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ANALYSIS AND IMPLEMENTATION OF VOLUME FLEXIBILITY IN MANUFACTURING PLANTS

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Analysis and Implementation of Volume Flexibility in Manufacturing Plants

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ABSTRACT

Analysis and Implementation of Volume Flexibility in Manufacturing Plants

Manufacturing flexibility – the ability to change or respond quickly has been heralded as a major competitive weapon for manufacturing organisations operating in turbulent markets and markets characterised by fierce competition and rapid developments in technology. It is also important for the achievement of new management paradigms such as time-based competition, lean production, business process re-engineering and mass customisation. However, many issues on the concept of manufacturing flexibility such as, the clarification of why flexibility is needed, when it is needed, and how it can be implemented in manufacturing organisations have not been sufficiently addressed and resolved in the literature. This research project has been carried out to resolve some of these issues by focusing on one aspect of manufacturing flexibility – volume flexibility.

The research design, which was developed to address the research issues, comprised the use of both quantitative and qualitative research methods. The quantitative research method is an exploratory mail survey of UK manufacturing plants in all the major industrial classifications. The survey was used to obtain broad patterns and evidence concerning the conditions that drive manufacturing plants to require volume flexibility and also to identify the mechanisms which manufacturing plants employ to achieve volume flexibility. The qualitative research method is an explanatory case-based research. Manufacturing plants in each sector that responded to the survey and provided rich and contrasting information about the issues being investigated were selected for the case study research. The case study research was used to confirm the survey results (triangulation) and more importantly to explain the trends and patterns observed in the survey analysis.

The research concluded that high variability in demand levels is a major driver of volume flexibility and that it is generic in nature. Other drivers of volume flexibility were also identified. However, the applicability of these drivers to manufacturing plants was found to be independent of the sector to which the plants belong but on other specific characteristics of the plants. Mechanisms being employed to achieve volume flexibility in UK manufacturing plants were identified and referred to as enablers of volume flexibility. These enablers are not sector dependent but they do depend on specific market conditions, and their perceived costs and benefits. Substitute and complementary enablers were identified. Substitute enablers can be used to replace other enablers to achieve volume flexibility and complementary enablers aid other enablers in achieving volume flexibility. The research project also identified strategies, which can be employed by manufacturing plants to implement the enablers in achieving volume flexibility.

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Writing a PhD thesis acknowledgement is like making a speech after winning a 'Grammy Award'. You want to acknowledge the contribution of many people to the work, but you have very little time (or space) to do so. The difference is that the 'Grammy Award' speech is usually made after an award has been won whereas the thesis acknowledgement is written before the award of the PhD. However, it is pertinent to note that whatever the outcome of a PhD, the author will have been indebted to a number of people by the time the thesis is completed.

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The Analysis and Implementation of Volume Flexibility in Manufacturing Plants

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Chapter 1 – Introduction

The discussion in this chapter can be divided into two parts. The first part focuses on why a study of flexibility is essential to the world of knowledge. Over the last few decades many markets have witnessed a number of changes including a transition from a seller's market to a buyer's market. As such, manufacturing organisations' response or business paradigm has shifted from mass production to new paradigms such as mass customisation, lean production and time-based competition. It is argued that for the successful implementation of these new paradigms, a manufacturing organisation requires high levels of flexibility. The summary of this discussion is shown in Figure 1.0. Having highlighted the importance of flexibility in organisations operating in the current dynamic market environment, the second part of the chapter focuses on how the research intends to address the unresolved issues on flexibility implementation in manufacturing organisations and what the research hopes to contribute to knowledge.

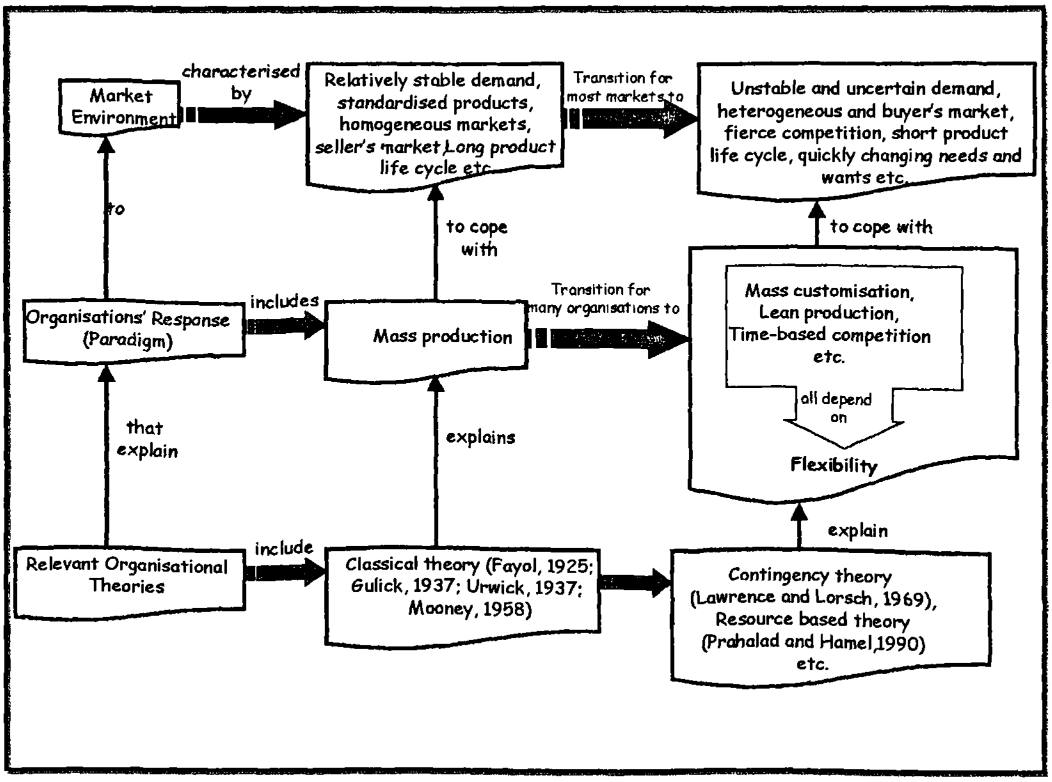


Figure 1.0: Changing market environment and organisations' response: Rationale for research on flexibility

1.0 The Changing Market Environment

The global market place is now characterised by intense competition and a scramble for increased market share. There exists limited demand for consumer products resulting in global over-capacity (Porter, 1986). Gone are the days when demand for products exceeded their supply in most markets. According to Pine (1993), those days are typified by the paradigm of 'mass production', a paradigm that is supported by theories such as the classical theory of organisations*. The mass production era was basically a seller's market, having characteristics described by Pine which have been summarised below:

• Emphasis is on volume. High product volumes reduce manufacturing costs through economies of scale. Selling the most products at the lowest cost generates the most profit and keeps the company in business.

• More products can be sold in large, homogeneous markets. Hence, niche markets that represent different customer desires and support only relatively low volumes are ignored since they merely increase costs.

• The stability of the inputs, process and outputs is important. This is achieved through product standardisation and inventory levels to adjust to changes in demand levels.

• Long product life cycle is encouraged as it reduces the development costs per unit and investments in product and process technology. Research and development should focus on new product breakthroughs that can be mass-produced. Marketing and sales should focus on selling what production makes with little regards to what customers want.

New forms of competition that are increasingly successful have challenged the mass production system, which in fairness, has been successful for many manufacturing firms for a number of years. Not only has competition changed, but so have societies, countries, markets technologies, and consumers (Pine, 1993). The market has witnessed a shift from a seller's to a buyer's market. Pine defines two factors, which best capture, the new form of the market environment. These are:

---

* The classical theory of organisations posit that organisations deal with the external environment by differentiating their tasks into functions where each function is required to deal with a portion of the external environment (Fayol, 1925; Gulick, 1937; Urwick, 1937; Mooney, 1958). Lawrence and Lorsch (1969) argue that the classical theory of organisations only tends to hold in a stable environment.

*1. **Demand Factors*** - factors that indicate the degree to which a firm can control and reduce the uncertainty within its market. These include:

Unstable and unpredictable demand levels – resulting from fragmentation of demand into new market segments.
Uncertain needs and wants – lack of knowledge about what the market will respond to
Heterogeneous demand – differences in demand that can be met with greater product variety and customisation
Quickly changing needs and wants – customer needs are not only fragmented but evolve quickly and constantly
Price consciousness – price-conscious customers who readily switch between brands if they find a better deal

*2. **Structural Factors*** – factors that reflect the basic nature of the industry and are therefore less subject to manipulation by individual firms. These include:

High buyer power – implies that firms have to respond more to what their customers need and want
High competitive intensity – contributors include the globalisation of markets and the blurring of industry lines resulting in high number of competitors battling for market share.
High levels of saturation – markets are becoming increasingly saturated resulting in the need for increase in product innovation rate, product variety and entering new markets.
Many substitutes – the more close substitutes there are to a company's products, the more the need for the company to differentiate its products to enhance its competitive position.
Short product life cycle – this calls for increased and fast product innovation rates.

As a result of increased competition and new opportunities opened through flexible automation, consumers have become more sophisticated, demanding increased customisation, higher quality, variety, innovation and novelty. Because of the need to avoid increasing risk of obsolescence and the need to implement low inventories policies, industrial customers are demanding smaller order quantities, rapid delivery on a short notice and reliable delivery (Hill and Chambers, 1991). Fast technological change, increased competition and customers demanding variety, novelty and innovation have led to more unstable demand patterns and shorter product life cycles, especially in high-tech markets (Chambers, 1992). These growing market constraints call for suitable coping strategies by organisations. According to Handy (1989), this change sequence has led to the questioning of old ways, which results in the emergence of new patterns of organisation. In view of these changes, the focus of the management literature in recent times has been on the necessity for organisations to change. Even as far back as the 1960s, early organisation theorists recognised the dynamics of the business environment and the need for organisations to adapt to the environment in order to survive, resulting in the proposition of the contingency theory of organisations and more recently resource-based theory[†] (Prahalad and Hamel, 1990). The contingency theory of organisations, proposed by Lawrence and Lorsch (1969), provides a good theoretical foundation for studies that seek to explore how organisations respond to the uncertainty in the business environment.

Contingency theory explains the results of Burns and Stalker's (1961) study of ten industrial firms each in a dynamic and a more stable industry in the UK. Their work focused on how the pattern of management practices in these companies was related to certain facets of their external environment. The study revealed that organisations in a stable industry tended to be what they refer to as "mechanistic" i.e. having formal rules and procedures with a highly centralised level of decision making and narrow spans of supervisory control. Effective organisations in a more dynamic industry were typically more "organic" with almost opposite structural attributes to those of the mechanistic organisations referred to above. Woodward's (1958) study of about 100 firms in widely diverse lines of business in the South Essex area of England revealed that successful organisations in different industries with different technologies are characterised by different organisation structures. Chandler's (1962) in-depth study of four major American companies led him to conclude that new strategic choices arise from environmental changes. He argues *"strategic growth resulted from an awareness of the opportunities and needs - created by changing population, income and technology - to employ existing or expanding resources more profitably"*. For instance, his research reveals that *"growth through geographical dispersion"* led to the establishment of territorial offices. In other words, organisational structures follow and are guided by strategic decisions.

What the above studies suggest is that different technical and economic conditions outside the firm require different organisational responses or patterns within it. Other studies have looked at organisations and the environment in the same light. Lenz (1980) argues that the external environment of an organisation is viewed as the source of events and changing

[†] The resource-based approach advances the view that a company's strategy should seek to maximise the competitive benefit offered by the resources to which it has access. These resources include "core competencies", technological and production skills and "collective learning" about products and processes (Prahalad and Hamel, 1990).

trends, which create opportunities and threats for individual firms. Lawrence and Dyer (1983) propose a concept of adaptation, which they define as the *"process by which an organisation and its environment reach and maintain an equilibrium ensuring the survival of the system as a whole"*.

Over the years organisations have sought for ways of coping with the demands of the market environment. For instance, manufacturing firms have introduced a number of strategies to reduce internal and external uncertainties. For example, buffers help to reduce internal uncertainties, and the use of excess capacity cushions and forecasting techniques help to reduce some of the external uncertainties. However, many of these have proven to be inadequate. For instance, having excess capacity to deal with an unexpected increase in demand will be cost ineffective in times of a slump in demand. The implication of this is that organisations need to rethink the way that they carry out their operations. As explained earlier, the old way of doing business is characterised by the pursuit of increased productivity, a "mass production" regime. It was time to make a change, a significant shift in paradigm to one that provides the capability of coping with the dynamic market environment. Pine (1993) argues that *"when one paradigm fails, it is time to shift to another"*. For many organisations, the regime of mass production has been replaced with new paradigms such as mass customisation, time-based competition and lean production. Piore and Sabel (1984) have referred to this shift in paradigm as "the second industry divide".

1.1 The New Paradigms of Competition

A term first coined by Davis (1987), mass customisation refers to the manufacture of products that meet exactly an individual customer's wishes, but at costs and within time scales equivalent to a mass-produced standard item. Pine (1993) argues that the focus of mass customisation is the creation of variety and customisation through flexibility and quick responsiveness. Lampel and Mintzberg (1996) posit that mass customisation (which they refer to as "the logic of individualisation") has always been practised in some areas of economic activity such as personal tailoring, fine jewellery making, fine restaurant cooking, engineering capital goods and grinding prescription eyeglass lenses. More recently, there has been a move to greater customisation in a wide variety of industries, including services (Lampel and Mintzberg, 1996).

Mass customisation does not occur in isolation. The achievement of mass customisation is linked with advances in management such as lean production, time-based competition and manufacturing flexibility (Pine, 1993). Womack *et al* (1990) introduced the concept of "lean production". They argue that lean production is "lean" because,

"...it uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time....and produces a greater and ever growing variety of products."

Thus, the lean producer, *"combines the advantages of craft and mass production, while avoiding the high cost of the former and the rigidity of the latter"* (Womack *et al*, 1990). Stalk and Hout (1990) introduced the term "time-based competition". According to Stalk and Hout (1990), the idea behind time-based competition is *to "give customers what they want when they want it"*. They argue that time-based competitors are offering greater varieties of products and services, at lower costs and in less time than are their more "pedestrian competitors".

A common theme appears to underpin each of the new paradigms discussed above. That is, organisations must be able to respond in a timely manner to satisfy customers' demands which may be uncertain and may vary, while keeping their cost of operation low. In other words, organisations need to be flexible for a successful shift from the paradigm of mass production to a new paradigm such as mass customisation, lean production and time-based competition. For instance, in their discussion of the transition process from flexibility to innovation, Bolwijn and Kumpe (1990) argue that, it is quite possible to be flexible without being innovative, but the reverse is not true: *"you cannot be innovative without being flexible"*. Other authors have also recognised the central role of flexibility in the new paradigms. According to Stalk and Hout (1990), companies are dramatically improving their manufacturing response times by streamlining their factories and becoming more flexible. For instance, new-generation competitors use flexible operations to respond to their customers' needs by expanding variety and by increasing the rate of innovation in the least elapsed amount of time (Stalk and Hout, 1990). Womack *et al* (1990) argue that in order to achieve increased flexibility and low cost, the lean producers employ teams of multiskilled workers at all levels of the organisation and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety.

In an exploratory survey of UK firms to determine the effects of mass customisation on operations management, Ahlstrom and Westbrook (1999) report that implementation of mass customisation requires manufacturing flexibility and a change in view of the company's product variety. Lampel and Mintzberg (1996) develop a continuum of strategies with pure standardisation (having "zero" flexibility) at one end and pure customisation (having maximum flexibility) at the other end of the continuum. Pure standardisation is based on a "dominant and standard design" targeted to the broadest possible group of buyers. With pure customisation, the customer's wishes penetrate into the design process itself and the product is truly made to order (Lampel and Mintzberg, 1996). Between these two extremes are different strategies that depend on the degree of flexibility of the firm or the extent to which specific individual's wishes can be met by the firm.

In spite of the recognition of the central role of flexibility as discussed above, a number of questions on the issue of flexibility remains unanswered for both academics and practitioners. Until these questions are resolved, it is doubtful that any meaningful advances can be made in managing effectively, the evolution process of the paradigm shift from mass production to the "so called" new paradigms. This project seeks to expand the understanding on the issue of flexibility. It identifies and addresses some of the unanswered questions on flexibility in the context of manufacturing organisations. These issues are addressed in the main body of the thesis. The project, however, starts by reviewing the importance of flexibility and concludes this introduction chapter by highlighting the contribution of the research and describing the structure of the thesis.

1.2 The Importance of Manufacturing Flexibility

Flexibility is becoming a frequently used concept in the business literature. It is often seen as a "panacea" for manufacturing companies experiencing increasingly complex and turbulent environments, and it is a central concept used to describe a whole new generation of production equipment. And yet it presents a conundrum, a paradoxical concept where authors cannot agree on the answers to even the most basic questions. What is it? When should a company strive for it? And how it can be implemented in manufacturing organisations?

Flexibility can be defined broadly as the ability to change quickly (Bolwijn and Kumpe, 1990). The Collins English dictionary (1990) defines 'flexible' as something that can bend or be bent easily or that is manageable and adaptable. Slack (1997) argues that this definition translates into the ability of a system to adopt a range of states and the ease with which it moves from one state to another. The definitions of flexibility reveal the multi-dimensional nature of the concept of flexibility. Clearly the concept of flexibility is broad in scope. The challenge, therefore, lies not in expanding the concept but in focusing its content to the uses that are relevant.

As discussed earlier, a number of factors are responsible for the increased international competition, erosion of traditional types of comparative advantage and removal of entry barriers to market segments. These factors are what most rationales for flexibility are built on. Based on the studies by Porter (1986) and Sanchez (1991), Table 1.0 has been used to summarise the reasons for more competition in the market place (threats) and the opportunities these provide for manufacturing organisations operating in the competitive environment (introduction of more flexible automation).

Threat: More competition	**Opportunity: More flexible automation**
• Growing similarity of countries in terms of infrastructures and buyers needs	• The falling costs of advanced manufacturing technology (AMT) and IT solutions
• Transportation costs have fallen	• The growing expertise in the implementation and use of AMT and IT
• More compact, lighter products ease transportation	• CAD/CAM offers new levels of flexibility and creates opportunities for increased segmentation and responsiveness
• Falling tariff barriers	• Global competition has increased industry concentration; firms have the cash to finance new investment
• Information technology makes integration of geographically distant activities easier	• The slowing growth has created mature firms who are being outperformed by flexible competitors.
• Slowing rates of economic growth increases the importance of geographical expansion for companies	• The demand for autonomy in the work place might have pushed some firms to automate trivial tasks
• Technological restructuring e.g. microelectronics, information systems and advanced new materials shake up industry structures and create opportunities for shifts in international industry leadership	• The unstable demand patterns and increased perceived risk. Opportunity for flexible operators to position themselves due to their ability to cope with unstable demand patterns.
• New global competitors principally from East Asia	• The demand for quality has led to complex products that can only be made on advanced equipment
• Global over-capacity. New technologies are making direct labour costs less - important for comparative advantage	• Competitors installing AMT and competing on the parameters of customisation, variety, innovation and novelty.
• New technologies diffuse rapidly among countries through licenses, engineering companies, the scientific community, and multinational companies themselves. The new technologies do not always need a highly developed economy to thrive	
• Markets for natural resources and components have become increasingly global, largely eliminating access to them as a sustainable edge	

Table 1.0: Reasons for more competition and use of flexible automation
Source: Madsen (1993), adapted from Porter (1986) and Sanchez (1991)

A number of authors have argued that, flexibility provides manufacturing organisations with the capabilities of adapting to the requirements of a fast changing environment. This includes the ability to change levels of production rapidly, develop new products, and respond to competitive threats (e.g. Garett, 1986; Swamidass and Newell, 1987; Tombak, 1988 and De Meyer *et al*, 1989). These authors argue that the increasingly turbulent market environment warrants the need for organisations to look beyond the traditional manufacturing objectives of achieving quality consistency, low cost and high reliability towards the more difficult goal of flexibility.

Flexibility is one of the key objectives of any manufacturing system (Chatterjee *et al*, 1984), since it provides a critical measure of total manufacturing performance (Hayes and Wheelwright, 1984). Garrett (1986) argues that manufacturing flexibility is significant in coping with turbulence both within and outside the organisation. Internal organisational turbulence may be due to equipment breakdown, high absenteeism, rejects and rework (Buzacott and Mandelbaum, 1985). External turbulence may arise from high variability in demand levels, product mix, shortened product life cycle and actions of competitors (Zelenovic, 1982; Garrett, 1986; Guptal and Goyal, 1992). Global competition and shortening product life cycles demand manufacturing flexibility in terms of designing, developing and delivering products faster and in greater variety (Oliff and Marchand, 1991). Herroelen and Lambrecht (1989) posit that marketing pressures call for flexible systems, which are in strong contrast with large volume production of standardised products. According to Goldhar, Jelinek and Schlie (1991), the conditions that formerly supported economy of scale type logic are gone. In their place, conditions now support and reward factories that exhibit economy of scope and strategies that utilise flexibility.

