside their industry sector, e.g. an electronics firm looking to integrate optical technologies in their products Roadmaps may provide other benefits to small companies· if a government roadmap favours a particular technological area, then there may be some financial support available to small companies which develop this technology. Also, industry roadmaps may reveal the thinking of industry leaders (which can be utilised by small firms), or they may provide a means of accessing technology trend information. The roadmapping process does have weaknesses however: both government or industry association roadmaps could potentially be swayed by the hidden agendas of influential stakeholders involved in the process, and this should be taken into account when using this type of information.

AIV.3. Technology Planning

Armed with a good understanding of current technology, and with adequate information about likely future technology development from a broad range of sources, the next step for the company is to plan. The company should have an integrated strategy and vision for the future which includes everything from finance and marketing to human resources and technology. It may be that technological developments will open up new possibilities for the company, requiring a change in strategy to reflect this - or it may be that business requirements demand the introduction of new technology.

The detailed technology planning and management should be consistent with the overall strategy. A significant part of planning at this level concerns questions of timing: when to adopt new technology and when to begin to develop it or set about acquiring it.

AIV.3.1. Timing Decisions

The pace of technological progress grows ever more rapidly, and product lifecycles are becoming ever shorter. Development times are also being squeezed, and the cumulative effect is that many small businesses live in a very short-term world, with planning horizons drawing closer and closer. Many companies in relatively mature industries now work with new product development cycles of around 2 years: for the high-tech industries that time may be measured in months. In some cases it is difficult for managers to plan even beyond the next order, but clearly it is essential to do so in order to give the business some direction

Introducing new technology takes time. Even if the technology is obtained by acquiring another firm, a process of integration will have to take place while the product developers learn about the capabilities and limitations of the technology. Therefore, the technology needs to be identified and selected well in advance, so that consideration can be given to the best way to acquire it or develop it, and the relevant expertise gained. These decisions will be influenced by when the technology will be needed - at what stage should it be introduced to gain the maximum competitive advantage?

Any information about the anticipated rate of technological development (e g. from technology trends or bibliometrics – see sections AIV.2.1 and AIV 2.2) may be helpful at this stage There are also market and economic factors to be considered when trying to establish the optimum time to adopt new technology, and some of these factors are discussed below

AIV.3 1 1 Individual Technology Adoption Decisions

First technology adoption timing decisions at the firm level are considered. This is an area which has not been neglected in the economics literature, and there are a number of models which attempt to establish the optimum time to adopt. These are generally either decision theory models or game theory models. Reinganum conducted an in-depth analysis of models concerning the timing of innovation (Reinganum, 1989), in which she examined forty different propositions (mainly game-theoretic in nature). Her analysis is particularly concerned with the race between competing firms to innovate, the rewards for being first to market (or for choosing to delay until the adoption costs have declined) and appropriate R&D investment Game-theoretic approaches have also been reviewed by Beath et al (Beath et al., 1995), addressing first the allocation of resources to in-house technological development and second the acquisition and licensing of external technology. They state the two key motivating forces for product and process innovation, which are to increase profits (i.e. looking for a good return on investment) and to gain strategic advantage over rivals (e.g through increased market share). These themes can be seen to underpin all the economic models for technology adoption timing A helpful literature review is provided by Bridges et al. (Bridges et al., 1991), which addresses both individual firm adoption decisions and aggregate diffusion models (a topic discussed below in section AIV.1.2). An introduction to the considerations involved in the technology adoption timing decision is given below, and this is mostly based on the review by Bridges et al. in combination with some of the more recent literature

The most simplistic models only consider known future events. Under this regime, the "*optimal time of adoption occurs when the present value of investment cost is equal to the present value of production cost savings*" (Bridges et al , 1991). The optimal time will be earlier if the adoption costs become lower or the predicted cost savings per unit increase - and if a competitor is also likely to adopt earlier. This assumes a situation where there is a one-off investment in the new technology. For situations where there is on-going expenditure e.g when a new technology is developed in-house, there are models to determine the optimum investment as a function of time. Different models use different assumptions concerning the probability distribution of rival innovation against time, and also make different assumptions about the rewards for being second to market. The latter depends partly on how good patent protection is assumed to be (Reinganum, 1981)

Another factor which can be included is the uncertainty of the profitability of innovation (Reinganum, 1983). Some models attempt to address this by setting thresholds. "*if the probability that an innovation being profitable exceeds the upper threshold, the firm should adopt, while if this probability crosses the lower threshold, the technology should be permanently rejected*" (McCardle, 1985). There is also a cost associated with delaying adoption and acquiring more information (associated with the loss of market share if a competitor adopts first), although delaying will reduce the uncertainty about the economic value of the innovation (Jensen, 1992; Mamer and McCardle, 1987, McCardle, 1985), and could potentially result in second-mover advantage (Hoppe, 2000) Entering the market too early with an under-developed technology can have a serious negative impact on market share (Kalish and Lilien, 1986).