Hyun and Ahn (1992) argue that, as competition grows fiercer in global markets, meeting customer needs requires an enhanced manufacturing capability such as manufacturing flexibility. Swamidass and Newell's (1987) study of thirty-five Pacific Northwestern machine tool manufacturing firms found a high degree of positive correlation between firm performance and flexibility. Thus, flexibility has major implications for a firm's competitive strength (Gupta and Somers, 1992). Flexibility can be used as an offensive strategy in which the firm is proactive and uses flexibility to create more uncertainty for others than for itself (Hyun and Ahn, 1992). It can also be used as a defensive strategy in which the firm becomes highly responsive to changing demand imposed on it (Swamidass, 1988).

To further highlight the strategic importance of flexibility, De Meyer *et al*'s (1989) study of manufacturers in Europe, North America and Japan showed that flexibility and cost efficiency are not necessarily trade-offs. Their study further revealed that in future, competitive battle would be waged based on manufacturing's ability to overcome the age-old trade-off between efficiency and flexibility. Miller and Roth's (1987) study of 270 large manufacturing firms revealed that flexibility was ranked from fourth to eighth (depending on the industry) with respect to future competitiveness. Cox's (1989) review of manufacturing strategies in eleven assembly plants revealed that the majority of the plant managers interviewed identified flexibility as a critical task for future competitiveness.

In spite of the recognition given to the issue of flexibility as outlined above, manufacturing flexibility does not appear to receive adequate attention with regard to investment in technology (Lim, 1987) and in implementation (Jaikumar, 1986). For instance, Cox's (1989) study mentioned above revealed that although all the managers interviewed identified flexibility as a critical task for future competitiveness, none of the plants included it among their top three formally tracked objectives for planning and control. In a comparative study of flexible manufacturing systems in the US and Japan, Jaikumar (1986) concluded that:

"...they (US organisations) are buying the hardware of flexible automation – but they are using it very poorly. Rather than narrowing the competitive gap with Japan, the technology of automation is widening it further. With few exceptions, the flexible manufacturing systems installed in the United States show an astonishing lack of flexibility. In many cases, they perform worse than the conventional technology they replace. The technology itself is not to blame; it is management that makes the difference. Compared with Japanese systems, those in the U.S. plants produce an order-of-magnitude less variety of parts".

The implication of the above is that flexibility must be carefully planned and managed and cannot be bought (Gustavsson, 1988). Slack's (1987) study of ten manufacturing companies echoes Jaikumar's observation. Slack's study revealed that managers had a partial rather than comprehensive view of manufacturing flexibility, and, that managers focused on resource rather than on system flexibility. The study also found that managers sought to limit the need for flexibility by pursuing three broad strategies:

1. Limiting product range and discouraging frequent product modifications
2. Pursuing make to stock rather than make to order strategies
3. Matching market segmentation with segmentation of the production system, thus reducing product range within each segment.

The general lack of proper understanding of the concept of flexibility and the neglect of the issue by practitioners is due to the multi-faceted nature of the concept itself. Because flexibility cuts across the entire organisation and academic literature, it has proved to be difficult to adequately conceptualise and understand, by both practitioners and academics. This research project has been undertaken to improve the understanding of manufacturing flexibility, thereby partially filling the gaps in the literature and practice of manufacturing flexibility.

1.3 Research Agenda

This thesis places the concept of manufacturing flexibility into a framework of manufacturing strategy. The reason for this is to make sure that nothing important is left out. As will be shown in the literature review, one can rarely argue sensibly about manufacturing flexibility without considering the appropriate strategic context. On the other hand, this thesis will not go further than manufacturing strategy. It will not consider how the corporate or business strategy is formulated, even though manufacturing strategy must operate within this context. The review of the manufacturing strategy literature is covered in Chapter 2 of the thesis.

In reviewing the literature cn manufacturing flexibility, this project adopts a classification proposed by Suarez *et al* (1996). They suggest that studies on manufacturing flexibility can be classified into the following categories.

1. Taxonomies of flexibility
2. Data-based studies of flexibility and performance
3. Historical and economic analyses of flexibility
4. Analysis and implementation of flexibility (theoretical frameworks and empirical evidence)

Many of the studies on manufacturing flexibility have focused on developing typologies of the concept (group 1 above). On the other hand, studies that seek to provide empirical evidence on the analysis and implementation of flexibility in manufacturing plants have attracted the least attention from researchers in the field (group 4). This project provides a critical review of the studies in the four groups stated above in Chapter 3.

Slack (1987) and Suarez *et al* (1996) classify the major taxonomies of manufacturing flexibility as follows.

1. Strategic or first-order manufacturing flexibility (i.e. types of flexibility that directly affect the firm's competitive position, e.g. volume, mix, delivery time and new-product flexibility).
2. Resource or Lower-order flexibility (e.g. routing, component, material flexibility, labour flexibility etc.)

This thesis will critically examine and contribute to the debate on manufacturing flexibility classification. The review of the manufacturing flexibility literature in Chapter 3, reveals that, of the strategic or first-order flexibility types, studies on the provision of empirical evidence on the analysis and implementation of *volume flexibility* in manufacturing plants have attracted the least attention in the literature. Thus, the thesis is focused on providing empirical evidence to understand better the issue of volume flexibility, and its implementation in manufacturing plants. This involves addressing issues such as, *what is volume flexibility? When should a company strive for it? And how can it be implemented in a manufacturing plant?* In order to maintain a logical chain of argument, these issues are covered in Chapter 4, where the literature on volume flexibility is reviewed, and the Research Questions for the project are developed.

The figure 1.1 below shows the road map for the literature coverage.

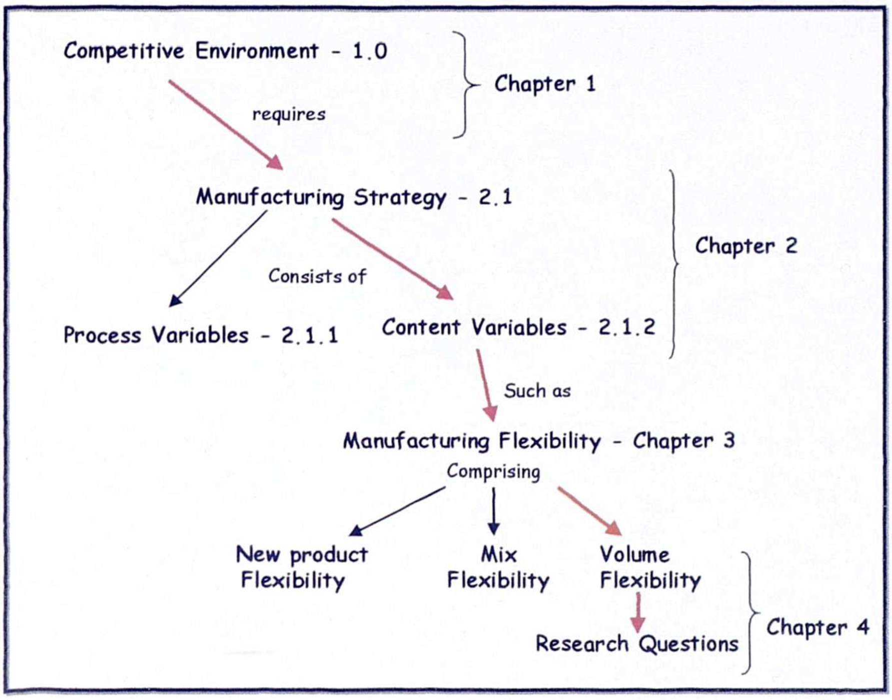


Figure 1.1: Road map for literature review coverage.

1.4 Research Strategy

Empirical research will be used to address the Research Questions developed for the project. It is planned to address the questions using research strategies that provide insights into the Research Questions from different perspectives (i.e. quantitative and qualitative research approaches). The main empirical research will be preceded by a pilot study. This is required to explore and provide insights into the basic issues of volume flexibility in manufacturing plants. The pilot study is also required to help refine data collection plans with respect to both the content of the data and the procedures to be followed (Yin, 1994).

1.5 Contribution of the Research

Voss (1995) proposes that because of the applied nature of the operations management field, many of the new developments in the field come from the interface between operations management and other disciplines. This study aims to bridge the gap between labour flexibility issues in the human resources management literature and technical aspects of production flexibility. This is addressed by identifying labour based solutions for achieving volume flexibility in manufacturing plants and explaining why and how these solutions are used to achieve volume flexibility. This has important policy implications in terms of how to achieve volume flexibility in manufacturing plants. It also has implications for the management of change in a production environment. Likewise, the research provides insights as to which solutions to employ and how to implement them for practising managers involved in managing in highly turbulent and uncertain environments.

The thesis builds on previous studies in the analysis and implementation of volume flexibility (e.g. Suarez *et al*, 1996). It expands the understanding of the classification of manufacturing flexibility and how volume flexibility can be measured in manufacturing plants, thus making a contribution to the manufacturing flexibility literature.

The study aims to identify the drivers of volume flexibility in manufacturing plants. This research also seeks to identify the contexts in which these drivers are applicable. These have important implications for the manufacturing flexibility literature as they show that volume flexibility is not an attribute that is always applicable to all manufacturing plants. Also, practising managers are able to do a proper assessment of volume flexibility needs prior to implementing volume flexibility.

1.6 Structure of the Thesis

Figure 1.2 below shows an overview of the structure of the thesis.

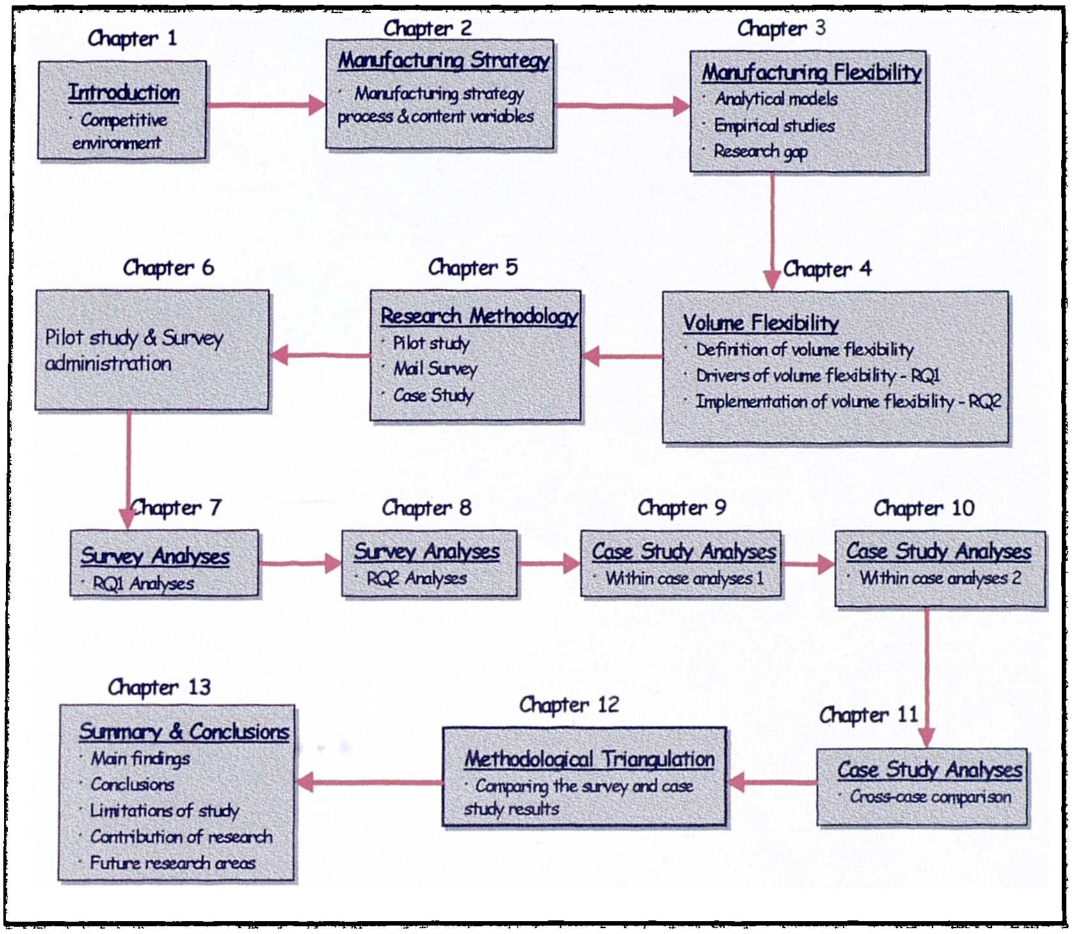


Figure 1.2: Structure of the thesis

The body of the thesis consists of thirteen chapters. The literature review is contained in Chapters 2, 3 and 4. Chapter 2 reviews the literature on manufacturing strategy. The chapter introduces two dimensions of manufacturing strategy as the process and content variables. Of the content variables, manufacturing flexibility is identified as the most suitable to cope with environmental uncertainty.

Chapter 3 reviews the literature on manufacturing flexibility. Studies within the manufacturing flexibility literature are classified as analytical models and empirical studies. Empirical studies on manufacturing flexibility are further divided into four groups including studies on the development of flexibility taxonomies, an area that has witnessed the bulk of the studies on manufacturing flexibility. In contrast, studies on the analysis and implementation of flexibility have attracted the least attention from researchers in the area. The research gap is identified within this group of studies and focuses on volume flexibility, a strategic flexibility type on which there is a dearth of studies compared to other strategic flexibility types such as mix and new product flexibility.

Chapter 4 reviews the literature on volume flexibility. It proposes a definition for volume flexibility from the review of various definitions proposed by notable researchers in the field. The chapter addresses the complex problem of measuring volume flexibility. It does this by reviewing the literature on volume flexibility measurement and contributing to the literature by suggesting a way forward. The chapter also compares the use of volume flexibility with the use of stock levels to cope with demand fluctuations. The discussion leads to the development of the first Research Question for the project. The chapter discusses various sources of volume flexibility and develops the second Research Question for the project to conclude the literature review phase.

The empirical phase for the project is covered in Chapters 5, 6, 7, 8, 9, 10 and 11. Chapter 5 explores the suitable research strategy for carrying out the empirical phase of the project. Based on the nature of the Research Questions, a combination of mail survey and case study is proposed. These are to be preceded by a pilot study, which is used to explore the basic issues of volume flexibility in respect of the Research Questions and to test data collection procedures.

Chapter 6 describes the pilot study. Four manufacturing plants from various sectors similar to targeted sectors for the mail survey and case studies are selected for the pilot study. The chapter presents the analyses of the cases and presents the variables identified in respect of the two Research Questions. These variables and others identified from the literature review are used to design a questionnaire for the mail survey. The chapter presents a justification matrix for the questionnaire design and describes the administration of the mail survey of 529 UK manufacturing plants selected from the Cranfield Best Factory Award database.

Chapter 7 describes the steps undertaken to analyse the survey response questionnaires in respect of first Research Question. This chapter compares the conditions identified from the pilot study with those identified from the survey analyses. Generally, this chapter provides some insights to answer the first Research Question.

Chapter 8 describes the survey analyses done in respect of the second Research Question. Labour based solutions for achieving volume flexibility are identified in this chapter. Furthermore, the chapter investigates the relationships between these solutions in achieving volume flexibility. Based on the results of the analyses, two additional Research Questions are developed in this chapter.

Chapter 9 describes the research design and analyses for the case studies. Of the 120 plants that responded to the survey, 8 manufacturing plants are selected for the case studies based on the richness of the information they provided. The selection is done using the replication rather than the sampling logic. The chapter describes the within-case analyses carried out in four plants relating to the Research Questions. The analyses also reveal the benefits derived from using various volume flexibility solutions and identify the key factors for implementing the solutions in manufacturing plants. Chapter 10 is a replica of chapter 9 but contains within-case analyses in the four remaining plants of the case study research.

Chapter 11 describes the cross-case comparison. It explores the similarities and differences in and across the 8 cases in respect of the four Research Questions. Chapter 12 is the methodological triangulation chapter where the results of the survey research are compared with the results of the case studies. Tentative conclusions resulting from the project are derived from this comparison.

Chapter 13 summarises and concludes the study. The chapter summarises the literature review and the main findings of the study in line with the Research Questions developed for the project. The chapter discusses the limitations of the research project and the contributions of the research to knowledge. Finally, the chapter identifies future research areas.

Chapter 2 – Manufacturing Strategy

2.0 Introduction

Figure 2.0 below has been used to summarise the literature coverage area of the literature review.

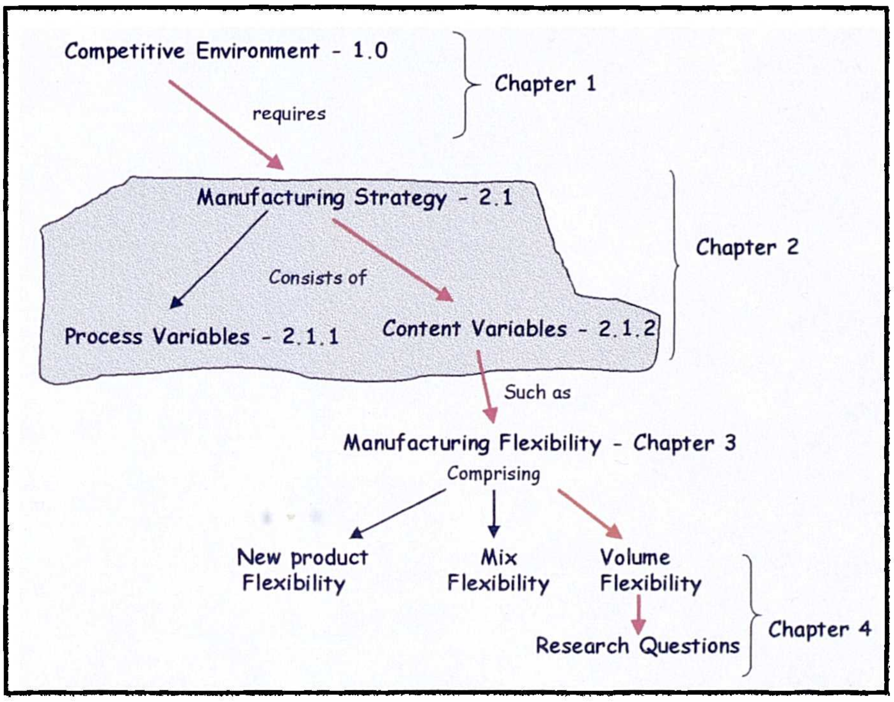


Figure 2.0: Structure of the literature review. Chapter coverage shaded

The literature review for this thesis is covered in Chapters 2, 3 and 4. Chapter 2 discusses the need for organisations to have an adaptive manufacturing strategy in a competitive environment. The chapter thus focuses on reviewing the manufacturing strategy literature. Chapter 3 reviews the literature on manufacturing flexibility. Chapter 4 reviews the literature on volume flexibility and identifies the research gap for the project.

The concept of manufacturing strategy has attracted increasing attention from researchers and practitioners. Over the years, manufacturing organisations have realised the importance that manufacturing strategy plays in firms' competitiveness. Reduced competitiveness, increasing turbulence and uncertainty in the market environment are some of the drivers of the need to re-evaluate the role of manufacturing in organisations (Skinner, 1969).

In reviewing the literature on the concept of manufacturing strategy, this chapter focuses on the process and content of manufacturing strategy. The chapter is concluded with the introduction of manufacturing flexibility as the content variable of manufacturing strategy needed by manufacturing organisations operating in highly turbulent and uncertain market environments.

2.1 Manufacturing Strategy

Hofer (1975), and Hofer and Schendel (1978) suggest a hierarchy of strategic decision making consisting of three levels. The first is the corporate strategy, which operates within large multi-business corporations. This involves the selection of product markets or industries and the allocation of resources among them. The second level is the business strategy required by business units within a multi-business corporation, which is required to identify and use the business's distinctive competencies as competitive weapons. The third level consists of a cluster of functional strategies of which manufacturing strategy is one. Others include marketing strategy, research and development strategy and financial strategy. These functional strategies are formulated to complement the business and the corporate level strategies. For a manufacturing organisation, *"an effective manufacturing strategy clarifies the links between overall competitive strategy and the development of the company's manufacturing resources"* (Slack, 1991).

Skinner's (1969) contribution is widely regarded as the pioneering work in helping to conceptualise manufacturing strategy as a significant enabler of competitiveness in manufacturing organisations. Traditionally, manufacturing was seen simply as an operational function. With increased technological changes in production equipment and increased foreign competition, the potential of manufacturing as a competitive weapon could no longer be overlooked by manufacturing organisations. Thus, Skinner (1969, 1974) advanced four principles which were later summarised by Adam and Swamidass (1992) as:

1. *The manufacturing function can and should be employed as a competitive weapon*
2. *Cost and efficiency are inadequate goals for manufacturing*
3. *A factory that focuses on a narrow product mix for a particular market niche will outperform a conventional plant (Skinner, 1974)*

4. *The successful implementation of manufacturing strategy is a top-down process that requires manufacturing to conform to a manufacturing task derived from competitive strategy.*

A number of authors have since addressed the strategic role of the manufacturing function. In support of Skinner's first principle above, Hayes and Wheelwright (1984) argue for the transformation of the manufacturing role from being primarily reactive to being primarily proactive. The fourth level of their stages in the evolution of manufacturing's strategic role proposes that manufacturing should develop capabilities in advance of need.