Other types of uncertainty have been considered. uncertainty about the time required for successful implementation of a new technology (Stenbacka and Tombak, 1994), about how quickly an (external) new technology will become available for adoption, and about the extent of the efficiency gains from using the new technology (Farzin et al , 1998). Sometimes a stream of technological innovations are anticipated, and there are complex decisions to be made regarding the timing of investment (this has been examined recently in (Rajagopalan, 1999)) If there are high expectations of future developments, companies may choose to postpone their investment (Weiss, 1994). For those companies with a large technological gap, early investment would be most appropriate. In some situations it may be possible for technological laggards to leap-frog ahead of hitherto more advanced competitors, but in other situations (e g. where experience and tacit knowledge is particularly important) those firms may only hope to catch up (Beath et al., 1995)

The models raise awareness of the various factors which need to be examined, but each model is tightly bounded by the stated assumptions - e g. the investment timings of a pair of identical firms operating in a duopoly, operating at Nash equilibrium output levels (Reinganum, 1981). This may be helpful for economists examining the dynamics of the system, but is unlikely to be of much practical use for small company managers operating in the complexities of the real world. As Bridges et al. conclude.

" *The models discussed predict expenditure patterns and timing of firms' adoption of innovation as a function of variables which are at best difficult to measure, such as rewards accruing to the first innovator, the expected cost and time required to obtain the knowledge needed to develop the innovation, the desirability of imitating the innovation should another firm develop it first, and the gap between the firm's current technology and the innovation Although the resulting models provide analytical results which are consistent with intuition, empirical testing for confirmation is generally not performed* " (Bridges et al , 1991) The lack of empirical testing can be seen as evidence of the difficulty of isolating and measuring the complex variables in the real world, rather than a failure to test the models properly

The timing of technology adoption has been the subject of management research outside the economic modelling literature One example is the resource-based view of Lieberman and Montgomery (Lieberman and Montgomery, 1988; Lieberman and Montgomery, 1998) who examine first mover advantages and disadvantages in terms of improving firm resources and capabilities. They suggest that "*early entrants may acquire the 'wrong' resources, which prove to be of limited value as the market evolves*". On the other hand, "*early entrants may be able to mould the cost structure of customers*". They suggest that where a firm's strengths lie in new product development, they should aim to be first to market, while companies with greater strength in marketing and manufacture should aim to enter later, "*after the initial market and technological uncertainties have been resolved*". Lint and Penning highlight the tension between the financial imperative to wait before investing (keeping options open), and the strategic marketing driver to leapfrog the competition by early market entry (potentially setting the new technology standards) (Lint and Pennings, 1999).

There is no simple formula which can be used to calculate the correct time to adopt and introduce a new technology. Each firm will need to weigh up the circumstances in their own market for each new technology

AIV 3.1 2 Technology Substitution and Market Diffusion

The S-curves described in section AIV.2 1 describe the technical performance of a technology against development effort. It is also possible, however, to use S-curves to describe the ownership level of a product or technology plotted against time. Instead of a physical upper limit which can be calculated from e g. material properties, the upper limit to this type of S-curve is market saturation. This can only be estimated using e.g. Delphi forecasts, because it depends on imprecise factors such as how much the product or technology appeals to customers For a small company, it will be difficult to afford expert Delphi forecasts, so other means will have to be used to estimate the market saturation. If the new product or technology has already been established in another country, this may help to estimate the saturation level, or it may also be useful to consider the market for a similar type of product or technology. The accuracy of the market saturation level is important, because misjudging this can lead to significant error in the shape of the S-curve

A product or technology may also be designed to replace an existing product or technology, through technological superiority, reduced cost or additional features. It may segment the market by fulfilling the needs of just one section of the market, and it may also attract first time buyers. If the new product is sufficiently attractive, then the users of the old product may purchase the new product before the old one is due for replacement

The Fisher-Pry model is used to forecast the market substitution of a superior technology or product (Fisher and Pry, 1971). It is based on the assumptions that if 5% of the total market have made the substitution, then it is likely that the substitution will proceed to completion, and that the fractional rate of substitution of new for old is proportional to the remaining amount of old to be substituted. It is based on the logistic or Pearl curve -

if the early adoption data is known, as well as the total market, then it should be possible to predict when a certain percentage of the market will have been replaced by the new product or technology.

$$f = \frac{1}{2}[1 + \tanh a(t - t_0)] \text{ OR } \ln[\frac{f}{1-f}] = 2a(t - t_0)$$

Equation AIV.2
Fisher-Pry model

f = fraction substituted

a = half the annual fractional growth in the early years

t_0 = time when f equals a half

The Gompertz model may be used instead of the Fisher-Pry model - this basically means that instead of using the equation for the Pearl Curve, the equation for the Gompertz Curve is used The early data is used in exactly the same way to fit the curve. The Fisher-Pry model forecasts a more rapid market penetration than does Gompertz - but there is some disagreement over where Gompertz may be more applicable. Porter et al (Porter et al., 1991) suggest that Gompertz is more appropriate where substitution is likely to occur as a result of replacement of worn out equipment, rather than because of any technological advantages It is considered to be helpful in situations where there is intense competition between technologies. Technology Futures Inc (Technology Futures, 2000), in contrast, suggest that Gompertz is better for adoptions driven by technological superiority of the new technology, although the assumption is that customers do not suffer any significant penalty for not adopting the new technology at a given time.

$$f = \exp[-b\exp(-kt)]$$

Equation AIV.3
Gompertz model

f = fraction substituted

values for b and k must be found by curve fitting or regression

If the outlook is very different depending on whether Fisher-Pry or Gompertz is used, then the forecast cannot be considered reliable.

A different type of substitution model has been presented by Loch and Huberman (Loch and Huberman, 1999). This is used to examine the situation where an old and a new technology are available and both are improving incrementally. Depending on the incremental rates of improvement, and on the resistance to switching in the market, the new technology may not necessarily be adopted (despite being superior to the old technology), or there may be a sudden switch to the new technology.

The S-curve described above shows cumulative market ownership of a product or technology. Another way of looking at this is the model for market diffusion shown in Fig. AIV.7 (Rogers, 1995)[p 262], also known as the technology adoption lifecycle. This is a normal or bell-shaped curve, with the number of sales or adopters of the new technology plotted against time (it would be an S-curve if the cumulative number of sales or adopters were plotted) The adopters are divided into the following classifications. innovators, early adopters, early majority, late majority and laggards. Moore has identified a "chasm" between the early adopters and early majority, which is where a great number of new technologies fail. Early adopters are prepared to accept teething troubles with the new technology, and radical discontinuity from the old technology, in order to get ahead of the competition. The early majority are looking for evolutionary change rather than revolutionary change - they want a fully tested technology which will not disrupt their existing ways of working (Moore, 1991). Anticipating the take-up of a new technology will therefore involve gaining an understanding of the potential adopters, so a small firm should consider how their current and potential customers might be classified.

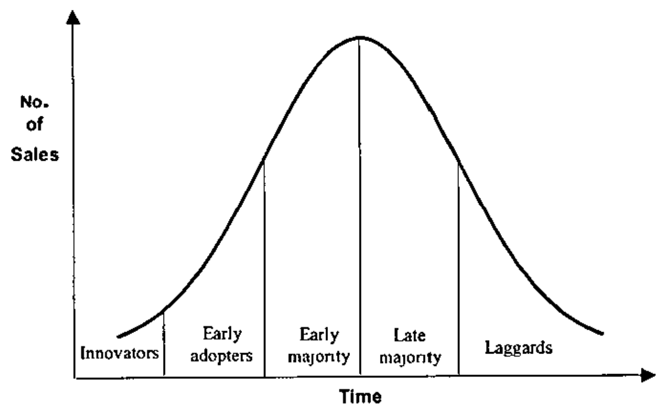


Figure AIV.7 Market diffusion model (adapted from (Rogers, 1995)[p 262])

There are a number of literature reviews which examine aggregate models of product and technology diffusion (e g (Bridges et al., 1991; Karshenas and Stoneman, 1995; Mahajan et al , 1990)). Unlike the game-theoretic models for individual firm technology adoption decisions, it has been possible to empirically test the majority of the aggregate diffusion models against historical market data

A well-known product diffusion model is the Bass model (Bass, 1969) This model considers two separate effects· adoption as a result of external influences such as the mass media, and adoption due to internal influences such as word of mouth. The adoptions due to internal influences follow a curve which includes a normal distribution similar to that shown in Fig AIV.7, but the adoptions due to external influences fall away from a peak level at the start. The forecasting success and fit to historical data of aggregate diffusion models can be improved by considering factors such as advertising, pricing, product replacement propensity, government regulations, learning effects, supply restrictions and a changing potential market (Bridges et al., 1991; Karshenas and Stoneman, 1995).

The models described here can be useful for forecasting sales over time, planning production and anticipating obsolescence of older products and technologies. Predicting the rate of technological change using these models is something which may be better left to market consultants. It is nevertheless useful for small companies to have an understanding of the potential and the limitations of such techniques when considering the timing of technology adoption.

AIV 3 1.3. Lifecycles and Economic Cycles

Having looked at technology adoption first at firm- and then the market-level, this section is concluded by briefly "zooming out" further still to look at industries and economies.