In respect of Skinner's second principle above, a number of authors have identified other goals for manufacturing, other than cost and efficiency, in support of Skinner's argument (e.g. Buffa, 1984; Hayes and Wheelwright, 1984; and Hill, 1993). These are referred to as manufacturing strategy content variables and are discussed in detail in Section 2.1.2.

Skinner's third principle is that of focus, and this leads to his "plant within a plant" concept. Focus in manufacturing is achieved by concentrating each part of the manufacturing system on a particular set of products and markets. So each "sub-plant" or "plant within a plant" would have its own dedicated facility and workforce, and concentrate on its own manufacturing task. Skinner (1978) describes the "manufacturing task" as a clear and concise statement of the goals and priorities which the manufacturing function must seek to deliver in terms of cost, quality and other applicable objectives of the manufacturing function. Hill (1993) extended Skinner's concept of focus by defining the "manufacturing task" as the means of determining an appropriate focus.

The concept of the focused factory advanced by Skinner has attracted some controversy. Hayes and Pisano (1996) argue that the "lean manufacturing" principle (Womack *et al*, 1990) appears to refute the necessity for focus. Womack *et al* (1990) argue that, by combining the advantages of craft and mass production (i.e. avoiding the high cost of craft and the rigidity of mass production), the lean producer is able to achieve different manufacturing objectives such as, lower cost, higher quality, faster product introductions, and greater flexibility – all at the same time. Ferdows and De Meyer (1990) argue that different competitive priorities are not necessarily in conflict with one another, and that they could even reinforce one another. According to Skinner (1996), *"advocates view the preview of focus as product and volume; that is, if you confine a plant to a limited product line and range of production schedules, you will have a focused factory"*. He argues that focus is about directing the entire set of a factory's manufacturing policies, toward one single manufacturing task. *"...this has nothing to do with size; it has everything to do with design of the system. Focus is a state of mind and focusing is the management process of designing a coherent structure to accomplish a strategic task"* (Skinner, 1996).

Skinner's third principle of focus invariably leads to making choices in manufacturing. *"In each decision area – plant and equipment, production planning and control, and so forth – top management needs to recognise the alternatives .... It needs to become involved to the extent that the alternative selected is appropriate to the manufacturing task determined by the corporate strategy"* (Skinner, 1978). According to Schonberger (1985), operations must aim to be good at everything. Heskett *et al* (1997) argue that trade-offs do not result in 'outstanding' achievements. However, in support of Skinner's views, New (1992) argues that although advances in technologies and process capabilities have overcome some trade-offs, others still exist. New (1992) argues *"...every manufacturing mix is a set of decisions about trade-offs and, however good you become at minimising the effects of the trade-offs, they will not all go away. You can certainly become better at everything simultaneously but some trade-offs, particularly those associated with levels of customisation/standardisation, will not go away"*.

Slack (1991) notes that the idea behind manufacturing management appears to consist almost entirely of handling trade-offs. He argues that while there is some truth in the trade-off argument, *"it is certainly not the only way to gain long-term competitive advantage"* (Slack, 1991). Using a conventional seesaw as an illustration Slack (1991) argues that in the short term, one performance objective can be improved at the expense of another. But over the longer-term horizon, it is possible to make improvements in all aspects of performance by *"moving the pivot"* (i.e. making changes in the structure, constraints, assumptions and culture of the manufacturing system). Slack (1998) reiterates this view by arguing that in the longer term, there is a need for the moderation of the trade-offs.

While the trade-off argument has attracted a lot of debate amongst researchers in the operations management field, a number of authors have agreed on the primary aim of manufacturing strategy, which is to support the achievement of an organisation's competitive advantage (Wheelwright, 1984; Buffa, 1984 and Skinner, 1985). Thus, Swamidass and Newell (1987) define manufacturing strategy as *"the effective use of manufacturing strengths as a competitive weapon for the achievement of business and corporate goals"*.

The common themes in the manufacturing strategy literature are classified as manufacturing strategy process and content (Adam and Swamidass, 1992). Issues regarding manufacturing strategy process and content have been discussed by many authors in the manufacturing strategy literature. The process of manufacturing strategy refers to how strategic decisions are reached in an organisational setting (Chin-Fu, 1996). Skinner's fourth principle, which suggests a top-down approach for defining and implementing manufacturing strategy, is an example of a process model of manufacturing strategy. Manufacturing strategy content refers to the specifics of what was decided in terms of the strategy (Adam and Swamidass, 1992). The manufacturing strategic process and content are examined next in Sections 2.1.1 and 2.1.2 respectively.

2.1.1 Manufacturing Strategy Process

This refers to the process of formulating and implementing manufacturing strategy. Skinner's model of manufacturing strategy process as discussed earlier is essentially a top-down view of manufacturing strategy. Others including Wheelwright (1978) and Womack and Roos (1996) have also supported this view. Swamidass and Newell (1987) propose three stages in the top-down manufacturing strategy process shown above as Skinner's fourth principle:

1. Developing a manufacturing task based on business strategy – making sure the goals and objectives of the manufacturing function are in line with the business strategy

2. Aligning the policies and efforts of the manufacturing infrastructure to the task developed - Skinner (1978) identifies the significance of the manufacturing infrastructure in the process of developing and implementing manufacturing strategy. Manufacturing infrastructure refers to the internal systems through which the production process is carried out. These include wage systems, organisations levels, production control and the like (Skinner, 1978). Thus, for an effective manufacturing strategy the internal systems must support or be compatible with the task or the statement of what the manufacturing function must accomplish.

3. Involving the manufacturing managers in the definition and implementation of the manufacturing strategy - In their empirical work on 35 manufacturers, Swamidass and Newell (1987) found that environmental uncertainty influenced the role of the manufacturing manager in strategic decision making. This study highlights the

significance of the role of the manufacturing managers in strategy formulation and implementation, thereby supporting Skinner's (1978) view on strategy formulation.

Hill (1993) argues for the need for manufacturing organisations to distinguish differences as part of the strategy formulation process. He suggests that this should be achieved by identifying and applying the concept of "order winners" and "qualifiers" to the manufacturing task. *Order qualifiers* are defined as those criteria that are necessary even to be considered by a customer as a possible supplier. *Order winners* are those criteria which win the order (Hill, 1993). He argues that in developing a manufacturing strategy, the identification of relevant order-winners for different products is a key step. Manufacturing strategy, therefore, should consist of the strategic tasks required of manufacturing in order to support those order-winners and qualifiers which exist in a company's markets and which relate directly or indirectly to manufacturing (Hill, 1993). This reflects a bottom-up view of manufacturing strategy development.

Harrison (1997) argues that neither bottom-up nor top-down versions are satisfactory. He proposes basing manufacturing strategy development on three categories of enablers, which combine the advantages of both versions of manufacturing strategy development. These are - trade-offs, best practice and specific enablers. Many authors have made a number of contributions to the process of developing manufacturing strategy. The core process variables identified in the literature have been summarised by Adam and Swamidass (1992) in the table below.

Process variables	Hill (1993)	Miller and Roth (1988)	Schroeder *et al* (1986)	Skinner (1978)	Swamidass and Newell (1987)	Wheelwright (1984)
Infrastructure	Yes			Yes		
Manufacturing task			Yes	Yes		
Order winning criteria	Yes					
Role of Manufacturing managers				Yes	Yes	
Consistency between manufacturing and business strategies	Yes					Yes
Consistency between manufacturing and other functional strategies	Yes					Yes
Consistency between manufacturing task and infrastructures				Yes		Yes

Table 2.1: Manufacturing strategy process variables in the literature.
Source: Adam and Swamidass (1992).

2.1.2 Manufacturing Strategy Content

The manufacturing strategy content focuses on the specifics of what was decided (Adam and Swamidass, 1992). These are the objectives of the manufacturing function. Traditionally, manufacturing objectives were limited to achieving low costs, high efficiency and productivity. The changing nature of the market environment has rendered these objectives inadequate for the achievement of excellence in the market place. The inclusion of other objectives or dimensions of manufacturing strategy such as quality, dependability, service and reliability, and flexibility has been suggested by a number of authors (Skinner, 1969, 1992; Buffa, 1984; Wheelwright, 1984).

Wild (1980) classifies the manufacturing objectives into those concerned with customer service and those concerned with resource productivity. He defines the customer service objectives as those related to product specification, delivery time and cost. The resource productivity objectives are concerned with the measures of the utilisation of the manufacturing resources. Hill (1993) defines manufacturing objectives in terms of "order-winning criteria" which include reliability, delivery speed, quality, price, colour range and design leadership. Slack's (1991) definition of manufacturing objectives includes cost, responsiveness, quality, dependability and flexibility.

Adapted from Adam and Swamidass (1992), the contribution of various authors on the issue of manufacturing strategy content or objectives are summarised in Table 2.2.

Content variables	New and Sweeney (1984)	Hill (1993)	Miller & Roth (1988)	Schroeder *et al* (1986)	Skinner (1978)	Swamidass (1986)	Wheelwright (1984)	Wild (1980)	Buffa (1984)	Fine & Hax (1985)	Slack (1991)	Hayes *et al* (1988)	Frequency
Capacity				Yes			Yes						2
Cost/Price/ Productivity	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	11
Delivery	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes	Yes	Yes	10
Product design & engineering		Yes				Yes							2
Distribution			Yes										1
Employee relations				Yes									1
Facilities							Yes						1
Flexibility	Yes	Yes	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	10
Focus		Yes			Yes								2
Infrastructures		Yes											1
Quality	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	11
Return on investment					Yes								1
Service			Yes	Yes	Yes								3
Standardisation		Yes											1
Technology-process		Yes		Yes	Yes	Yes	Yes						5
Innovativeness	Yes											Yes	2
Vertical integration							Yes						1

Table 2.2: Manufacturing strategy content variables in the literature. Adapted from Adam and Swamidass (1992).

It is pertinent to note from the above table that the most frequently stressed content variables in the literature appear to be cost efficiency, delivery speed and dependability, quality and flexibility. Adam and Swamidass (1992) refer to the four variables as the core content variables of manufacturing strategy.

As argued previously, cost efficiency and productivity have been the traditional focus of the manufacturing function. In the seventies, in response to the increasing competitive strengths of some Japanese companies, the objective of achieving consistency in product quality came to the fore of manufacturing objectives in western countries such as the United States and the United Kingdom. As the environment becomes more competitive and increasingly uncertain, the objectives of achieving delivery speed and dependability as well as flexibility have become increasingly important competitive priorities for manufacturing organisations in addition to the traditional objectives. Thus, in terms of manufacturing content, the shift of the manufacturing literature in the last few years has been towards emphasising the increasing importance of achieving delivery dependability and flexibility. However, it is not sufficient to focus only on the content variable in the formulation of manufacturing strategy. Swamidass and Newell (1987) argue that getting the process and content of the manufacturing strategy right is vital to the success of a firm's manufacturing strategy.

Swamidass and Newell (1987) propose a model, which shows that manufacturing strategy content as well as process is influenced by environmental uncertainty. The model shown in Figure 2.1 is based on the premise that since industrial organisation, marketing and administrative behaviour literature have identified strategy to be a major determinant of a business's performance, and the environment in turn a determinant of strategy (Jemison, 1981; White and Hamermesh, 1981), there exists a sequential relationship among external environment, strategy and business performance (Swamidass and Newell, 1987).

Skinner (1978); Wheelwright (1978); Raffi and Miller (1983); and Raffi (1984a,b) all recognise the importance of the 'role of manufacturing managers' in the formulation and implementation of manufacturing strategy. Schonberger (1982); Hall (1983); Buffa (1984); Wheelwright (1984); Slack (1991); and Chambers (1992) recognise the value of flexibility in adapting to changes. Swamidass and Newell (1987) argue that of the core dimensions of manufacturing strategy content and the dimensions of manufacturing strategy process, *'flexibility'* and the *'role of manufacturing managers in strategy formulation'* are respectively the most significant in coping with environmental uncertainty.

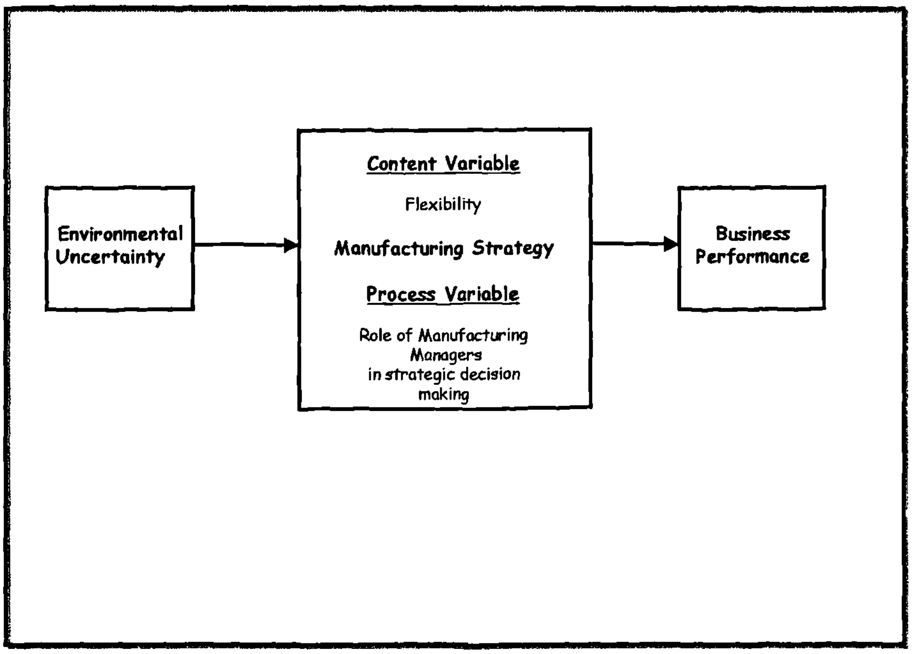


Figure 2.1: A contingency theory based model of manufacturing strategy
Source: Swamidass and Newell (1987)

Very few empirical studies have been carried out on manufacturing process variables. This may be due to the general agreement that exists in the literature about the process of developing manufacturing strategy (Correa, 1992). For instance, many authors agree on a top-down approach of formulating manufacturing strategy. Also, there is a general agreement about the need for the manufacturing function to assume a proactive rather than a reactive role within the organisation, implying that a bottom-up component should be incorporated into the top-down approach (Correa, 1992; Hill, 1993 and Harrison, 1997). In contrast, there has been a general lack of consensus on the manufacturing strategy content issues especially on the concept of manufacturing flexibility. In a market environment witnessing increasing uncertainty, fierce competition and turbulence it has become absolutely necessary for practitioners and academics to address the issue of manufacturing flexibility, which appears to be the most novel of the manufacturing strategy content variables. Thus, the literature review process in this research is narrowed down to the issue of flexibility in manufacturing plants, a manufacturing strategy content variable that provides the necessary hedge against environmental uncertainty and turbulence.

2.2 Chapter Summary

This chapter builds on the introduction chapter. The introduction chapter examined the nature of today's competitive environment and highlighted the fact that strategic decision making provides organisations with the capability of adapting to the environment. For manufacturing organisations, defining the direction of manufacturing through the formulation of a manufacturing strategy within the context of an organisation's corporate strategy is vital for effective competitiveness. This chapter has reviewed the contributions of various authors on the issue of manufacturing strategy formulation. The dimensions of manufacturing strategy classified as the process and content of manufacturing strategy have been discussed. Based on the summary of literature on these dimensions, the chapter has identified the core manufacturing content variables of which flexibility is one. The chapter is concluded with a focus on the issue of flexibility in manufacturing organisations as a top priority objective of manufacturing organisations operating in an uncertain and turbulent environment. The next chapter will review the literature on manufacturing flexibility.

Chapter 3 – Manufacturing Flexibility

3.0 Introduction

Following the discussion of manufacturing strategy and the identification of flexibility as the research focus in Chapter 2, this chapter builds on this work by reviewing the literature on the manufacturing flexibility concept. Studies in the literature on manufacturing flexibility are grouped as analytical and empirical models. The chapter focuses on empirical studies of manufacturing flexibility. It discusses the various taxonomies of manufacturing flexibility and concludes by focusing the research on the issue of volume flexibility in manufacturing plants. An edition of this chapter titled, *"Manufacturing flexibility, an invaluable component of manufacturing strategy"* was presented at the International Symposium on Manufacturing Strategy (ISMS '98) in Tokyo, Japan, November, 1998.

The shaded portion of the figure below shows the focus of the literature coverage in this chapter.

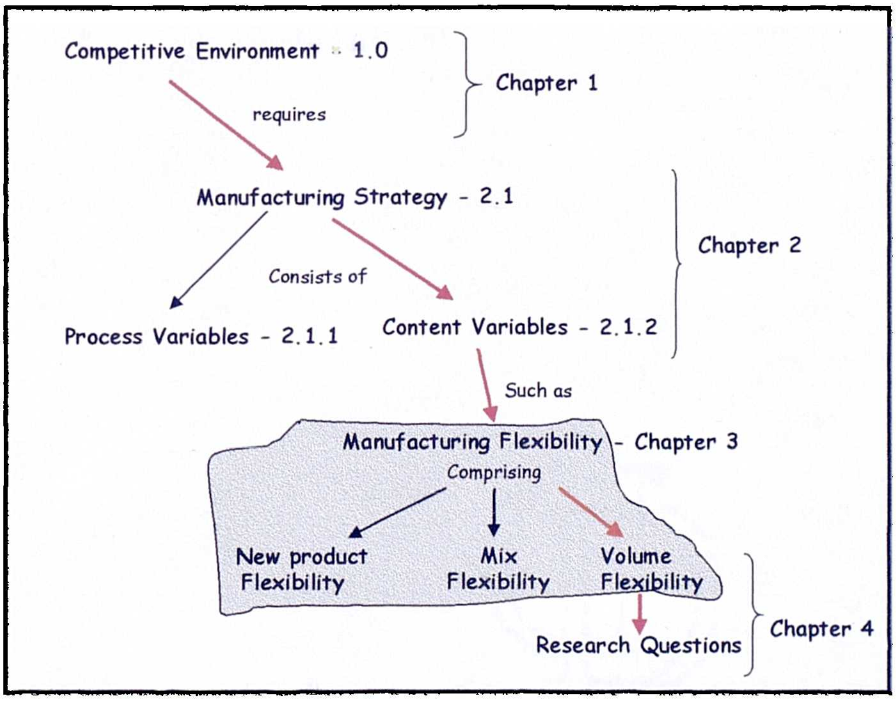


Figure 2.0: Literature review road map. Focus of the chapter (shaded)

3.1 Manufacturing Flexibility

The concept of flexibility has attracted much attention in recent years from managers and academic researchers concerned with firms' competitiveness and the evolution of production and design technology. As noted in the previous chapter, flexibility is seen as one of the core content variables of manufacturing strategy. Slack (1989) initially argues that flexibility is a second order competitive criterion as it only supports the other criteria upon which a firm wins orders. Subsequently, Slack (1991) promotes flexibility as not only a means to an end but an objective that could sometimes be a direct competitive criterion. Correa (1992) argues along the same lines. He notes that although flexibility can have an important role in supporting the achievement of the other competitive criteria, there are circumstances where it can be a first order criterion for a firm.

This research project posits that the interactions between flexibility and some of the other performance objectives are not always in one direction. In other words, some performance objectives support the achievement of flexibility just as flexibility supports their achievement. Take for instance a performance objective, *speed*. A certain plant 'A' may be inflexible (referring to the inability of the equipment set to switch between different products without significant loss in total output), but is able to operate a particular production process to produce a particular product at high speed. This plant will be able to change into producing a different variety of products quicker than a similarly inflexible plant 'B' that has the same equipment set configurations but a slower production process. From the customer's point of view, plant 'A' is perceived to be more flexible than plant 'B' at least in terms of supplying a variety of products quicker. In other words, *speed* enables plant 'A' to have the flexibility of being able to change from the production of one product to the other quicker than its competitor. It is, however, also true that having this type of capability may result in lower *cost* for plant 'A', better *dependability* and even further improves the *speed* of delivery.

Some researchers have discussed flexibility in terms of the versatility of people and skills (e.g. Piore and Sabel, 1984) while others have viewed it in terms of programmable machines and capabilities for mixing models in production (Jaikumar, 1986, Fine and Pappu, 1988). Generally the literature on the concept of flexibility is fragmented and attempts to reach a consensus on its definition have been inconclusive.