Just as technologies tend to follow a pattern of performance against time (see the S-curve shown in Fig AIV 1) successful industries also tend follow a lifecycle pattern such as that shown in Fig AIV.8 The industry lifecycle and S-curve of technological performance are not unrelated, because industries are often based on a dominant technology (whilst also relying on secondary technologies). Usually, however, the progress of the dominant technology is already beginning to slow before growth in the industry takes off. The following discussion of the industry lifecycle is based on Twiss (Twiss, 1992)[pp 72-78]

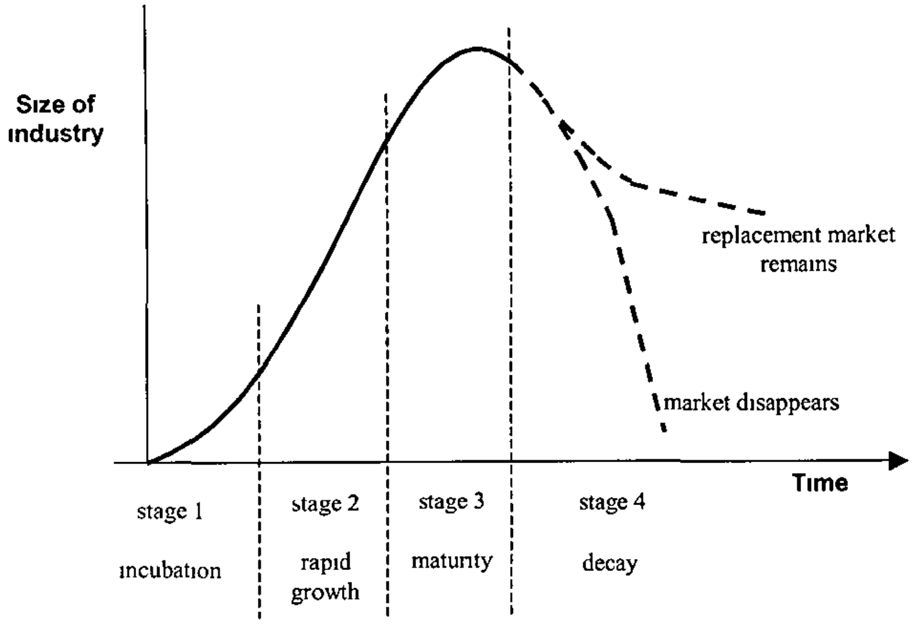


Figure AIV.8 Conceptual diagram of industry lifecycle (adapted from (Twiss, 1992)[p 73])

The first stage of the industry lifecycle is incubation, where the first applications of a new technology appear on the market in the form of expensive and rather unreliable products, and product performance drives competitiveness. The next stage is rapid growth, when the main product design features have been established but the market begins to segment, with product differentiation to meet the needs of particular users At some point the market will become saturated, and this is the stage when the industry reaches maturity Cost becomes the key to competitiveness, and process innovation becomes more important than product innovation. Finally the industry will reach a peak, and although there may then sometimes be a long-term market for the product, occasionally the industry will completely disappear, replaced by an alternative based on an entirely different technology.

An understanding of how the industry is maturing will be useful to small companies in anticipating future technology requirements, and in determining what type of technological forecasting information will be useful to them (Twiss, 1992)[pp 72-78]. If the industry is in the incubation stage, performance is all important, and technology S-curves (see section AIV.2.1) may be helpful for planning to meet the anticipated performance trajectory. Experience curves (see section AIV 2 1) may also be useful for predicting how the unit cost will fall In the rapid growth phase, market considerations become more important, and techniques such as Fisher-Pry (see section AIV.3.1.2) can be used to estimate the rate of product substitution As the market matures and then begins to decay, cost becomes more critical, and Fisher-Pry may be used to estimate rates of process substitution to save costs. At this point, the firm will need to think about what new technologies may threaten the industry they are in, with a view to diversifying into those technologies or utilising current technologies in new markets - again considering the Fisher-Pry technique for anticipating product substitution. Monitoring and scanning (see section AIV 1) are important at this stage, and techniques such as scenario planning (see section AIV 3 2 1) may be helpful. Expert opinion (see section AIV.2.3) may be used where available to assist in identifying the new growth areas

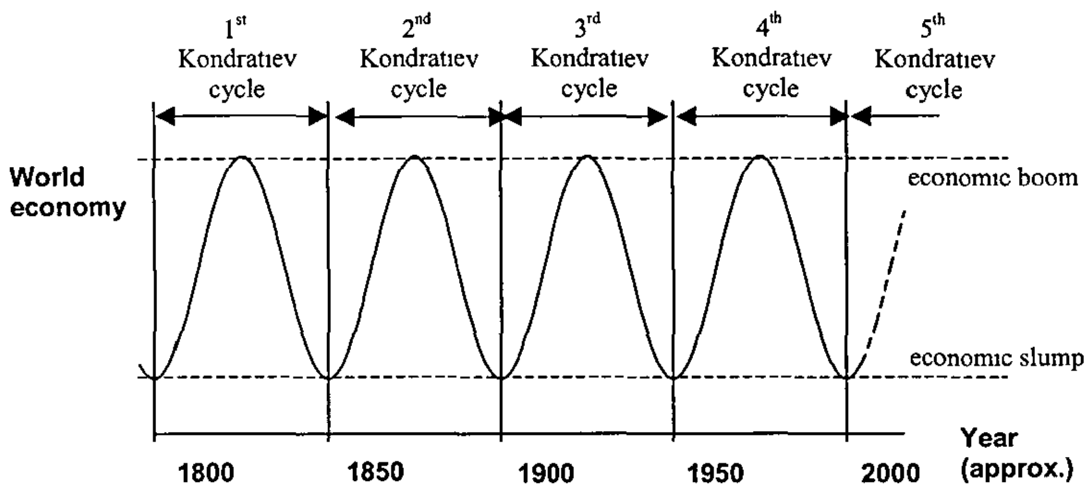


Figure AIV.9 Kondratiev economic long waves (adapted from (Braun and Elliot, 1996))

At a rather more abstract level than the industry lifecycle, there has been some interest over the years in the relationship between technological activity and the long economic cycles known as Kondratiev waves (Fig AIV 9). Kondratiev observed long wave patterns of 50-70 years in the level of economic activity, with each period of growth being linked to the deployment of radical technologies which stimulate the economy (Mensch, 1979). There is debate firstly about the existence of such regular economic waves, and secondly about whether economic upturns are caused by major innovation, or instead the upturn (or expected upturn) causes sufficient optimism to invest in bringing radical new technologies to market (Rosenberg and Fritschtak, 1994). Aside from these debates, there are clearly economic booms and slumps, and new technologies do emerge which are linked with growth. For small firms struggling in times of recession, it may be worthwhile looking around to see which emerging technologies may lead in the economic recovery.

AIV.3.2. Planning Frameworks

In this section, two techniques are introduced which can be used as frameworks to draw together all the information which has been gathered about current and up-and-coming technologies, and about the optimum time to introduce new technology (or phase out old technology) These techniques also require inputs concerning markets and external factors, and stakeholders from every area of the company should be involved. In many ways, the information gathering and communication processes are all that is needed for technology lookahead, but the creation of documents such as scenarios and roadmaps serves to focus the attention of participants, and helps to achieve consensus on priorities for the company

AIV 3 2 1 Scenario planning

Scenario planning is a technique which is particularly useful when the future is uncertain and there may be complex factors for which to allow. It is more commonly used for time frames of around 5-20 years, since in the short term there is less uncertainty (Porter et al , 1991)[Ch 13]. As described in section AIV 2.3, it has been used in national Foresight exercises, but it is a technique which can also be used at the company level The awareness and understanding generated through this process will correspond (to some degree) to the amount of time and resource which can be put into it, but even a day spent on scenario planning may be helpful to a small company.

The French have specialised in the scenario-based approach, introducing the term "La Prospective" Godet suggests that "La Prospective" is helpful "*to clarify present actions in the light of the future; to explore multiple and uncertain future, to adopt a global and systemic approach, and to take into account qualitative factors and the strategies of actors*". It is also important "*to remember that information and forecasts are not neutral; to opt for a plurality and complementarity of approaches, and to question preconceived ideas on forecasts and forecasters*" (Godet, 1986). Scenario building should lead to action (Wilson, 2000), and so it is important that the scenarios are relevant, consistent and likely (Godet and Roubelat, 1996).

Schoemaker has described the steps involved in the basic process of constructing scenarios (Schoemaker and Mavaddat, 2000; Schoemaker, 1991): Firstly it is necessary to define the scope of the study by identifying the issues which need to be understood, and setting a time frame The scope should be broader than the industry or set of technologies in question The major stakeholders and actors should then be identified, and the relevant drivers and trends identified and studied The next step is to identify the key uncertainties - i e. which of the important forces for change have an unpredictable outcome. The most significant uncertainties can then be used as a basis for developing "learning scenarios", with an iterative process checking for internal consistencies in the scenarios, examining how key stakeholders and actors may respond in each scenario, re-examining the uncertainty ranges and acquiring further information where necessary. The end result should be a wide range of possible future outcomes, including models of complex interactions where appropriate.

The process of creating the scenarios is really more important than what the final scenarios contain. The future is unlikely to match those predictions, but at least if the important influences and factors have been identified, it becomes much easier to anticipate how change will affect your business and plan accordingly

AIV 3 2 2 Company Roadmaps

Roadmaps at a national and industry level were described in section AIV 2.3.3 (N B. the term routemap is sometimes used in place of roadmap). It is becoming increasingly popular for companies to have their own roadmapping process, although company roadmaps will take a rather different form than the national or industry roadmaps. A general technology roadmapping process both for both industries and companies (developed by a government research laboratory) is described in (Garcia and Bray, 1999) As Kappel (Kappel, 2001) points out, however, industry roadmaps serve a very different purpose from company roadmaps, and his roadmapping taxonomy (shown in Fig. AIV 10) demonstrates this for four types of roadmap.