Mandelbaum (1978), reported in Gerwin (1987) defines flexibility as "the ability to respond effectively to changing circumstances". Mandelbaum's definition highlights the complexity of the concept of flexibility. As Correa (1992) argues, *"..the ability to.."* in the above definition implies a *"potential"*. Suarez *et al* (1996) highlight the importance of differentiating between aspects of flexibility as the *"ability"* to cope with change and as *"efficiency of effectiveness in coping with change"*. The latter implies a flexibility measure that can be based on historical records, that is a demonstrated flexibility. However, this past performance may not give a true reflection of the system's ability (or potential) to cope with changes. This poses another challenge in terms of measuring flexibility. Measurement of flexibility is an issue, which has been dealt with but not yet resolved by researchers in the flexibility literature.

The *"...changing circumstances.."* part of Mandelbaum's (1978) definition of flexibility has two underlying factors of uncertainty and variability (Correa, 1992). This adds to the complexity of the definition and indeed of the flexibility concept itself. Bhattacharya *et al* (1995) reported in Harrison (1996) describe variability measures as *"the changes in demand on a manufacturing system over a given sequence of time buckets forecasted at a given point in time"*. Uncertainty is defined as *"the changes in demand on a given time bucket as it moves in time and approaches the delivery due date"*. Slack (1991) differentiates between short-term and long-term uncertainty. Short-term uncertainty relates to a situation whereby demand is highly unpredictable from period to period but the overall total demand over the planning horizon may be relatively predictable. With long-term uncertainty, a firm cannot be sure of the demands placed on it over the planning horizon. Thus, with an umbrella term like *"changing circumstances"* Mandelbaum's definition may not be that useful to a firm exposed to either of the conditions of variability or uncertainty. This is because different conditions may require different coping strategies. This further highlights the complex and generic nature of Mandelbaum's definition of flexibility. However, this definition has been very useful as pioneering work in understanding the nature of the concept of flexibility.

The general lack of a proper understanding of the concept of flexibility and the neglect of the issue by practitioners is due to the multi-faceted nature of the concept itself. Because flexibility cuts across the entire organisation and academic literature, it has proved to be difficult to adequately conceptualise and understand, by both practitioners and academics. However, a number of authors have tried to conceptualise and provide classifications of flexibility.

Suarez *et al* (1991, 1996) classify the literature on manufacturing flexibility into two broad groups. These are analytical models and empirical studies.

3.2 Analytical Models

The literature in this group has provided a set of models that try to capture, usually in rather restrictive settings, the relationship between flexibility and other policies such as inventory levels, and the conditions under which flexibility may be valuable. Fine (1989) classifies the studies under this group into four areas.

1. Flexibility and life cycle theory
2. Flexibility as a hedge against uncertainty
3. Interactions between flexibility and inventory
4. Flexibility as a strategic variable that influences competitor' actions (mainly game-theoretical models).

Most of the modelling work on flexibility has actually come from the operations research and operations management fields. Many of these models are based on the premise that there are two types of production technology available to a firm. One is dedicated and the other is a flexible manufacturing system (Suarez *et al*, 1991). These models of flexibility are also based on different assumptions about demand. Demand could be random, seasonal or cyclical. Suarez *et al* (1991) argue that different assumptions are also made in terms of timing and investment reversibility in order to suit the particular problem being explored by the researcher.

By evaluating the benefits which flexible manufacturing systems provide over a dedicated line, one would observe that the benefits vary for each area of studies outlined above. Studies in areas listed above have been analysed for their benefits below.

1. *Flexibility and life cycle theory* - Flexible Manufacturing Systems (FMS) give the possibility of capturing inter-temporal economies of scope (Goldhar and Jelinek, 1983).
2. *Flexibility as a hedge against uncertainty* - The ability of flexible manufacturing systems to cope with a range of types of uncertainty in production provides the benefits.
3. *Interactions between flexibility and inventory* - Flexible Manufacturing Systems tend to reduce the need for inventories, hence saving possible inventory holding costs.

4. *Flexibility as a strategic variable that influences competitors' actions* - By their very nature, flexible manufacturing systems provide the firm with the ability to enter new markets. FMS could also involve heavy investments thereby increasing barriers to entry to potential competitors having traditional dedicated lines. In both cases, they tend to act as a strategic weapon against competitors.

Critique of Analytical Models

Analytical models have added important insights and dimensions to the problem of technology selection, but there are some problems associated with the studies. Suarez *et al* (1991) argue that in many of the mathematical models, the players are worse off with flexible manufacturing systems. For instance, in studies of group four above, Fine and Pappu (1988) argue that the FMS player's creation of barriers to entry may not hold since firms with dedicated lines have investments that are irreversible and may not be interested in shifting the focus of manufacturing.

Most analytical models make no distinction between flexibility and flexible manufacturing systems. The studies regard flexibility as a box of embodied technology that a firm can easily buy and operate (Hutchinson and Holland, 1982; Karmarkar and Kekre, 1987; and Fine and Li, 1988). The models focus on issues in operations management including inventories and scheduling and neglect the strategic and organisational issues of flexibility (Caulkins and Fine, 1990). For instance, the analytical models ignore the human resources aspects of flexibility such as the role of workers in providing flexibility for a firm (Suarez *et al*, 1991). This narrow view of flexibility by authors in this area is due to the way that flexibility has been defined. Many of the models define flexibility as the ability to produce a variety of products. Thus, the studies all tend to fall within a dimension of flexibility referred to as mix flexibility.

The table below summarises the studies that are based on analytical models of flexibility.

Flexibility & Life Cycle Theory	Fine and Li (1988) Hutchinson and Holland (1982) Hutchinson (1986)
Flexibililty & Uncertainty	Kulatikala (1988) Gupta, Buzacott and Gerchak (1988) He and Pindyck (1989)
Flexibility & Inventory Levels	Porteus (1985, 1986) Karmarkar & Kekre (1987) Caulkins & Fine (1990) Graves (1988)
Flexibility & competitive Dynamics	Gaimon (1988) Fine & Pappu (1988) Tombak (1988)

Table 3.0: Summary of studies on analytical models of flexibility
Source: Suarez et al (1991)

3.3 Empirical Studies

The literature in this group addresses issues such as the importance of flexibility, and the characteristics of flexible manufacturing systems and organisations as compared to more rigid "mass production" regimes (Suarez *et al*, 1991).

Studies in this group are classified into four groups. These are:

1. Data-based studies of flexibility and performance
2. Historical and economic analyses of flexibility
3. Strategic frameworks used for analysing flexibility.
4. Taxonomies of flexibility

Most of the studies relating flexibility to performance have been based on hypothesis testing, where data on flexibility are collected and analysed to test specific hypotheses. Studies in this group includes Tombak's (1988) sample of 1445 business units using PIMS data and Fiegenbaum and Karnani's (1991) analyses of the relationship between size of firm and output flexibility. The research carried out by Fiegenbaum and Karnani (1991) is critically evaluated in Chapter 4.

The studies in the second group (i.e. historical and economic analyses of flexibility) consider the strategic importance of flexibility for the firm, industry or country competitiveness. Embedded mainly in the social sciences, economics, management and political science disciplines, these studies generally seek an understanding of the relationship between flexibility and industrial competitiveness as an evolutionary process. The studies differ from those in the first group in that they seek to develop frameworks to understand the concept of flexibility rather than collect data to test specific hypotheses. Examples of studies in this group include Piore and Sabel (1984), Womack *et al* (1990) and Cusumano (1992).

Studies in the third group build strategic frameworks for the analysis and implementation of flexibility. The studies in this group can be sub-divided into two areas. These are:

a. Studies that provide theoretical frameworks for analysing the implementation of flexibility (e.g. Cox 1989; Sethi and Sethi 1990; Suarez *et al* 1991; Gerwin 1991; and Hyun and Ahn 1992).

b. Studies that provide actual empirical evidence for the implementation of flexibility (e.g. Suarez *et al,* 1996). By and large there has been a general dearth of studies in this group.

The fourth group consists of studies that develop and discuss the various dimensions and taxonomies of the concept of flexibility.

Taxonomies of Flexibility

Manufacturing flexibility is a complex, multi-dimensional and difficult-to-synthesise concept (Sethi and Sethi, 1990). In trying to understand the concept of flexibility, various authors have recognised the necessity of identifying and presenting taxonomies of manufacturing flexibility. In fact the bulk of research on the issue of flexibility deals with identifying the taxonomies of flexibility. These classifications vary according to the approach adopted by the particular author (Correa, 1992).

Mandelbaum (1978) defines two types of flexibility as *state* and *action* flexibility. *State flexibility* is the ability to function with an unchanged system under new circumstances. *Action flexibility* is the ability to implement changes to the system itself under new circumstances.

Zelenovic (1982) defines two types of flexibility as *design adequacy* and *adaptation* flexibility. *Design adequacy* is the probability that the given structure (i.e. measuring equipment, machines, storage and control devices, handling equipment and plant layout) of a production system will adapt itself to the changing environmental conditions and to the process requirements within the limits of the given design parameters. *Adaptation flexibility* is the ability of the system to transform from one to another job task in a minimum amount of time.

Buzacott (1982) classifies manufacturing flexibility as *job* and *machine* flexibility. *Job flexibility* is the ability of the manufacturing organisation to cope with the changes in the jobs to be processed by the system. *Machine flexibility* would be a lower level flexibility defined as the ability of the system to cope with changes at the resources or machine level. Increasing total capability can increase job flexibility at the system level and increasing machine capability can increase job flexibility at the machine level. Machine flexibility can be increased at the machine level by buffering the machine with inventory and at the system level by being able to route products through different machines in case of breakdown on one machine.

Brown *et al* (1984) develop a broad typology of flexibility as follows:

Machine Flexibility - ease of retooling for a given part
Mix Flexibility - ease of changing the part being processed
Design Flexibility - ease of changing a single product design
Routing Flexibility - ease of circumventing a halted system component
Volume Flexibility - ease of operating at non-optimal levels of output
Expansion Flexibility - ease of expanding plant capacity
Operation Flexibility - ease of changing the sequence of operations
Production Flexibility - ease of changing the universe of part types produced.

Based on the above definitions, Brown *et al* (1984) build a model that shows the inter-relationships between the different types of flexibility identified.

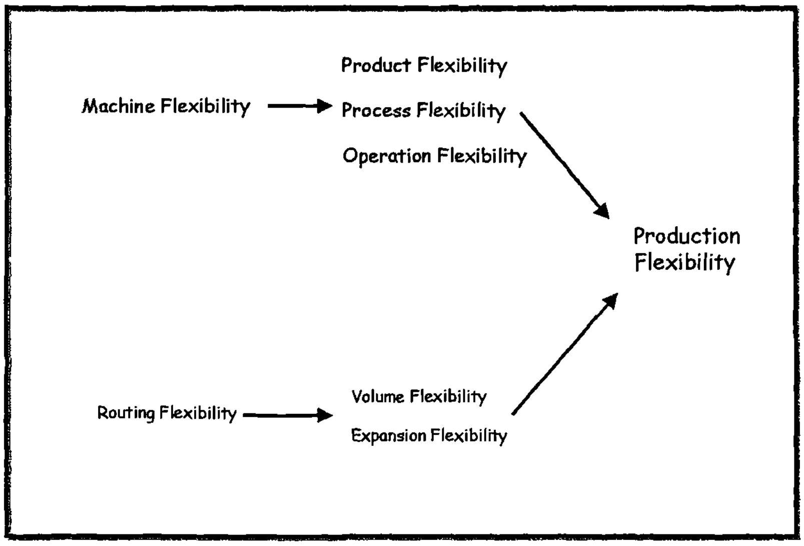


Figure 3.1 Dependency between flexibility types. *Source: Brown et al. (1984)*

Slack (1983) suggests looking at flexibility as a manufacturing objective. He divides the concept into dimensions of *range* and *response*. *Range flexibility* is the total envelope of capability or range of states which the production system or resource is capable of achieving. *Response flexibility* is the ease (in terms of cost, time or both) with which changes can be made within the capability envelope. These dimensions are not entirely independent. Systems tend to be more responsive to small changes than to big changes (Slack, 1989). Slack's response dimension appears to be similar to Zelenovic's adaptation flexibility defined earlier.

Slack (1987, 1991) further defines four types of flexibility, which were similar to a previously published typology (Slack, 1983) with the omission of quality flexibility. The types identified are:

Product flexibility - the ability to introduce and manufacture novel products, or to modify existing ones.
Mix flexibility - the ability to change the range of products being made by the manufacturing system within a given period.
Volume flexibility - the ability to change the level of aggregated output

Delivery flexibility - the ability to change planned or assumed delivery dates.

According to Slack, the typologies above can be used to describe the manufacturing system flexibility.

Gerwin (1987) identifies different types of flexibility necessary for organisations to cope with different types of uncertainty with which they are faced. The types, which are, in many aspects, similar to Brown *et al*'s (1984) typologies, are:

Mix - the ability of a manufacturing process to produce a number of different products at a certain point in time
Changeover - the ability of a process to deal with additions to and subtractions from the mix over time
Modification - the ability of a process to make functional changes in the product
Re-routing - the degree to which the operating sequence through which the parts flow can be changed.
Volume - the ease with which changes in the aggregate amount of production of a manufacturing process can be achieved.
Material - the ability to handle uncontrollable variations in the composition and dimensions of the parts being processed
Sequencing - the ability to rearrange the order in which different kinds of parts are fed into the manufacturing process.

Carlson (1989), an economist, divides flexibility according to time scale into operational, tactical and strategic flexibility. These are defined as:

Operational flexibility - is short-term so plant, equipment, routine, procedures and schedules are considered fixed. Operational flexibility is built into the plant and procedures permitting a high degree of variation in sequencing and scheduling, thereby accommodating breakdowns, shortages of materials and expediting.

Tactical flexibility - is medium-term and built into the organisation and production equipment. It enables the firm to change output, product mix and make moderate changes in design. It is determined by the choice of technology and therefore reflects the firm's expectations as to future developments.

Strategic flexibility - is the long-term ability to strategically reposition the firm in a market. Technology is not fixed. The barriers are cultural and organisational.

Dooner and De Silva (1990) identify four types of manufacturing flexibility. These are:

Machine flexibility - the ability of a machine to accommodate different tasks.
Mix flexibility - the ability of a system to accommodate different types of part design which, can be manufactured simultaneously.
Part flexibility - the ability of a system to accommodate new or modified part designs.
Volume flexibility - the ability of a system to accommodate variations in the production rate

Hyun and Ahn (1992) develop a unifying framework, which classifies various types of manufacturing flexibility into three perspectives namely the systems view, the environmental associated view and the decision hierarchy view. The figure below shows the system's view as described by the authors.

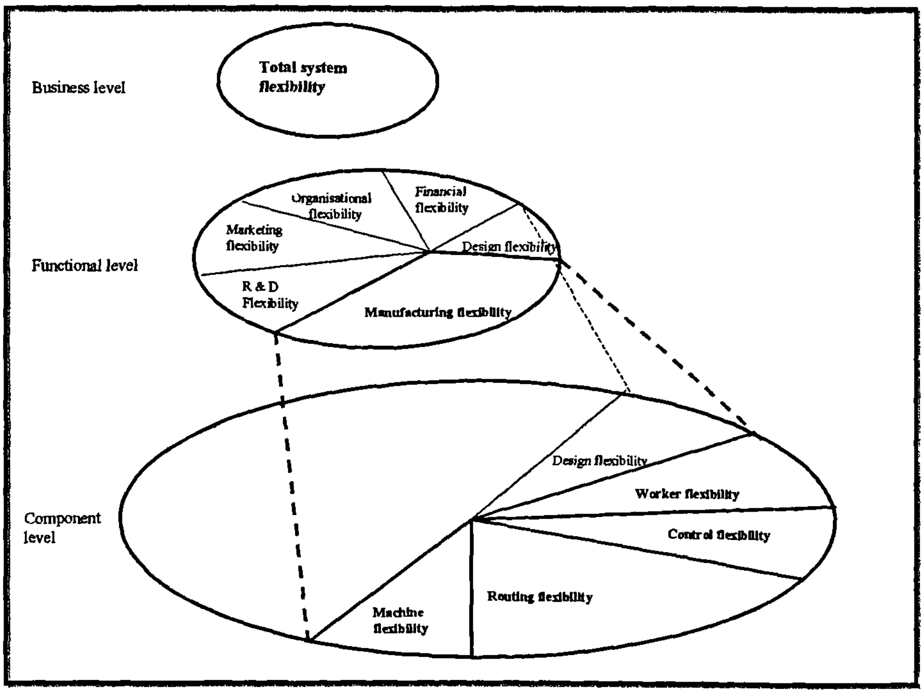


Figure 3.2: The system's view conceptualisation of manufacturing flexibility
Source: Hyun and Ahn (1992)

The idea behind the system's view is that the total system flexibility depends on functional flexibilities such as manufacturing flexibility, design flexibility, marketing flexibility, financial flexibility and the like. Each functional flexibility is a system that comprises component flexibility. For example, manufacturing flexibility, as a system, comprises flexibilities provided by the hardware and the software of the system. The flexibility of the hardware includes machine and routing flexibility, while control and worker flexibility are considered to be software components (Hyun and Ahn, 1992).

The system's view components of manufacturing system flexibility are defined in the table below.

Flexibility types	Definitions
Machine Flexibility	The ability to replace worn out or broken tools, change tools in a tool magazine, and assemble or mount the required fixture, without interference or long setup time, and the capability to process wider range of products.
Routing Flexibility	The ability to vary machine visitation sequences (for example, in case of breakdowns), and to continue producing the given set of part types.
Control Flexibility	The ability to interchange the ordering of several operations for each part type
Worker Flexibility	The ability of line workers to operate various types of machines, to alter working methods and standards

Table 3.1: The systems view of manufacturing flexibility
Source: Hyun and Ahn (1992)

The environment-associated view of flexibility posits that the components of flexibility are characterised by the types of interactions they have with environmental uncertainties. The flexibility types that fall within this category include expansion flexibility, product, mix, volume and program flexibility.

Flexibility types	Definitions
Expansion flexibility	The ability of the system to handle increases in capacity or change in the product range
Product flexibility	The ability to handle difficult, non standard orders and to take the lead in new product introduction. It encompasses the ability to make functional or engineering design changes.
Mix flexibility	The adaptability of a manufacturing system to changes in product mix (changes in the relative volumes of products or production sets)
Volume flexibility	The ability to accelerate production very quickly and juggle the orders to meet demands for unusually rapid delivery, and to operate profitably at different production volumes.
Program flexibility	The ability to handle various contingencies during operations such as machine breakdowns, quality problems, input material associated problems, and so forth

Table 3.2: The environment-associated view of manufacturing flexibility
Source: Hyun and Ahn (1992)

Hyun and Ahn (1992) argue that the concepts of flexibility identified in Table 3.2 above are static because their uncertainty handling capabilities are defined under a fixed product and production structure. In a changing environment, the dynamic aspect of flexibility becomes relevant. They argue that static flexibility is conventionally embodied in process technology while dynamic flexibility is embodied in organisational culture. The implication of this is that it is necessary to evaluate the viability of the flexibility types in non-stationary and dynamically changing environments.

The decision-hierarchical view of flexibility proposed by Hyun and Ahn (1992) has three main components. These are long-term (strategic), mid-term (tactical) and short-term (operational). Long-term decisions deal with strategic issues involving major decisions about market segments, missions, goals, requirements in technology and the like. Mid-term decisions deal with changes in product mix, design changes and variability in demand levels. Short-term decisions typically consider short-term uncertainties within the plant such as absenteeism, and change of tools.

Hyun and Ahn (1992) also classify flexibility types in terms of the types of uncertainties imposed on them i.e. external or internal. They argue that there are different types of uncertainty strategies required for externally and internally imposed uncertainties. These are:

Reactive internal uncertainty strategy - means of acquiring smooth production without intervention by internal contingencies, e.g. routing and worker flexibility (multiskilling) that relate to process and program flexibility.

Reactive external uncertainty strategy - means of absorbing external environmental uncertainty (also related to the environment-associated view). This includes having mix, volume and product flexibility.

Proactive internal uncertainty strategy - means of rooting out causes of internal uncertainties. This includes continuous improvement, manufacturing reliability programmes and the like.

Proactive external uncertainty strategy - means of exploiting superior information advantage to create more uncertainty for competitors. This includes having dynamic process or product flexibility that gives process or product innovation.

Faced with this array of different aspects of 'flexibility', it is essential to provide some framework that helps to bind these together. Fortunately, this has already been done by Hyun and Ahn (1992) who developed a 'flexibility map' shown in Table 3.3.