Motorola first developed the technology roadmapping process in the 1970s (Bergelt, 2000; Willyard and McClees, 1987) Due to the increasing complexity of their products and processes, they felt there was a danger that they could overlook an important new technology, and so roadmaps were introduced to help formalise their forecasting process Roadmaps were also seen as assisting communication between design and development engineers and marketing personnel. Motorola's roadmapping process has evolved over the years, but a brief description based on Willyard and McClees 1987 paper is presented here to illustrate the use of roadmaps

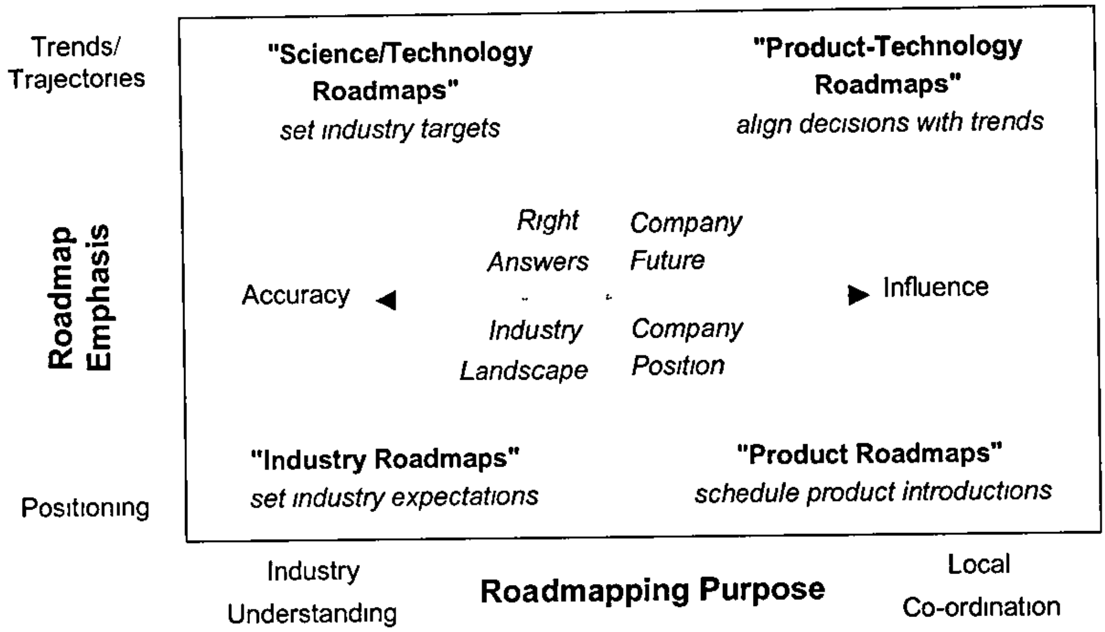


Figure AIV.10 Kappel's roadmapping taxonomy (Kappel, 2001)

Motorola classified two different types of roadmap: the emerging technology roadmap and the product-technology roadmap. The first type is prepared and maintained by a small group of technical experts, and deals with single technologies which are at the stage of having been demonstrated in a laboratory - whether in a university or research institution, or in their own or a competitor's research facility The emerging technology roadmap includes a forecast of the progress of the technology and evaluates the company's (and their competitors') capabilities in that technology now and in the future

The product-technology roadmaps introduced by Motorola operate on a much nearer time frame, and are a collection of documents describing the history of a product line of a particular group or division, and extrapolating to the future. The roadmap comprises eight sections, starting with a business description covering business mission, strategies, market share, sales history and forecast, product life cycle curves, product plan, experience curve (see section AIV.2.1) and competition. The next section is a technology forecast, which may be based on technology trends (see section AIV.2.1), and this is combined with the product plans to create a technology roadmap matrix (Fig. AIV.11) which summarises technological requirements for future products by plotting the products, functional requirements and technologies against time. The remaining sections include reports concerning quality, allocation of resources, patent portfolio, project status reports, and finally a minority report - designed to capture minority points of view about potentially beneficial products and processes.

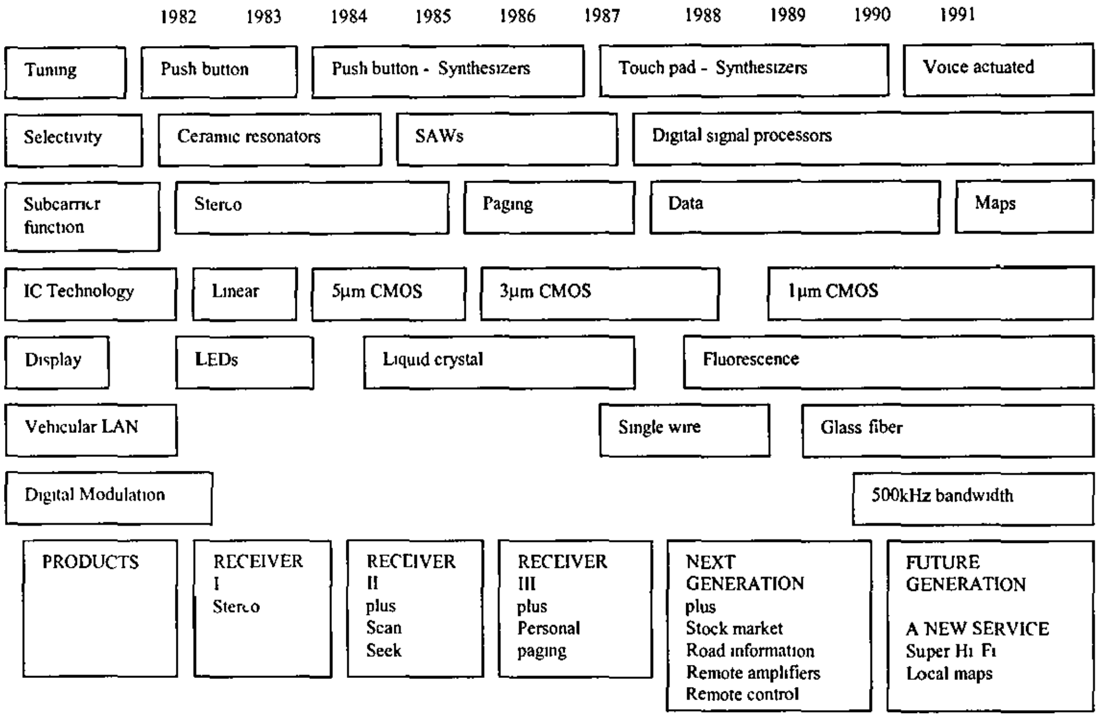


Figure AIV.11 Motorola's technology roadmap matrix for a broadcast automotive FM receiver (Willyard and McClees, 1987)

Groenveld published a detailed description of the roadmapping process used at Philips Electronics (Groenveld, 1997) Their product-technology roadmapping is aimed at improving both the integration of business and technology strategy and the creation of product ideas Different depths of detail are required in roadmaps depending on whether they are designed for business strategy discussions or for the operational level The time frame of the roadmap is usually something of the order of 5 years (unless the roadmap concerns a consumer product with a much shorter lifecycle), which means there is an element of short term planning and an element of long term vision. Tools used to support creation of the roadmap include Quality Function Deployment (QFD) and the Innovation Matrix QFD is a means of establishing what customers want from a product, and translating this into technical requirements, while the Innovation Matrix plots technological uncertainty (whether the technology is well understood, proven or not proven) against the time frame when it is required to be available Product-technology roadmapping was implemented differently according to the various requirements of the different divisions within Philips Electronics. Where groups were functionally orientated, they had a tendency to generate what was purely a technology roadmap which did not take account of the wider world. This needed to be addressed by cross-functional co-operation Other lessons learned included the need for management commitment, and that roadmapping requires sustained time and effort.

BP have used roadmaps to help link their R&D priorities with business strategy, although their roadmaps do not have an explicit time frame (Barker and Smith, 1995) They emphasise the importance of consulting with as many stakeholders as possible - the roadmaps are simply a visual summary of these discussions. Their approach involves extracting technical needs from the business strategy (market pull), and also linking R&D programmes to commercial goals (technology push)

A roadmap format developed for Lucas has a much stronger emphasis on the time frame - a minimum of 10 years for their automotive business and 20 years for their aerospace business (Probert et al , 1999). Their chart plots market and external events (such as new regulations, customer and competitor launches), system demonstrators, components and subsystems, and technology projects, and linking arrows are used to connect these four levels of activity (Fig. AIV.12)

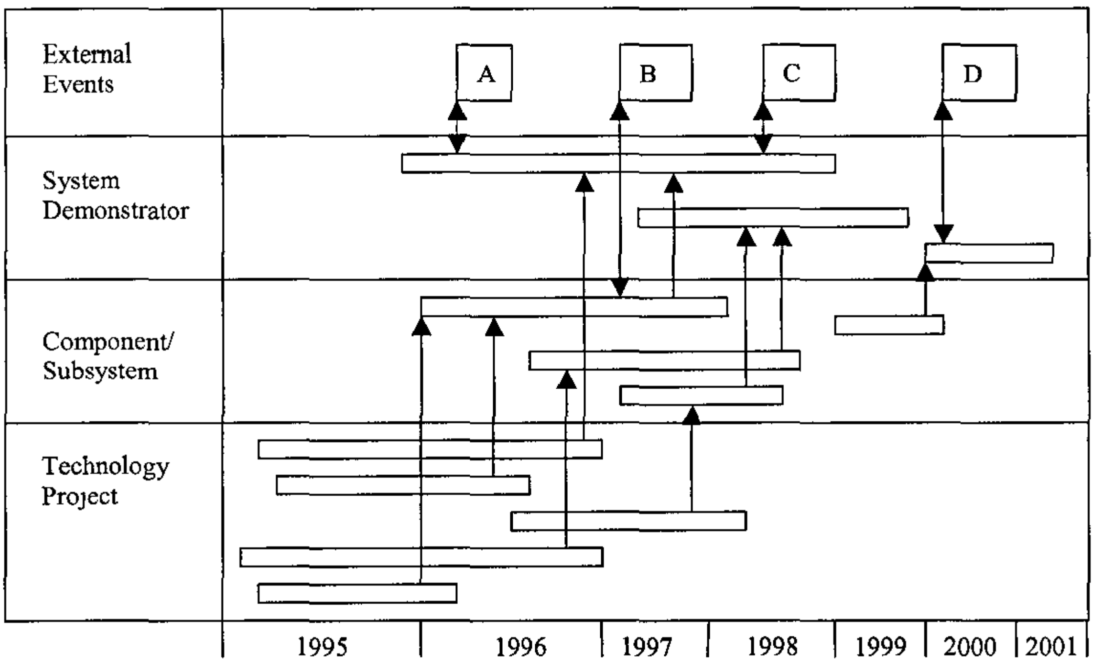


Figure AIV.12 Lucas technology roadmap (Probert et al., 1999)