Environmental uncertainty	Static	Dynamic	Static	Dynamic	Static	Dynamic
Flexibility type	Program	Program	Volume Process Product	Volume	Expansion	Process Product Expansion
Decision hierarchy flexibility components	Short - term	Flexibility	Mid - term	Flexibility	Long - term	Flexibility

	Static Flexibility	Dynamic Flexibility	
Program flexibility (internal)	• ability to handle quality or materials problems • ability to control high degree of variations in sequencing and scheduling	• ability to conduct continual improvements on procedures or NC programming skills • ability to improve quality or materials problems • high degree of accumulated worker knowledge	Short term operational flexibility
Volume flexibility (external)	• ability to adjust to short-term volume fluctuations • wide volume range of profitable operation • ability to adjust relative volume change within mix (volume mix flexibility)	• ability to improve static volume flexibility measured in time or cost	Mid-term tactical flexibility
Process flexibility (internal)	• short setup or changeover time • wide range of specifications • multi-function, general-purpose machines • more integration between workcentres	• ability to conduct continual improvements on processes (plant layout, setup time, etc.) • ability to innovate processes	Long-term strategic flexibility
Product flexibility (external)	• capability in minor design changes • ability to change product mix set (product mix flexibility)	• ability to introduce new products or major design changes • ability to introduce new product families • ability to improve static flexibility	
Expansion flexibility (external)	• aggregate capacity adjustments capability • modular process or layout designs	• ability to improve in time and costs for capacity additions	

Table 3.3: Integration and manufacturing flexibility map
Source: Hyun and Ahn (1992)

The flexibility map in Table 3.3 above unifies the various views of flexibility (i.e. decision hierarchy, environmental associated and system views). However, unlike many other studies on flexibility, Hyun and Ahn did not classify mix flexibility, as a separate dimension of flexibility. They classified mix flexibility as falling under product flexibility. This research has critically reviewed and modified this flexibility map and adopted it as a framework for analysing flexibility. The modified framework is presented in Section 3.5.

The table below summarises the studies classified under the empirical studies of flexibility.

Taxonomies of flexibility	Mandelbaum (1978) Zelenovic (1982) Buzacott (1982) Slack (1987) Carlson (1989)	Brown *et al* (1984) Gerwin (1987) Dooner and De Silva (1990) Piore (1989) Hyun and Ahn (1992)
Flexibility & Performance	Jaikumar (1986) Tombak (1988) Fiegenbaum & Karnani (1991)	De Meyer *et al* (1989) Tombak & de Meyer (1988)
Historical & Economical Analyses of flexibility	Piore & Sabel (1984) Cusumano (1988) Womack *et al* (1990)	Jaikumar (1988) Piore (1989)
Analyses & Implementation Of flexibility	Cox (1989) Suarez *et al* (1991) Gerwin (1991) Correa (1992)	Sethi & Sethi (1990) Hyun & Ahn (1992) Suarez *et al* (1996)

Table 3.4: Summary of empirical studies of manufacturing flexibility
Source: Suarez et al (1991).

Critique of Empirical Studies on Flexibility

Starting with the second group in the table above (i.e. flexibility and performance), like the analytical models, most of the studies in this group view flexibility as a uni-dimensional concept ignoring the multi-dimensional nature of the concept. For instance, Jaikumar's (1986) study implicitly refers to flexibility as the ability to produce a wide variety of parts, which is what has been defined as mix flexibility. Thus, the study ignores the existence of other possible sources of flexibility that have been identified by studies in the first group of the above table, such as volume, delivery and product flexibility. In contrast, Fiegenbaum and Karnani (1991) focus their study only on volume flexibility (which they refer to as output flexibility). The fact that they identify and differentiate between volume flexibility and other flexibility types mitigates against their study suffering from the drawback of studies in this group.

Studies in the third group of Table 3.4 (historical & economic analyses of flexibility) share some of the weaknesses of the studies in the second group discussed above. Many propositions are put forward but few of the studies present data to back up these propositions. Also, many of the studies have a narrow view of flexibility, referring to it as product diversity or mix flexibility (Suarez *et al*, 1991).

As explained earlier, most of the existing literature on flexibility has been concentrated in group one of Table 3.4 (i.e. taxonomies of flexibility). However, the literature in this group has produced little consensus over the years. It appears that different names have been used to refer to the same type of flexibility thus causing some unnecessary confusion. The unified framework developed by Hyun and Ahn (1992) is a good way of unifying the different types of flexibility and understanding their relationship with internal and external uncertainties. However, the link between the flexibility types defined from the systems view (such as worker and routing flexibility) and those defined from the environmental-associated (such as mix and volume flexibility) view is missing from the framework (Figure 3.2). A review of the other studies on the development of flexibility typologies (e.g. Brown *et al* 1984; Slack, 1987; and Suarez *et al*, 1996) establishes that component flexibility types such as routing and worker flexibility are actually needed to support the Hyun and Ahn's environment associated flexibility types (e.g. volume and mix flexibility). These would in turn provide the required manufacturing flexibility, which is a component of total system flexibility.

In line with Hyun and Ahn's framework, some authors have identified types which look at flexibility from the manufacturing system's strategic point of view (e.g. Slack, 1987) while others have included the component or resources flexibility types as the main typologies of flexibility. The classification developed by Brown *et al* (1984) helps to distinguish between the two different levels of flexibility. It shows the relationships between the flexibility types identified (Figure 3.1). However, only the product and volume flexibility types (Brown *et al's*) are similar to Slack's (1987) manufacturing systems flexibility typologies.

Suarez *et al's* (1996) work supports Slack's major typologies of the manufacturing system's flexibility. They refer to them as "first-order" flexibility types, since they argue that, these flexibility types directly affect the competitive position of a firm in a market.

They argue that the other types of flexibility proposed in the literature such as routing, component, material and machine flexibility do not by themselves directly affect the competitive position of the firm but rather operate through the so called "first-order" flexibility types. They called these other types, "lower-order" flexibility types (see Figure 3.3). This research study agrees with Suarez *et al's* view, but proposes a slightly different classification that is discussed in the later part of Section 3.4.

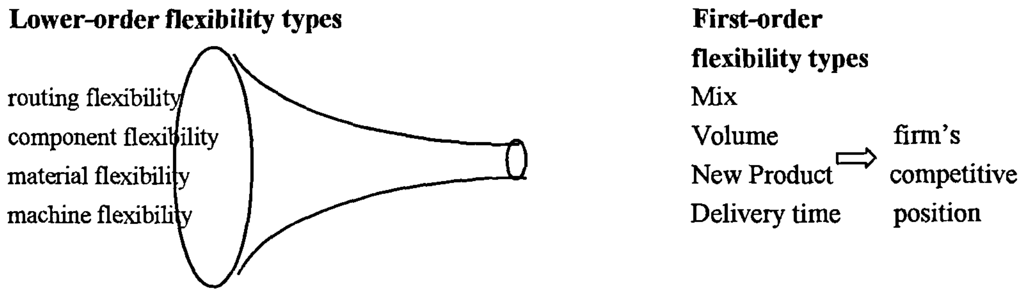


Figure 3.3: The Flexibility Funnel
Source: Suarez et al (1996)

Slack's (1987) and Suarez *et al's* (1996) classifications described above appear to be dominant in the literature on flexibility classifications.

3.4 Identification of the Research Gap

Figure 3.4 below shows the grouping of the empirical studies on flexibility adapted from Suarez *et al*'s (1991, 1996) classification. The figure has been used to identify the research gap and the focus for this thesis. It is pertinent to note that the research focus is centred around groups 1 and 4 of the empirical studies on flexibility. The reason for this is explained in the following discussion. Group 1 produces the dimension of flexibility that is of interest (i.e. volume flexibility) and group 4 produces the issue of interest.

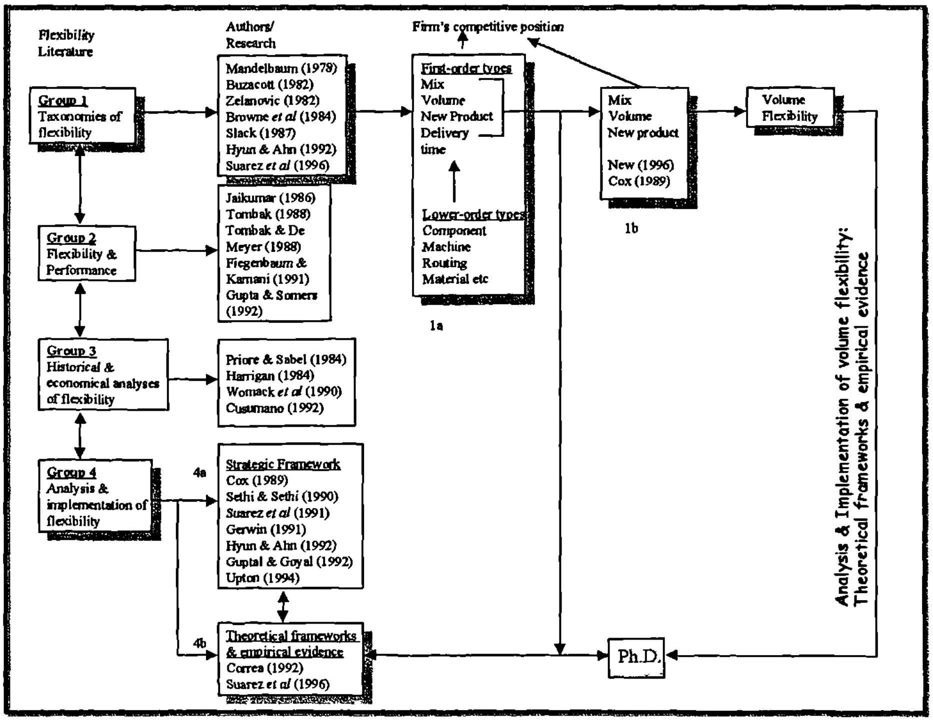


Figure 3.4: Identification of the Research Gap

Studies in the fourth group (i.e. analysis and implementation of flexibility) include those by Cox (1989), Sethi and Sethi (1990), Suarez *et al* (1991), Gerwin (1991), Guptal and Goyal (1992), Hyun and Ahn (1992), Correa (1992), Upton (1994) and Suarez *et al* (1996). Apart from the studies carried out by Correa (1992) and Suarez *et al* (1996), all of the other studies in this group provide only strategic frameworks for analysing flexibility. They do not provide empirical evidence for the implementation of flexibility.

In order to carry forward the research on manufacturing flexibility, it is necessary to undertake research in the fourth group (i.e. provide empirical evidence for the implementation of manufacturing flexibility), before any further useful and meaningful research can be carried out in groups 2 and 3 of Suarez *et al's* (1996) classification. Thus, this research is located in the fourth group of the above classification (box 4b of Figure 3.4). That is, the "analysis and implementation of flexibility: theoretical frameworks and empirical evidence". But there is another problem.

As argued previously, one of the weaknesses of the empirical studies and the analytical models on flexibility has been the tendency to treat flexibility as a uni-dimensional concept. The foregoing discussions and argument have highlighted the multi-dimensional and complex nature of the concept. Hence useful and meaningful research on the issue of flexibility needs to treat the dimensions of flexibility separately within an integrative framework.

Although the lower-order flexibility types are fundamental to the overall manufacturing flexibility, they are too far removed from strategic manufacturing flexibility. In other words, they do not affect the competitive position of a firm directly and are not readily perceived by the customers like the first-order types (systems and environmental-associated view of Hyun and Ahn, 1992). For instance, consider a lower-order flexibility type, routing flexibility (the ability to route production through different production paths). A customer would not care about a firm having more routing flexibility, but this flexibility type gives a firm more delivery time or volume flexibility, since the plant will probably be able to deliver a given production order faster or change production volume faster than its competitors (Suarez *et al*, 1996). It is this ability (i.e. delivery time and volume flexibility) that is visible to the market place, not routing flexibility. Furthermore, of the two (i.e. first-order and lower-order) types of manufacturing flexibility, more studies have been carried out on the lower-order types such as machine flexibility. Because of the strategic importance of the first-order flexibility types, the research is narrowed down to the analysis and implementation of the strategic (or first-order) flexibility types, which are mix, volume, new product and delivery time flexibility (Figure 3.4, box 1a).

Some researchers (e.g. Cox, 1989 and New, 1996) have argued that volume and mix flexibility are the two most important strategic manufacturing flexibility types. This is because of the close relatedness of volume with delivery time flexibility and, product with mix flexibility. One could argue that the classifications that have been proposed depend on how the flexibility components have been defined. As Hyun and Ahn (1992) put it, *"there is no refined concept of flexibility.... "*.

Consider Slack's (1987) definition of volume flexibility (incorporating the response dimension of time and cost implications of changing aggregate production volumes). The implication of the definition is that a plant that cannot deliver varying volumes of orders to its customers when the orders are required cannot be said to be truly volume flexible, even if it is able to meet the volume requirements at a later date. One could argue that this therefore incorporates the delivery time flexibility type. In other words, a plant, which is, truly volume flexible is by definition capable of delivery time flexibility. This suggests that delivery time flexibility should not be seen as separate, but as falling under the umbrella of volume flexibility.

The major strategic flexibility types proposed in this project can be illustrated using Suarez *et al's* (1996) flexibility funnel as shown in Figure 3.5 (also box 1b in figure 3.4). Note that volume flexibility now incorporates delivery time flexibility.

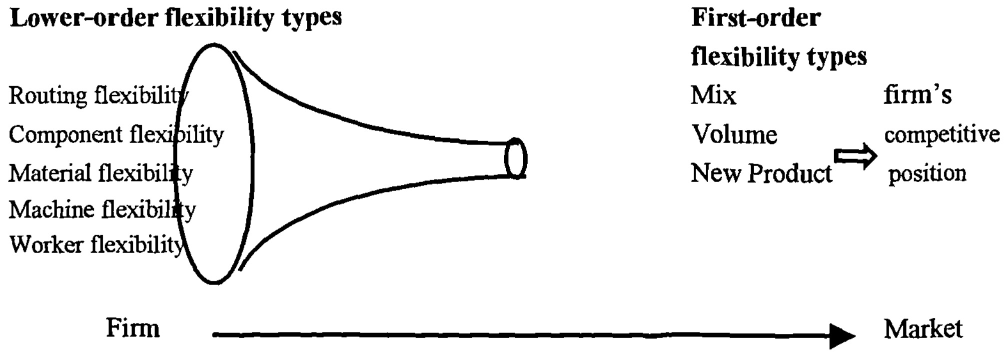


Figure 3.5: Modified flexibility funnel
Adapted from Suarez et al (1996)

Focusing on Volume Flexibility

The ability to create new products (new product flexibility) quickly is an attribute that has become extremely important in many industries today. This research project will not be looking into this flexibility type. This is because, compared with mix and volume flexibility, the issue of new product flexibility in the form of new product development has theoretical affiliation with and has received relatively greater attention from the marketing and general management literature (e.g. Urban and Hauser, 1980; Abegglen and Stalk, 1985; and Imai *et al*, 1985).

Thus, the area of interest has been narrowed down to the analysis and implementation of volume and mix flexibility in manufacturing plants. Although the two types of manufacturing flexibility (volume and mix) are required by a plant to achieve total production flexibility, factors affecting volume flexibility have been found to be completely distinct from those affecting mix flexibility (Suarez *et al*, 1996), suggesting the need to separate them for analysis purposes. Relatively speaking, mix flexibility has received more attention in the literature. In contrast, apart from identifying volume flexibility as one of the major classifications of a firm's flexibility, very little work has been done on the analysis and implementation of volume flexibility in manufacturing plants. Therefore, in order to avoid the problem of treating flexibility as a uni-dimensional concept and to achieve a manageable focus for the research, the research is focused on the analysis and implementation of volume flexibility in manufacturing plants. This represents the gap in the literature on manufacturing flexibility and provides the title for the thesis (Figure 3.4).

The research recognises that volume flexibility is just one of the components required by manufacturing organisations to attain manufacturing system flexibility. Therefore, the Hyun and Ahn's (1992) system's view framework of flexibility has been adapted in this research (Figure 3.6) to show the relationships between first-order flexibility types, manufacturing flexibility and total system flexibility as a complete system.

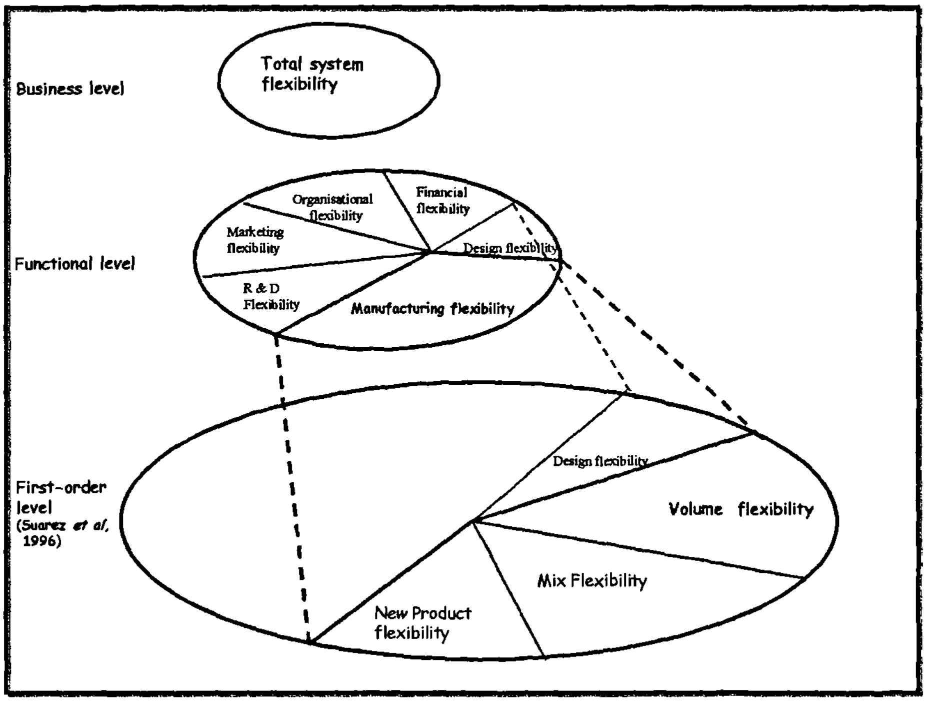


Figure 3.6: System's view of the relationship between flexibility types
Source: Adapted from Hyun and Ahn (1992)

The framework in Figure 3.6 shows the relationships between the total system flexibility, manufacturing flexibility and the strategic flexibility types (i.e. volume, mix and new product flexibility). Unlike Hyun and Ahn's system's view of flexibility, the framework in Figure 3.6 proposes that all component or resource level flexibility types (e.g. routing, material, worker etc – not shown) express their final competitive effect through any one of the three first-order types shown in Figure 3.6. These first-order flexibility types give a manufacturing firm its required manufacturing flexibility.

The flexibility map of Hyun and Ahn has also been modified and adapted in this research. Flexibility types are classified as *static* "*....in the sense that their uncertainty handling capabilities are defined under a fixed or given product and production structure. Dynamic flexibility is concerned with a system's capability to cope with a changing environment*" (Hyun and Ahn, 1992).

In other words, when the fixed product values change, static flexibility is no longer viable. Table 3.5 below shows that in the short to medium term, all the flexibility types can be classified as *static* (except volume flexibility, which can be classified both as *static* and *dynamic*). For example, new product flexibility is obtained from inherent capability to make minor design changes. It is rather difficult to achieve a *dynamic* state (when new products are required) for new product flexibility in the short-medium term. In contrast, it is relatively easier to achieve *dynamic* volume flexibility through varying labour hours to meet short-term demand fluctuations as long as there is sufficient machine capacity.

Environmental uncertainty	Static	Dynamic	Static	Dynamic
Flexibility type	Volume Mix New product	Volume		Volume Mix New product
Decision hierarchy flexibility components	Mid - term	flexibility	Long - term	flexibility

	Static Flexibility	Dynamic Flexibility	
Volume flexibility	• Ability to adjust to short-term volume fluctuations • Wide volume range of profitable operation	• Ability to improve static volume flexibility measured in time, cost & other competitive criteria	Mid-term tactical flexibility
	• Ability to adjust relative volume change within mix (volume mix flexibility)	• Ability to improve in time, cost and other competitive criteria for capacity additions	Long-term strategic flexibility
Mix flexibility	• Ability to change product mix set for existing products	• Ability to change product mix set for potential new product families measured in time, cost and other competitive criteria	
New Product flexibility	• Capability in minor design changes	• Ability to introduce new products or major design changes quickly and cheaply • Ability to introduce new product families measured in time, cost and other competitive criteria • Ability to improve static flexibility	

Table 3.5: Flexibility map incorporating different views of flexibility
Adapted from Hyun and Ahn (1992)

3.5 Chapter Summary

The classification of studies on manufacturing flexibility proposed by Suarez *et al* (1996) is adopted. These are studies on analytical models and empirically based studies of flexibility. The two groups are each sub-divided into four areas. The review of the literature in each of these areas reveals that the bulk of the studies on manufacturing flexibility have concentrated on the development of flexibility taxonomies. The contributions of different authors in this area have been discussed in this chapter and it is suggested that manufacturing flexibility can be looked at from the systems view (Hyun and Ahn, 1992). The firm's total system flexibility is characterised by functional flexibilities of which manufacturing flexibility is one. Manufacturing flexibility as a system comprises first-order flexibility types, which are mix, new-product, delivery and volume flexibility. Due to the inter-dependency that exists between volume and delivery time flexibility, it is proposed that delivery time flexibility fall under the umbrella of volume flexibility. The three first-order flexibility types identified, therefore, are volume, mix and new product flexibility (Figure 3.6). These first-order flexibility types in turn comprise components or flexibilities embodied in both the hardware and software aspects of a manufacturing system. These are not shown in Figure 3.6 but include routing, machine and worker flexibility.