The examples given demonstrate that company roadmaps vary considerably between organisations (see also (Phaal et al , 2001)[Ch 4]), since they reflect the industry sector, market and nature of the firm itself. The author has yet to find a small company using the roadmapping technique, and it is clear that the in-depth process used by Motorola would be completely inappropriate for a small firm. Attempts have nevertheless been made to assist companies in creating technology roadmaps (Phaal, Farrukh, and Probert, 2000; Phaal et al , 2001), and this process has been tested (with some success) in one small firm. Roadmaps can be very simple documents - while the roadmapping process can be as detailed or basic as resources allow.

Kappel (Kappel, 2001) observes that the roadmapping process may not provide adequate early warning when discontinuous change approaches from the outside. This is partly because the roadmaps are often based on extrapolation of trends, which are only really helpful in a stable situation (as has already been observed - see section AIV.2.1). Kappel suggests that this weakness could be overcome by using scenario techniques as part of the roadmapping process.

The particular value of company roadmaps is their role as a communication tool (Probert and Shehabuddeen, 1999; Groenveld, 1997; Barker and Smith, 1995). They can be used within companies to create a shared vision which integrates business and technology strategies, and they can also be used to help align the technology strategies of customers and suppliers where there is mutual benefit in doing so. From interviews in the UK with a senior technology manager in an automotive first tier supplier, and a supplier development manager in a defence company, it is apparent that suppliers' technology roadmaps are now beginning to be assessed as part of the benchmarking and selection of suppliers. It may therefore be increasingly desirable for small companies to prepare and maintain a product-technology roadmap in order to convince potential customers that they are technologically prepared for the future, and thus win business.

AIV.4. Conclusions

In conclusion, there are some key points and principles which can be drawn having examined the techniques available for technology lookahead in small firms For some firms, it may be enough simply to take on the principles of technology lookahead – i e having a forward- and outward-looking attitude. This will enable the company to make good use of the informal sources of technological information surrounding it, such as customers, suppliers and other business contacts. Yet for firms whose business is heavily technology-based, it may be worth implementing some level of formality into the technology lookahead process, particularly where the technological environment is uncertain This should ensure that the activity is not forgotten in times of crisis, when decisions should be made in light of the long-term needs of the company as well as the urgent needs of the moment.

The techniques described in this appendix should be seen as a toolkit of possible approaches to technology lookahead. There is no suggestion that it is necessary for every company to attempt to use all of the techniques described - instead it will depend on the individual situation of each firm which techniques may be appropriate. Monitoring and scanning the environment is relatively simple for any firm to do, and is useful regardless of whether the firm believes itself to be in a stable or a rapidly changing industry. It may be more beneficial to have a broad understanding of the technological landscape than to spend too much time analysing particular areas in great depth, but the degree to which monitoring and scanning should be systematic will correspond to the turbulence of the environment. Techniques such as technology trend extrapolation and bibliometrics may fulfil certain needs for future technological information in high technology based firms, although trends are only really helpful where there are a limited number of technologies competing on the same performance criteria in a fairly stable environment. Where the industry is a lot more chaotic in terms of market and technology drivers, the opinion of experts can be accessed by small companies through public sources such as Foresight and industry roadmaps This information will have to be interpreted carefully by the small firm in the context of their own situation

A major difficulty for small firms is the lack of time to engage in technology lookahead. Where finance is less of a problem, the answer may be to employ specialist consultants. While consultants may be utilised to find the relevant information for technology lookahead, the employees and directors of the firm must also be deeply involved in the lookahead process. This is important because decisions will have to be made regarding the best technological direction for the firm, and this will depend very much on current capabilities, products and markets.

Having identified which technologies are likely to be important in the future, the next step is to plan when and how to acquire or develop the relevant technology. This decision will be affected by a complex set of factors, including the expected actions of competitors, the risk and uncertainty surrounding the new technology, the current technological position of the firm, and the likely enthusiasm of existing and potential customers for adopting the new technology quickly. At this stage, technology and other types of business planning must be properly integrated, and formal processes such as scenario planning and company roadmapping may be helpful as a means of assembling all the relevant information and achieving consensus amongst all the stakeholders. If detailed documents are prepared, then they will serve to stimulate communication and ensure that all the relevant factors are considered in setting priorities for the company.

The greatest benefit of the techniques described in this appendix comes from participation in the process, not from the predictive power of technology lookahead. By developing a mindset which recognises the influence of drivers in technology, the market and society, the small firm can develop its technology base for maximum competitive advantage.