The review of the literature also reveals that there is a dearth of study in the area of providing empirical evidence on how to implement manufacturing flexibility. The research gap is located in this area of study. Flexibility is a multi-dimensional concept. However, most of the empirical studies have treated flexibility as a uni-dimensional concept. In order to make the research manageable and to carry out an in-depth analysis, this research focuses on just one dimension of flexibility (i.e. volume flexibility). But the research recognises that this is only looking at a single aspect of manufacturing flexibility.

The next chapter will review further the limited literature on volume flexibility. It will explore the issues on the analysis and implementation of volume flexibility in manufacturing plants, and will identify the Research Questions for the study.

Chapter 4 – Volume Flexibility: Research Issues and Questions

4.0 Introduction

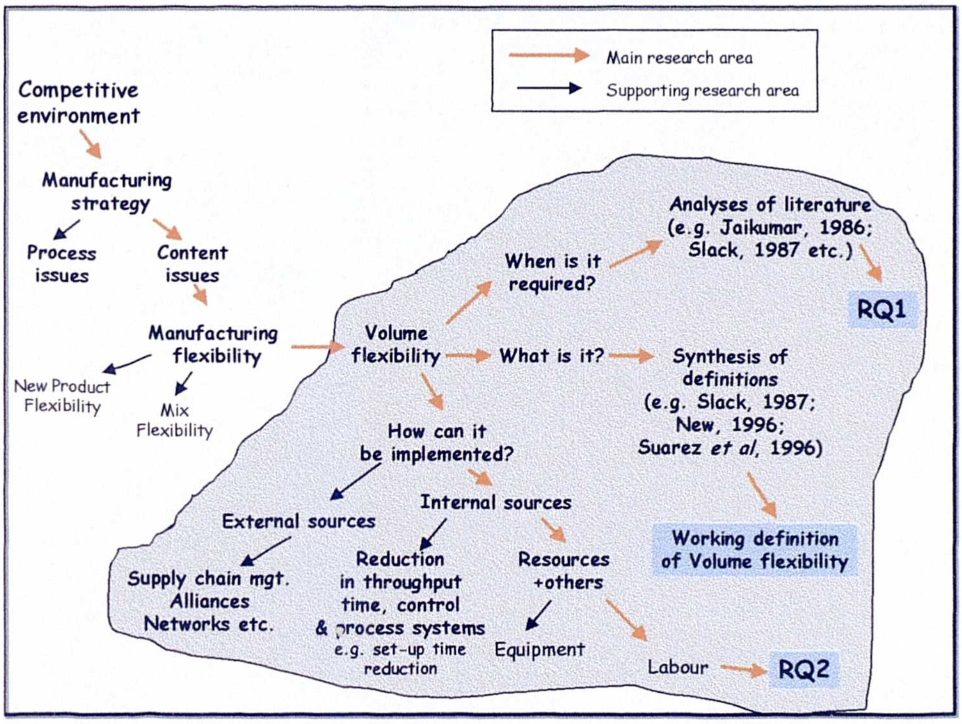


Figure 4.0: Summary of literature coverage. Chapter coverage is shaded

This chapter builds on the previous chapters, which have discussed and identified manufacturing flexibility as the content variable of manufacturing strategy that is helpful in coping with environmental uncertainty. Within the manufacturing flexibility literature the research gap is identified around the issues of volume flexibility in manufacturing plants.

Analysis of volume flexibility involves defining what the concept is, when it is required and desirable and how it can be measured and implemented in manufacturing plants. Thus, this chapter has been divided into four main sections. Section One presents the background to volume flexibility and reviews the definitions of the concept in the literature and proposes a working definition of volume flexibility for the research. Section Two discusses the need to identify when volume flexibility is required in manufacturing organisations and the section identifies the first Research Question for the project. Section Three reviews the literature on volume flexibility measurement. Section Four discusses how volume flexibility can be implemented from sources both internal and external to the firm and concludes with the identification of the second Research Question for the research project.

An edition of this chapter (Section 4.2) titled *"How should we fill our orders, use stock levels or volume flexibility?"* was presented at the International Symposium of Inventories Research held in Budapest, in August, 1998.

4.1 What is Volume Flexibility?

Stigler introduced the concept of volume flexibility into economics literature in 1939. Stigler's reasoning is that a firm's volume flexibility is reflected in the shape of its average total cost function. He formulated a model based on a 'U' shaped average total cost curve as a function of volume. So, a flat average cost function gives a firm more flexibility, as it can depart from the optimal output* without much cost penalty (Figure 4.1). The most influential assumption of Stigler's (1939) model is that flexibility is not a free good.

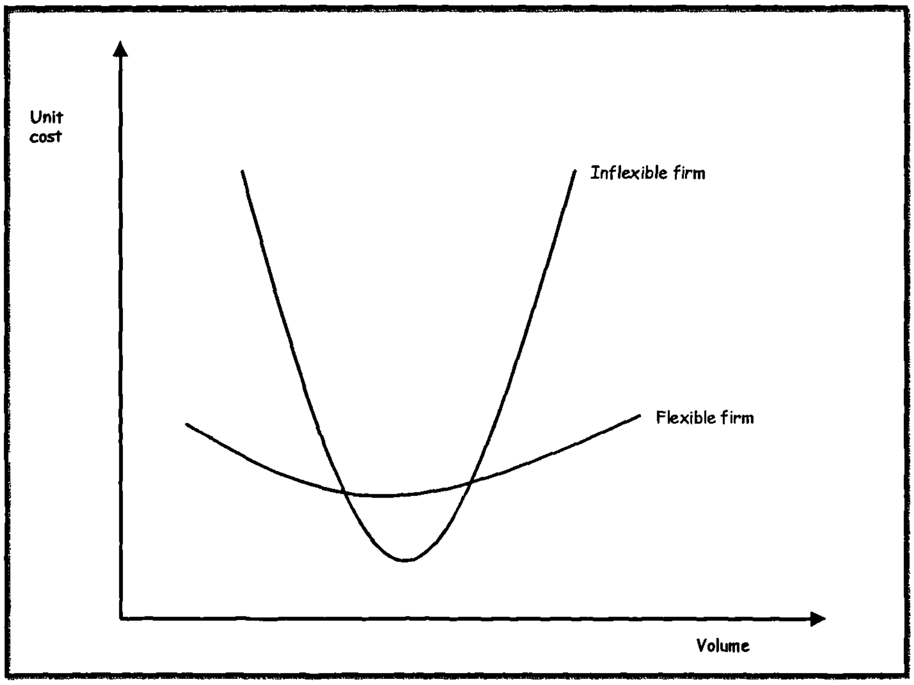


Figure 4.1: Average total cost curves
Source: Carlsson, (1989)

* According to basic economic theory, a firm in competition maximises profits by producing at the lowest point of its average cost curve, where marginal revenue equals marginal cost. This point gives the optimal output for the firm.

Oi (1961) elaborated on Stigler's analysis and introduced it into the area of industrial organisations. He showed that expected or average profits would increase with the variance of price if a firm producing a single output under increasing marginal cost equates (ex post) marginal cost to price. Thus, increased uncertainty of demand would attract new firms into the industry because it increases expected profits (Oi, 1961). Sheshinky and Dreze (1976) examined the implication of this theory under less restrictive assumptions and concluded *"demand fluctuations increase the number of firms sustained in competitive equilibrium, and each firm produces less on average with fluctuations than without"*.

Over the last two decades, several authors in the manufacturing and operations management literature have proposed definitions for the concept of volume flexibility within the overall issue of manufacturing flexibility. Some selected definitions of volume flexibility are listed below:

Gerwin (1987) defines volume flexibility as the ease with which changes in the aggregate amount of production of a manufacturing process can be achieved.

Slack (1987) defines volume flexibility as the ability to change the level of aggregated output.

Dooner and De Silva (1990) define volume flexibility as the ability of a system to accommodate variations in the production rate.

Hyun and Ahn (1992) define volume flexibility from an environment-associated view as the ability to accelerate production very quickly and juggle the orders to meet demand for unusually rapid delivery and to operate profitably at different production volumes.

Suarez *et al* (1996) define volume flexibility as the ability to vary production volumes without any detrimental effect on efficiency and quality.

New (1996) states that "volume flexibility of a plant is concerned with the range over which the output volume of the plant can be varied on a daily/weekly/monthly/yearly basis and with the impact such variability in output has on the unit cost characteristics of the plant".

The common characteristic of the above definitions is that all the authors agree that the volume flexibility of a firm relates to its ability to vary production outputs or volumes. If one sticks by this definition, then, in theory, volume flexibility will only be constrained by capacity availability. However, as Stigler (1939) argues, flexibility does not come as a free good. Achieving higher than normal production volume may mean investing in excessive overtime hours for employees or building additional machine capacity. In other words, there are cost implications for achieving flexibility. Some of the authors listed above recognised this fact (e.g. Slack, 1987; Hyun and Ahn, 1992; Suarez *et al*, 1996; and New, 1996). Slack (1987) defines a response dimension of volume flexibility, which includes the time, and cost of achieving any changes in say production volumes within or outside the current range. The use of the term *profitably* by Hyun and Ahn (1992) in their definition implies that a volume flexible firm will not prejudice its profit in meeting different production level requirements. Suarez *et al* (1996) refer to efficiency and quality as the critical factors that must not be prejudiced while New's (1996) focus is on the impact on the unit cost characteristics of the plant.

The above analyses of the definitions raise the issue of the critical success factors or the competitive criteria required in the industry where a firm operates. For instance, if quality is the competitive criterion in a particular industry, a firm seeking to achieve volume flexibility in that particular industry should do so without sacrificing the level of quality of its product. Slack (1998) notes that:

"..all measures of performance will not have equal importance for an individual operation. ...their relative importance being determined by both the competitive characteristics of the market in which the operation is competing and, more importantly, the way in which the company chooses to position itself within that market".

Rather than proposing a narrow definition of volume flexibility based along the lines of certain competitive criteria or critical success factors, a generic definition of volume flexibility for manufacturing organisations is proposed as follows:

The extent to which a manufacturing system can vary its output level for a given product mix, within a given time period without any unacceptable effect on cost and other competitive criteria of the plant.

4.2 When does a Manufacturing Plant require Volume Flexibility?

Slack (1987) suggests that general trading turbulence has increased the need for flexibility in manufacturing plants. The increase in the turbulence is due to large demand fluctuations, technological advances and increasingly effective competitors (Slack, 1987).

Goldman *et al* (1995) highlight that the pressure on organisations to become flexible comes as a result of:

- Increasing market fragmentation
- Growth in the need to produce to order
- Shrinking product life cycles
- Globalisation of production
- Co-operation and competition between firms

The uncertainty that results from changes or fluctuations in demand levels leads to external disturbances that increase the pressure on manufacturing organisations to have volume flexibility (Garrett, 1986; and Gupta and Goyal, 1992). These issues raise the questions, *'why volume flexibility?' 'Is volume flexibility the only strategy available to plants to meet volatile demand requirements?'*

Plants have in one way or the other always taken steps to be able to meet volatile demand requirements. In the case of 'stockable' products, volatile demand was almost always met by using inventories. This typifies a make-for-stock (MFS) business where, *"the manufacturing/procurement cycle time is totally speculative for the producer and the customer sees a zero lead-time (or rather dispatch time only)"* (New and Sweeney, 1984). Where the product was not 'stockable', demand was still met usually by offering a customer a delivery lead time sufficient to cover the whole manufacturing lead time. New and Sweeney described this as a 'make-to-order on manufacturing lead-time' (MTO) type of business. It assumes that materials (not products) are 'stockable' and are immediately available. The 'true make-to-order' business must offer the customer a delivery lead time that must not be less than the full composite lead time (New and Sweeney, 1984). In this type of business, the activities of making a product from the purchase of raw materials through to manufacturing are not triggered off until a firm customer order is received. Thus, as one moves from one end of the continuum ('true make-to-order') to the other end (make-for-stock), the degree of volume flexibility that a firm has, by our definition, decreases.

Today, due to increasing competition and the need to remain competitive, plants are more conscious of the time, cost and quality implications of responding to volatile demand. Thus, there is less use of stock levels (for cost saving and risk of obsolescence reasons), in favour of volume flexibility to cope with demand level fluctuations.

The model below has been developed to compare the use of two strategies (inventories and volume flexibility) to cope with high variability in demand levels (Oke, 1998).

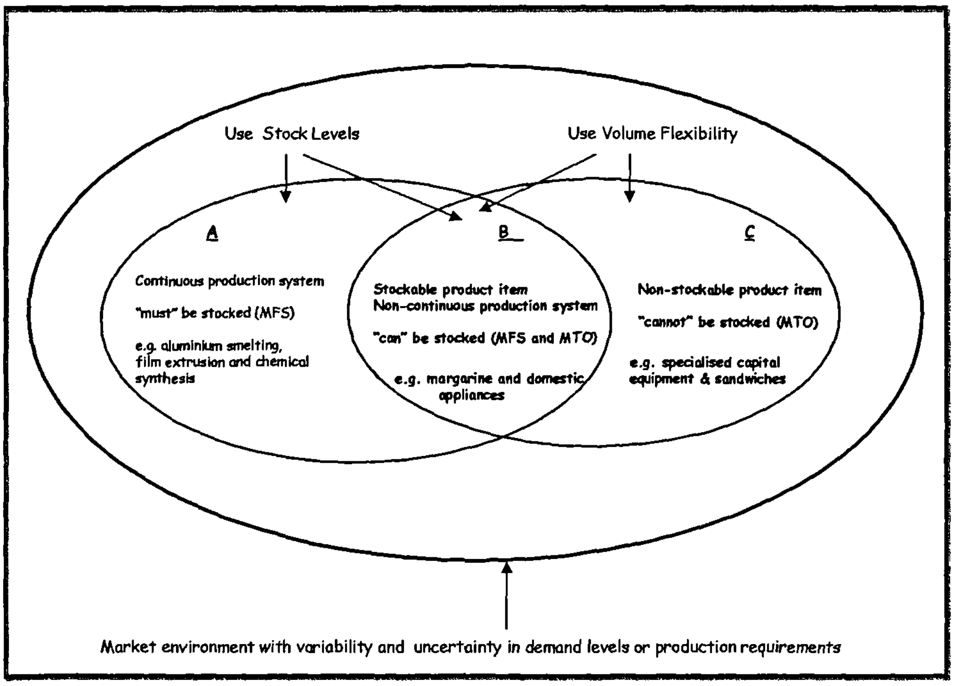


Figure 4.2: Contextual Framework: Using volume flexibility versus using stock levels (Not to scale)

Group A consists of plants having continuous production systems (i.e. 24 hour operation, 7 days a week). Such plants are usually limited to the option of producing to stock and responding to variations in demand levels through variations in inventory levels. This is because it is either too costly to switch off the equipment and restart, or it may be that it is not technically feasible. When there is a slump in demand, such systems continue to produce for stock at a normal rate and when there is a surge in demand above capacity, stock is depleted until used up and then a 'backlog' of orders is created and lead time is extended. In general, such plants are either 'on' or 'off' for relatively long periods. The products of such systems are usually standardised, inseparable (being produced in an endless flow) and of high volume. Continuous processes are often associated with relatively inflexible, capital-intensive technologies with highly predictable flow (Slack *et al*, 1995). However, very few operations fall within this area. Examples include aluminium smelting plants and film extrusion plants.

Group B consists of plants having "stockable" product items but a non-continuous production system. Such plants can use stock or volume flexibility to respond to demand variations. The plants in this group often produce standard products, which have relatively long shelf lives. Examples include the manufacture of domestic appliances.

Group C consists of plants that are limited to the option of either varying lead time or using volume flexibility. The non-stockable nature of the products of these plants implies that the businesses are either largely "make to order"(at least for part of the manufacturing processes) or the products themselves may be perishable. Examples include the sandwich making business.

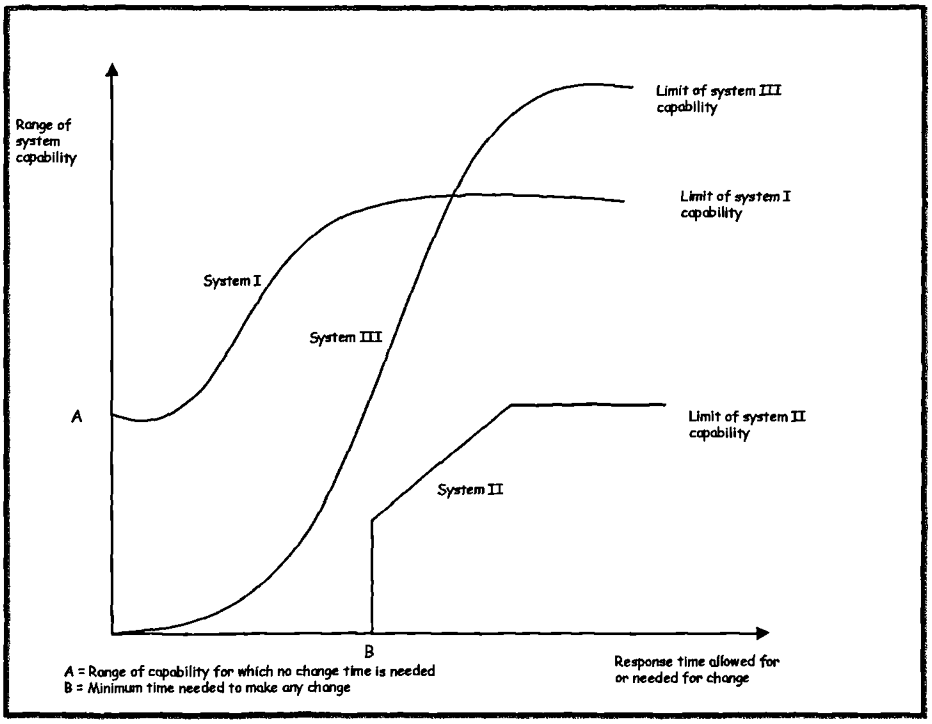
The implication of the model is that not all manufacturing plants can or even need to employ a volume flexibility strategy. This can be used to explain the results of Jaikumar's (1986) study in which he found that implementation of "flexibility" by some companies in the United States resulted in more inflexible operations. He noted that this was due to the inadequate assessment of flexibility needs by management prior to implementation. Slack (1991) also argues that one of the ways in which flexibility can be improved is to clarify why flexibility is needed. Thus, although flexibility in manufacturing in the 1990s is seen as a way of gaining competitive edge, some plants have more need for it than others.

The above argument leads to the first Research Question of the project:

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

4.3 Measurement of Volume Flexibility

Clearly, the definition of a concept provides a way for its measurement. Slack (1988) argues that unlike other manufacturing objectives (such as cost and quality) which can be assessed by their historical operating behaviour, the assessment or measurement of flexibility is not straightforward. He argues that any measure of flexibility has to rely on the relevant manager's subjective opinion of how the operation could perform and under what conditions. He proposes the use of a model (Figure 4.3: range-response curve) for the measurement of the manufacturing system flexibility based on the managers' opinions on how far and how quickly the operation could change (range and response dimensions of flexibility). The general type of information produced (in the case of volume flexibility) is shown in Table 4.0.



Figurc 4.3: Range – Response curves
Source: Slack (1988)

Flexibility Type	Range of what is needed	Response; time to make changes
Volume flexibility	Limits to aggregate output fluctuations	Lead-time to effect output change

Table 4.0: Flexibility audit
Source: adapted from Slack, (1988)

The range-response curves are helpful tools that can be used only in some circumstances. They are good for auditing by how much a plant can expand its production volume and how long it takes the plant to do so. However, they are not of much help when considering the economics of contraction in production volume. It is pertinent to note that volume flexibility is the ability to operate economically at any level of production (above and below the normal production volume).

Slack (1988) argues that flexibility does not have to be demonstrated for it to be real. He notes that the measurement of flexibility cannot be based solely on historical data. The implication of this assertion is that using historical data may measure the flexibility of a system in terms of its *effectiveness* in coping with change. But this should be complemented with subjective measures such as the range-response curves to provide a measure of the ability of the system to cope with change.

Cox (1989) argues that like other measures of efficiency, flexibility is mainly concerned with the speed and cost of accomplishing a task. He then suggests the use of perceptual measures of flexibility, such as Slack's (1988) range-response curve model, as a supplement to the objective measures.

Fiegenbaum and Karnani (1991) carried out a research study (mentioned in Chapter 3) to investigate the issue of volume flexibility as a source of competitive advantage for small firms in the USA. Their research measures volume flexibility in small and large firms and reveals that small firms will use volume flexibility to secure competitive advantage as a trade-off for their cost inefficiencies when compared to large firms. An earlier study carried out by Mills and Schumann (1985) focused on the trade-off between size, static cost efficiency and volume flexibility, and the results are similar to those obtained by Fiegenbaum and Karnani (1991).

Fiegenbaum and Karnani (1991) measure volume flexibility as the standard deviation of annual sales while Mills and Schumann (1985) measure it as the sales deviation from a trend line over time. If New's (1996) and Suarez *et al's* (1996) definitions of volume flexibility are anything to go by, then one can argue that what Fiegenbaum and Karnani (1991) and Mills and Schumann (1985) measure are sales or volume fluctuations rather than volume flexibility. This is because the implications of the sales variations on cost, quality and efficiency or any other applicable competitive criteria were not taken into consideration in the analyses. Also, their use of sales variations (either over a trend line or as standard deviation) to operationalise production volume variation is highly questionable. Price fluctuations and other factors that are unrelated to production volume may actually influence the sales variations. Also, the effects of lead-time manipulation to level load and failure to deliver an item would not have been reflected in the sales profile. It is also pertinent to note that the measure only accounts for *effectiveness* (as it considers only demonstrated capability) and does not include the *ability* to cope with change.

It will be recalled that Stigler's (1939) work, described in Section 4.1, measures volume flexibility of a firm by how flat the bottom of the firm's unit cost function is. In other words, the flatter the unit cost function, the more volume flexible the firm can be considered to be (Figure 4.1). Falkner (1986) tends to support this view by suggesting that volume flexibility can be measured by looking at the stability of costs as production fluctuates. Gerwin (1987) argues it can be measured from the ratio of average volume changes to the production capacity limit while Sethi and Sethi (1990) suggest that a measure of volume flexibility would be to determine the range of volumes in which the firm can run profitably.

Suarez *et al* (1996) suggest that volume flexibility can be measured by taking the logarithm of the ratio of production volume fluctuations to the product of cost per placement and number of rejects. This measure that they used places a penalty on cost and quality. It is an improvement over Fiegenbaum and Karnani's (1991) measure because it uses actual production volume fluctuations and penalises the plants on both cost and quality. However, the measure is also inadequate in the sense that it only considers demonstrated capability of the plants and neglects the potential volume flexibility. There was no justification for penalising the plants only on cost and quality when there might have been other factors critical in the printed circuit board assembly industry, which they studied, such as the time taken to respond to the required fluctuations.

The above discussion highlights the inconclusive state of research on the measurement of volume flexibility and the flexibility concept as a whole. What is clear from the above is that future measures of flexibility need to be based on a combination of objective measures that utilise historical data and perceptual measures that measure the potential or ability of the system to cope with future changes.

4.4 Implementation of Volume flexibility

Implementing volume flexibility in manufacturing plants depends on some factors that are external and others that are internal to the plant. Cox (1989) identifies sources of flexibility as being dependent on:

1. The input-supply network
2. The labour force
3. Facility/equipment
4. Production control processes.

Suarez *et al* (1996) identify sources of flexibility as:

1. Production technology
2. Production management techniques
3. Relationships with subcontractors, suppliers and distributors
4. Human resources

Hill (1993) defines resources in organisations as infrastructural and processes. Infrastructural resources include the set of structures, controls, systems, experience and skills of the people involved with the manufacturing system. Processes deal with the technology, equipment and facilities of the system.

Slack (1989) classifies the sources of manufacturing flexibility as infrastructural and structural resources, and the supply and control systems. The infrastructural resources include relationships and information couplings that bind the operations together. Structural resources are defined as labour and technology. The labour issue is classified as a structural and an infrastructural resource by Slack and Hill respectively. Correa (1992) argues that since the workforce is being regarded as the most important asset of organisations, making or changing decisions about people issues in organisations generally does take a long time and a considerable amount of organisational effort. Hence, labour is better classified as a structural resource.

Slack (1991) further posits that an operation's flexibility depends on the flexibility of its resources, which are:

1. Flexible technology
2. Flexible labour
3. Flexible supply networks

Labour and technology are classified as structural and the supply networks as infrastructural. This research agrees with Slack's (1989) and Correa's (1992) classification of structural resources to include labour resource. However, two broad sources of volume flexibility are adopted in this research. The first is based on external sources of volume flexibility, which incorporate Slack's flexible supply systems. The second is based on internal sources, which incorporate, Slack's structural and infrastructural internal resources (i.e. technology, labour and control systems). The classification of the sources of volume flexibility used in this research is shown in the figure below:

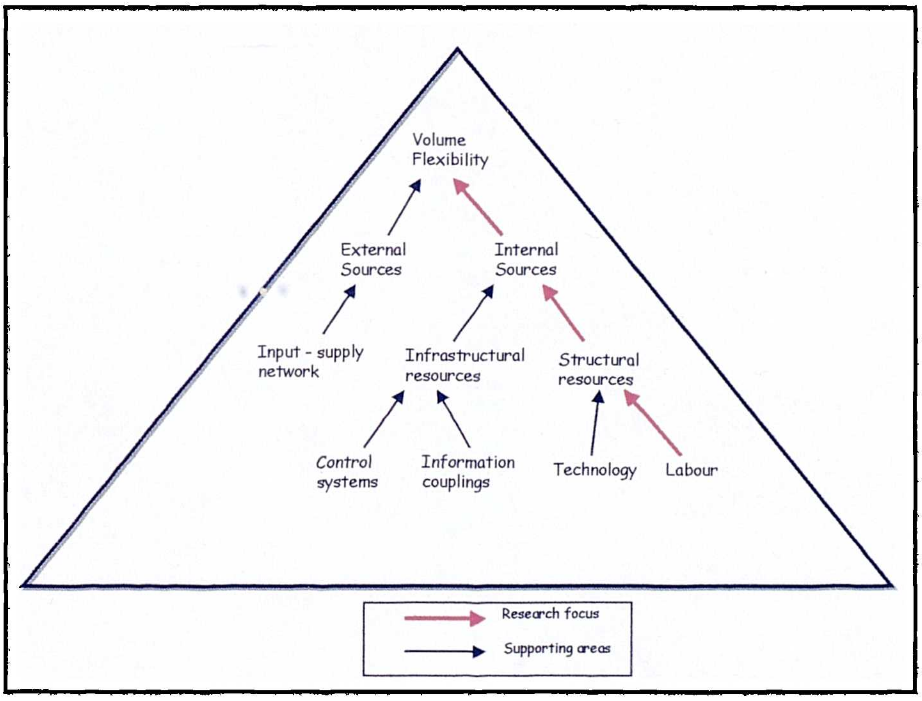


Figure 4.4: Sources of volume flexibility

4.4.1 External Sources

Integrating the input-supply network is vital to the achievement of flexibility in manufacturing plants. The importance of integrating the functions within an organisation in order to achieve a common strategic goal and avoid sub-optimisation cannot be overemphasised. Integration is achieved via many routes including the formulation of multi-disciplinary teams that cut across the entire functions of the organisation.

The importance of integration can be illustrated with the story concerning the development of radar before and during the Second World War as reported by Burns and Stalker (1961). The British Air Ministry had been interested in the feasibility of stopping aircraft engines by wireless 'death rays' directed from the ground. After a series of exchanges between the ministry and the head of the radio research station at Southampton, the latter advised that you couldn't destroy an aircraft in flight with death rays but you could use the same technique to identify its position in flight. This led to the formation of a team at the Bawdsey Research Station to develop radar and the creation of what was known as the British equivalent of the Manhattan project. The research team that actually developed radar into a workable system comprised quite an astonishing galaxy of British scientific talents drawn from a whole variety of places put together in a way that would not have been possible other than in war time. The success of that team, as Burns and Stalker (1961) noted, depended not only on the scientific talents assembled but the incredible social and communication systems that it led to. They introduced a system whereby every Sunday afternoon, meetings were held over drinks not only amongst the team of researchers but with a whole variety of people who might be potential users or in some cases potential victims of radar. Thus integration of technical knowledge with users' requirements through social contact and communication was vital for the success of the team.

Supply chain management extends the concept of functional integration beyond the firm to all firms in the supply chain (Ellram and Cooper, 1990). Due to the continuous search for competitive edge, emphasis is now being placed on managing the process from the point of raw materials supply through to the consumer end of the chain. For instance, "what used to be thought of as a purely tactical exercise - purchasing- is now regarded as a strategic function" (Goffin *et al*, 1996). And, "external suppliers now exert a major influence on a company's success or failure" (Monszka *et al*, 1993). Thus supply chain management has been defined as "an integrative philosophy to manage the total flow of a distribution channel from supplier to user" (Jones and Riley, 1985; Houlihan, 1985, 1988; Steven, 1989; and Ellram and Cooper, 1990).

If one recalls the story of the radar development, one recognises the importance of close relationships and communication to achieve integration. Clearly then, close relationships amongst the players of the supply chain is an important ingredient for achieving effective management and securing competitive edge. Slack (1991) notes that for industries subject to fierce competition these relationships have changed substantially over the last decade. The idea of partnership with suppliers, based on trust, shared destiny and long-term development with fewer suppliers has taken over the traditional arm's length customer-supplier relationships. Womack *et al* (1990) note that closer relationship is one of the reasons why lean manufacturers are more flexible in their operations.

A number of studies, especially in the supply chain management literature, have looked at ways of achieving close relationships between the members of the supply chain. One of these is by having a reduced number of players within the supply chain. Goffin *et al* (1996) argue that a reduced supplier base makes available more time for the development of the relationship. Backler (1991) argues that shippers in Europe are gradually reducing the number of hauliers with whom they are involved. Hellberg and Engh (1990) note that firms see a reduction in the number of suppliers as a means to an end. The end is attaining a win-win situation via continuous co-operation between the purchaser and the supplier. This close co-operation is demanding on resources, hence the need for the reduction in the total number of suppliers.

Having fewer suppliers or distributors or even shippers from the supplier's point of view results in a partnership type of relationship. Supply chain management is made up of a series of partnerships among firms working together and sharing information and channel risks and rewards (Ellram and Cooper, 1990). LaLonde *et al* (1989) defines partnership as "a relationship between two entities in the logistical channel that entails a sharing of benefits and burdens over some agreed upon time horizon". It can be likened to the "for better for worse" vows of marriage.

A number of studies have identified several benefits which partnering amongst the players in the supply chain can bring. Ellram and Cooper, (1990) classify the benefits as economic, managerial or strategic and view the benefits from the both the buyer's and the seller's perspectives. Ellram and Cooper (1990) argue that partnerships bring such economic benefits as lower cost, increased quality and the transfer of financial risks from the buyer's perspective. Managerial benefits obtained will include the ability to concentrate on the core business and efficiencies obtained in managing fewer relationships. The strategic benefits include the ability to position the supply chain for competitive advantage through gaining global flexibility and meeting customer service objectives. According to Hellberg and Engh (1990), a closer relationship leads to trust which results in higher confidence in the quality of information between the buyer and the seller. Thus, there is a reduction in the amount of time spent on inspection of incoming goods and simplified ordering routine, leading to increased responsiveness of the firm to production requirements (or volume flexibility).

The classical economic theory of 'economies of scale' encourages buying in large quantities to obtain lower unit cost (higher discount) of raw materials. The effect of this on the production system is high inventory of raw materials, large batch sizes, high work in progress inventory, increase in lead-time and decrease in flexibility. Close relationship between the supply chain partners can help to achieve increased frequency of small size deliveries (Just in Time deliveries) without adverse impacts on purchasing price. Small lot sizes give low inventory, shorter lead-time and increased flexibility.

Ellram (1991) cautions that supply chain management should not be seen as a cure and that its drawbacks must be evaluated. Ellram and Cooper (1990) identify some economic, managerial and strategic risks that shippers may be exposed to in supply chain management. The economic risks include the cost of switching (or alimony payments in the case of a marriage!) if the partnership eventually ends in a dissolution, since a long-term relationship which supply chain management encourages will have involved deep integration and transfer of proprietary information between the players. Managerial risks include information transfer risk since trust and close relationship warrant that participants have access to sensitive information about each other.

Strategically, there may also be a risk of losing flexibility from the participants' point of view. A long-term relationship locks in the parties and where, for example, a single-source supplier is concerned, there is the possibility of a drop in efficiency or rates of innovation due to reduced competition (complacency). It is also the case that, even where the efficiency does not drop, a highly uncertain market situation may cause a dramatic shift in the buyer's needs. If the supplier is not capable of matching the requirements, the buyer will have to worry about changing his sourcing and logistics strategy, which may involve high switching costs and take a considerable amount of time. By and large, the market may not wait for the length of time required for these unforeseen changes.

Generally, studies in the supply chain management literature recognise that close relationships are facilitated by the use of Electronic Data Interchange (EDI). Close relationships also encourage small lot sizes and JIT deliveries between the buyer and the seller, which will reduce the lead-time and increase volume flexibility. Subcontractors may be asked to absorb some of the volume fluctuations that the buyers face. In the manufacturing strategy literature, very few studies have been carried out to show the link between effective supply chain management and manufacturing flexibility. Although there have been contributions from various authors in the field (e.g. Hayes and Wheelwright, 1984; Schonberger, 1990; Womack *et al*, 1990; and Slack, 1991). However, Suarez *et al*'s (1996) study on the implementation of volume flexibility in 31 printed circuit board plants in Europe, Japan and the United States reveals that a close relationship with suppliers and sub-contractors will increase volume flexibility as sub-contractors may be asked to absorb some of the volume fluctuations.

4.4.2 Internal Sources of Volume Flexibility

Volume flexibility within the manufacturing plant can be obtained from infrastructural and structural resources (Figure 4.4).

Infrastructural Resources

Few authors have analysed the flexibility of infrastructural resources. These are specifically the manufacturing planning and control systems and procedures that support the functioning of the structural resources (Berry and Hill, 1988; Slack, 1989; and Tidd, 1991). Examples of such control systems in manufacturing include Just-In-Time principles, Materials Requirement Planning and Optimised Production Technology.

Slack and Correa (1992) stress the importance of distinguishing between the "philosophy" that underpins the systems and the "technical core" of the control system when exploring the relationship between the system and volume flexibility. The philosophy consists of the implicit and explicit assumptions and the general ideas underpinning the system. The technical core includes the actual software and tools required for the implementation of the control system. For instance, the philosophy underpinning Optimised Production

Technology (OPT) are the ten rules of OPT (Goldratt and Cox, 1994) while the technical core might be an OPT software package.

Slack and Correa (1992) examined two manufacturing plants for their use of different manufacturing planning control systems to cope with different circumstances. Using the range-response curves (discussed earlier), they found that in neither of the two cases studied did the technical core of the systems (in this case JIT: *Kanban* and MRP) have any significant effect on the plant's volume flexibility. But they found also that in one of the plants, the JIT philosophy had a more significant impact.

Other studies (e.g. Cusumano 1985; Krafcik, 1988 and Womack *et al*, 1990) have shown that production management techniques such as "lean production" tend to reduce set-up times, which leads to faster response and an increase in volume flexibility. Suarez *et al*'s (1996) study, however, did not reveal any significant differences between the use of production management techniques (such as participation in quality circles and techniques that reduce set-up times) and volume flexibility.

Structural resources

The structural resources in manufacturing organisations are classified as technology and labour (Slack, 1989 and Correa, 1992).

a. Production Technology

The flexibility of the technological resources appears to be the first major source factor associated with flexibility. The advent of Numerically Controlled Machines, Flexible Manufacturing Cells, Machining centres and Flexible Manufacturing Systems have been significant in the achievement of flexibility in manufacturing plants. Correa (1992) describes each of these technology elements as follows:

Numerically Controlled (NC) Machines: a process whereby operations are performed automatically according to a detailed set of coded instructions.

Machining centres: the combination of different NC operations into one centre. Optimisation of operations is achieved due to the localisation of the NC machines.

Flexible Manufacturing Cells: Machining centres with automatic loading and unloading (Voss, 1989).

Flexible Manufacturing Systems: combination of NC machines and other automated handling systems at a single location to achieve fast changeovers between operations.

Zelenovic (1982) argues that by changing the production elements (such as assembly lines and materials handling systems) in a manufacturing system to more highly automated concepts, the flexibility of the production elements can be increased. Having flexible automated technology as listed above leads to more uniform loading and a decline in defects, which results in higher quality products (Kaplan, 1996). Higher quality products mean faster response to demand since delays due to quality problems are eliminated. Hill (1993) argues that the NC machines are able to cope with a wider range of products over time than the non-NC alternatives. Hence, the former are able to provide more mix flexibility. Where the machines are able to adjust to relative volume changes within the mix, volume flexibility is enhanced.

Suarez *et al* (1996) found that the use of newer and programmable machines in the plants they studied increased the levels of volume flexibility in the plants. However, Jaikumar's (1986) study of U.S. flexible manufacturing systems reveals that generally the flexible manufacturing systems installed in the USA show *"an astonishing lack of flexibility"* compared to their Japanese counterparts. The implication of this is that unless managed adequately, new manufacturing technologies cannot provide the flexibility or competitive advantages sought through their adoption (Hyun and Ahn, 1992). To summarise the state of research on the flexibility benefits of new manufacturing technology, Correa (1992) argues that there is yet to develop a consensus on how to actually assess the impact of such technologies on flexibility.

b. Human Resources Flexibility

Atkinson's (1985) model of the flexible firm was the first major study into the issue of human resources flexibility in firms. The flexible firm model consists of a structure involving the division of the labour force into peripheral (or numerically flexible) groups of workers (who usually have weaker links with the company) clustered about a numerically stable core group, which conducts the organisation's "firm specific activities" (Figure 4.5)

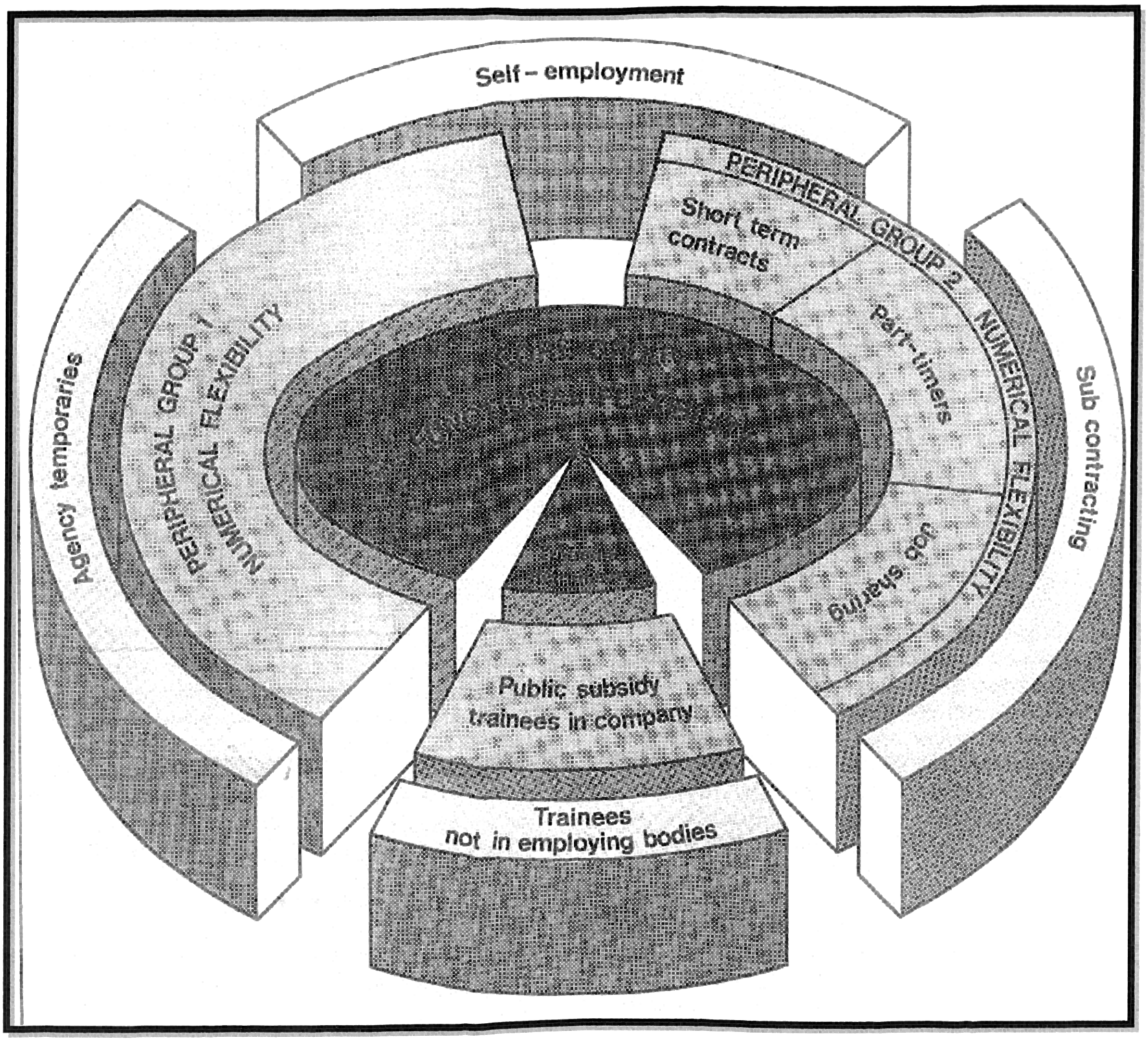


Figure 4.5: The Flexible Firm Model.
Source: Atkinson (1985)

In a volatile demand environment, the peripheral staff (temporary staff, part-timers etc.) expands to take up the slack (or provide additional capacity) as demand grows and contracts (the workers are easily released) as demand slows. The implication of the model is that workers at the core are only involved in changes in tasks and responsibilities and are insulated from medium term fluctuations while the peripheral workers are more exposed to them. He defines three types of human resources flexibility as functional, financial and numerical flexibility, and relates these to the model of the flexible firm.

Functional flexibility is described as that type of flexibility which enables employees to be re-deployed quickly and smoothly between activities and tasks (Atkinson, 1985). The requirement for this is that employees are highly trained in multiple tasks such that the same labour force changes its activities as the products and production methods change. If workers are multi-skilled, they can easily be moved from a quiet area of process requirement to a busy area (thus providing volume flexibility – especially if there are relative volume changes in aggregate production volume). In relating this to the flexible firm model, Atkinson (1985) argues that employees who provide functional flexibility for a firm form the core group in the model. They are characterised by their firm specific skills (i.e. skills that cannot be easily bought-in), and level of training and re-deployment (i.e. there is likely to be a higher proportion undergoing retraining at any one time in multi-task oriented areas and general problem solving).

Suarez's (1992) study in the electronics industry reveals a significant positive correlation between the percentage of workers that regularly use computers to perform their work and mix flexibility. He argues that the results support the notion that computer-literate workers should enhance a plant's ability to deal with variety (mix flexibility) in an automated industry like printed circuit board (PCB) assembly in terms of being able to down-load information and programme machines faster to perform different tasks.

Financial flexibility is sought so that pay and employment costs reflect the state of the external labour market in terms of supply and demand and as a means of facilitating either numerical or functional flexibility in the long term (Atkinson, 1984). In his work, Suarez (1992) describes financial flexibility as changes in the workforce wage level and structure associated with the type of labour policies employed by the firm. He argues that a firm whose wage system is localised and contingent on the firm's performance in the market place will have less difficulty in coping with production volume variations than a firm that sets wages by bargaining and wage formulas.

Numerical flexibility is described as the ease with which the number of workers employed (or hours worked) can be adjusted to meet fluctuations in the level of demand (Atkinson, 1985). This type of flexibility will provide tactical volume flexibility for a plant.

The literature has identified various forms of flexible working practices through which a firm can achieve numerical (and hence volume) flexibility. These include part-time working, temporary or non-permanent working, overtime, shiftworking, annual hours and teamworking. Further discussions on the issue of human resources flexibility will be restricted to the various ways of achieving numerical flexibility. This is because the impact of numerical flexibility on volume flexibility (the research subject) is more direct.

The objective of part-time employment is to enable employers to tailor labour costs to regular peaks and troughs in demand and help to meet regular variations in workload (Brewster *et al*, 1993). One could argue that this description of part-time employment does not make it exactly a source of numerical flexibility, which deals with uncertain and regular variations in demand or workload. Part-time employment will only provide volume flexibility where the hours of the part-timers can be increased or decreased as the requirement varies.

Temporary employment includes casual, freelance, short-term cover and fixed-term employment. The use of these employment forms provides flexibility for employers in that it enables them to cope with fluctuations in workload due to variations in demand without incurring premium costs accruing from recruitment. However, employees engaged in this way may lack motivation or commitment to the organisation because of the nature of their employment terms. This may lead to low productivity, an increase in the number of rejects and associated costs, which may be contrary to the objectives the organisation sets out to achieve.

In their survey of employers' use of different types of non-standard or flexible workers, Hunter and MacInnes (1992) discovered in some of the cases they studied that cost-saving solutions were perceived to be more expensive in the longer term when factors like employee commitment and loyalty were taken into account. One could argue, however, that temporary employment should only be considered as such, that is, as cover for short to medium term variations in the market demand. If, for instance, the growth of the market remains steady over the long term, then there is a case for changes in the form of the employment from the peripheral to the core group, which encourages functional flexibility if the original advantage of cost savings is to be maintained.

Overtime working enables employers to respond to increases in the workload due to demand variations by providing for longer hours than the standard day. In this sense, it provides the firm with the ability to vary its production volume (volume fluctuation) through the variability of labour capacity hours. It is, however, a relatively expensive option for many manufacturing organisations and it tends to become institutionalised. There are also other negative implications of overtime working. One of these can be explained by the economic law of diminishing marginal returns[†]. Overtime hours tend to be less efficient (Kossoris and Kohler, 1974). This may be attributed to problems of health, well being and disruption to social life, which long hours at work can entail (Brewster *et al*, 1993).

The European commission has defined shiftwork (reported in Brewster *et al*, 1993) *"as a situation in which a worker or group of workers, having completed a normal day's work at a particular job, is replaced by another worker on the same job within a 24 hour period"*. Different forms of shiftworking include double day shifts (i.e. two shifts run each day); night shifts; three-shift systems; twilight shifts (regular early evening shifts); weekend shifts or continuous shift (everyday around the clock) (Brewster *et al*, 1993). The choice of the shift pattern depends on the level of work requirements. With shiftworking, the capacity of the production system can be increased because it provides the ability to change production output and at the same time provide maximum utilisation of expensive equipment, which reduces the production cost per unit. Whether shiftworking provides flexibility is a question that needs to be addressed. Also, there are associated costs in terms of labour costs (premium paid for some types of shifts), administrative costs and problems with staff supervision.

Brewster and Connock (1985) define an annual hours contract as *"a contract which enables the employer to vary the number of hours worked in a defined period (daily, weekly, quarterly, yearly) within a context of the agreed standard working hours for the year"*. Unlike the other forms of employment or working patterns, which involve basically the use of the peripheral workforce to achieve numerical or volume flexibility, annual hours labour contracts can be used where higher skills of the workforce are required and where there is variation in demand over a given period (New, 1996). Thus, it is suitable for providing both numerical (in the form of variation in number of hours worked) and functional flexibility (in the form of multi-skilling) for an organisation. Costs due to hiring or engaging additional labour, loss in productivity (as a result of lack of motivation by peripheral workers) and quality are eliminated. However, underestimation or overestimation of the annual hours could be costly and actually make the firm inflexible. In the case of the former, the organisation has to resort to engaging extra labour to fill the slack, and excessive overestimation will incur losses in the form of paid for but unworked hours for the organisation (a gain for the employees!).

[†] The law of diminishing marginal returns states that "given that the amount of all other productive factors remain unchanged, the use of increasing amounts of a variable factor (*e.g. labour hours*) in the production process beyond some point will eventually result in diminishing marginal increases in total output" (McGuigan *et al*, 1993)

Teamworking is another way of achieving flexibility. In the most basic form, it consists of self-managed teams under the leadership of a team leader and employees in the team are responsible and accountable for the quality and operation of their own work. Due to their involvement in the activities of the team, employees are interested and motivated to carry out their tasks, hence an effect (even though marginal) on volume flexibility. The effect this sort of work style has on mix flexibility is, however, more significant since teams may consist of employees with different skills, thus encouraging appreciation and learning of different skills within the team (Kohler, 1989; and Womack *et al* 1990)

Pollert (1987) observes that the concept of core and periphery workers of Atkinson's (1985) flexible firm model is too fragile and that the model does not help understand the relationships between labour flexibility and the production system as a whole. The fact that the model ignores the issue of motivation and commitment of the peripheral workforce shows the bias of the model towards cost control rather than to the achievement of labour flexibility (Pollert, 1987). By and large, a number of authors in the operations management literature (e.g. Deming, 1986; Hayes *et al*, 1988 and Womack *et al*, 1990) have highlighted that workers' commitment and motivation are necessary ingredients for operational success in manufacturing organisations.

Although Suarez's (1992) research, which investigated the effect of human resources flexibility on volume flexibility in the electronics industry in the USA, provides an insight into the issue, it has some limitations. The study considers temporary working, wages (or financial flexibility), training and education as sources of human resources flexibility. The research in other words did not consider the other factors suggested in the human resources management literature for their effects on volume flexibility. It is probably not surprising then that the factors used display very low positive correlation with measures of volume flexibility.

The literature on human resources flexibility is still growing. There is, however, a dearth of empirical research that links human resources flexibility with the technical aspects of production flexibility especially in the operations management field. There is a need to identify labour capacity flexibility strategies that enable the achievement of volume flexibility and the operations contexts in which they are applicable. It is against this backdrop that the second Research Question has been formulated to attempt to partially fill this gap in the literature.

RQ2: Given the required capacity of equipment and effective flow of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

Assumptions

Three main sources of volume flexibility are identified by Slack (1991) as flexible technology, flexible supply networks and flexible labour. In terms of technology, what is of importance is to have spare capacity, short set-ups and changeover times to achieve volume flexibility. Hyun and Ahn (1992) argue that these variables are *static* and are defined under a fixed product or production structure in the short-term. It may be difficult to reconfigure the technology to cope with changes in the short-term. Having a flexible supply network system simply means having a smooth flow of materials into and out of the production system. Achieving this depends on a number of variables including building a close relationship with suppliers and distributors. These in most cases are not easily achievable in the short-term.

In terms of flexible labour, what is important is to have sufficient labour capacity flexibility (or numerical flexibility) to achieve volume flexibility. That is, the operation's ability to change its staffing levels quickly to cope with changes. This is achievable in the short-medium term through a number of strategies, some of which have been discussed in Section 4.4.2. This is the focus of the second Research Question.

The assumptions behind the second Research Question are:

1. There is a process technology with enough *range* flexibility to cope with whatever levels of demand it is faced with (Slack, 1991)
2. The input-supply network is flexible

Given the above assumptions, the second Research Question seeks to investigate what the other enablers of volume flexibility are in manufacturing plants (i.e. labour capacity flexibility sources and other strategies that would enable a manufacturing plant to achieve tactical volume flexibility).

4.5 Chapter Summary

The chapter has reviewed the literature on the analysis and implementation of volume flexibility in manufacturing plants. From the syntheses of various definitions of the concept, a working definition of volume flexibility was obtained. The chapter has also discussed the need to examine the requirement for volume flexibility in manufacturing plants. A framework is developed, which compares the use of volume flexibility with an alternative strategy of filling orders using stock levels. The discussion of the requirement for volume flexibility resulted in the identification of the first Research Question.

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

The literature on volume flexibility measurement was reviewed and the lack of consensus and problems inherent in measuring volume flexibility were highlighted. Implementing volume flexibility depends on sources both external and internal to the firm. Securing flexibility externally involves having a flexible supply chain, an area that is being covered mainly in the supply chain management literature. Securing volume flexibility within the firm depends on the flexibility of infrastructural and structural resources within the firm. Infrastructural resources include the control systems, which support the functioning of the structural resources (labour, and technology). A review of the literature on the effect of infrastructural resources on volume flexibility reveals a dearth of studies and a lack of concrete links between the control systems (especially in terms of their technical core) and volume flexibility. Similarly, the review of the literature on the effect of new manufacturing technology on volume flexibility does not reveal a clear positive association.

The flexible firm model of Atkinson (1985) which kicked off a series of studies on the issue of human resources flexibility was discussed. While the model provides a good conceptualisation of human resources flexibility, it fails to provide the needed link between labour flexibility and the production system as a whole. The review of the literature in this area reveals a dearth of studies especially in the operations management field. The second Research Question is formulated to partially fill this gap.

RQ2: Given the required capacity of equipment and the effective flow of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

The empirical phase of the research commences in the next chapter. The chapter will discuss the research methodology for executing and resolving the Research Questions developed from the review of the literature.

Chapter 5 – Research Methodology

5.0 Introduction

Figure 5.0 below shows the road map for the empirical phase of this research project.

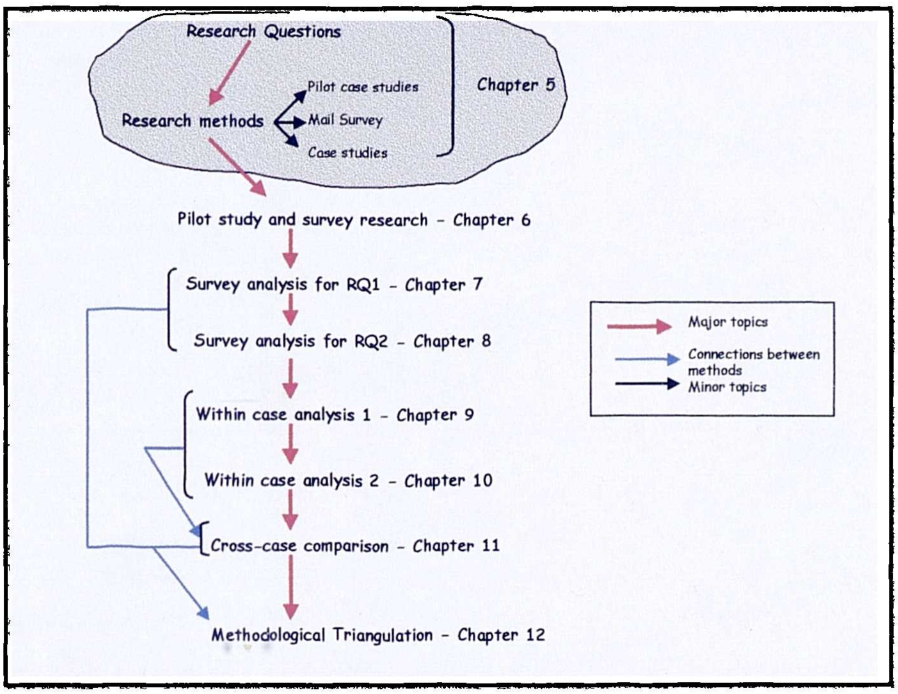


Figure 5.0: Empirical research road map. Chapter coverage is shaded

The literature review on manufacturing flexibility reveals a dearth of studies on the issue of volume flexibility in manufacturing plants. It is this gap which is the focus of the research. Two Research Questions are developed from the review of the literature in the previous chapter. This chapter discusses the methodology for carrying out the empirical phase of the project. By exploring the various research methods available in management research the chapter selects and provides justification for the adoption of the survey and the case study research methods. The case study research method is used to complement the results of the survey research as well as to provide explanations for the emerging trends from the survey analyses.

5.1 Research Questions

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

The literature review reveals that conditions of high unpredictability in demand levels, high variability in demand levels and a shortening product life cycle will drive manufacturing plants to require high levels of volume flexibility. These drivers are represented in the figure below.

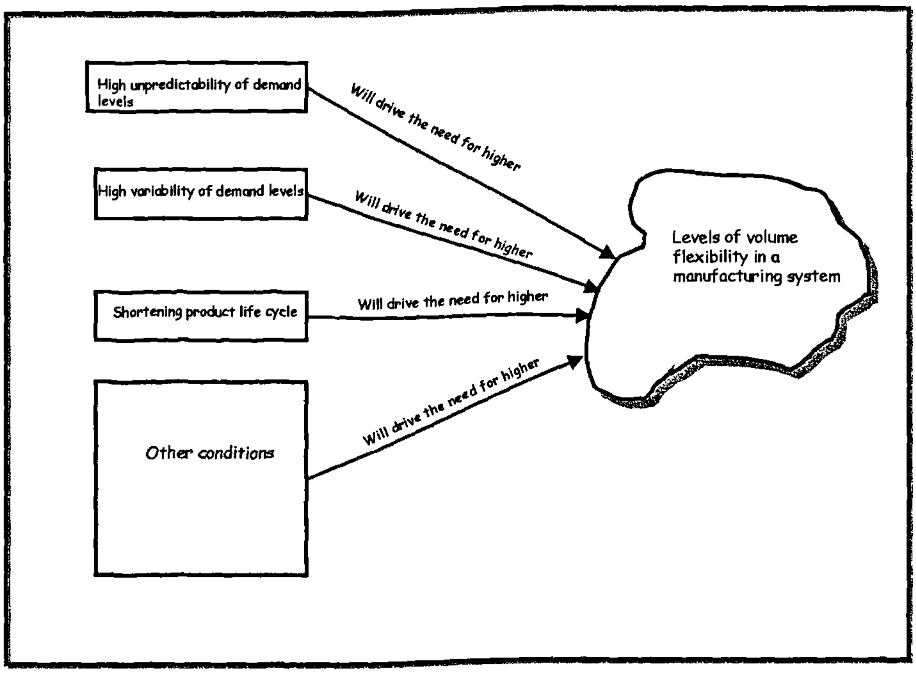


Figure 5.1: Conceptual framework for Research Question One.

The objectives of the research with regard to RQ1 are:

1. To undertake an exploratory study to provide empirical evidence to support the drivers of volume flexibility identified in the literature and pilot study.
2. To identify other drivers of volume flexibility needs in manufacturing plants.
3. To investigate the applicability of these drivers to manufacturing plants in different operating contexts.

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

The literature review reveals that high levels of volume flexibility can be achieved via factors that are external and factors that are internal to the plant. External factors include the flexibility of the input-supply network (assumed as available in RQ2). Internal factors consist of flexible technology (assumed as available in RQ2), labour and infrastructural resources (see Section 4.4.2, Chapter 4).

Enablers of volume flexibility can be defined as features of an operations management system which facilitate the achievement of volume flexibility, while inhibitors can be defined as features of an operations management system which prevent the achievement of high levels of volume flexibility (Harrison, 1997). The enablers and inhibitors in RQ2 thus refer to the labour strategies and infrastructural resources that aid and prevent the achievement of high levels of volume flexibility in manufacturing plants respectively. Figure 5.2 shows a conceptual framework for RQ2.

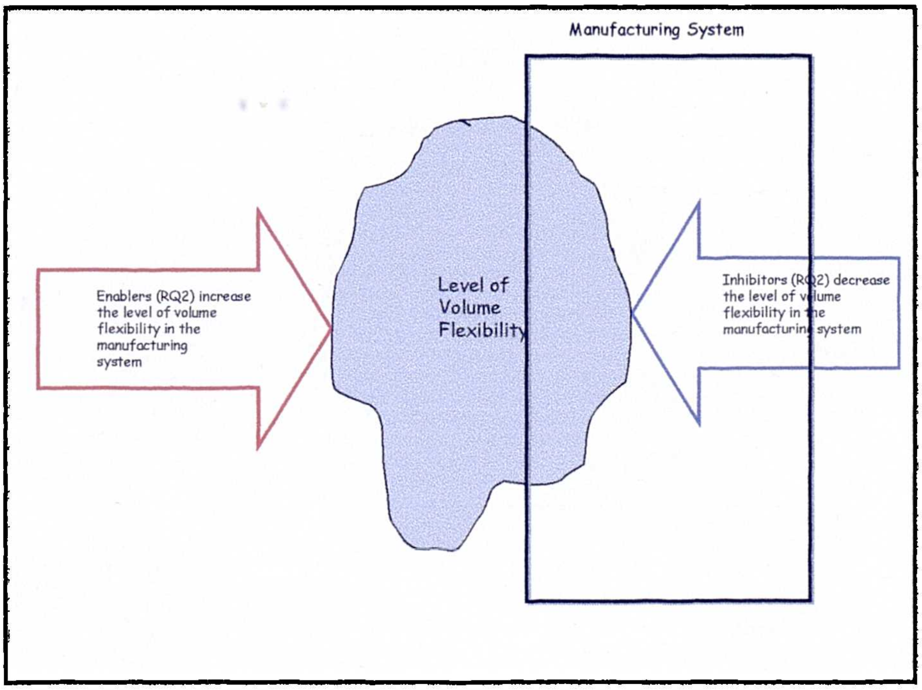


Figure 5.2: Conceptual framework for RQ2

The mass in Figure 5.2 above represents the level of volume flexibility. As the figure shows, there is an implicit assumption in the framework above that there already exists some level of volume flexibility in the manufacturing system (probably due to flexible technology and flexible supply networks). However, there are other attributes or enablers, which can be employed to achieve more or in fact increase the level of volume flexibility in a manufacturing system. There are also certain factors (inhibitors) that tend to resist and serve as frictional forces to the implementation of volume flexibility in a manufacturing system. The objectives of the research with respect to RQ2 are:

1. To identify the enablers of volume flexibility other than external enablers and technology based enablers
2. To identify the inhibitors of volume flexibility implementation in manufacturing plants in the same contexts as in point 1 above.

5.2 Criteria for Choosing a Research Method

The nature of the research problem has implications for the choice of the research method required for the empirical phase of the research. At the very least, however, the choice of method should consider the following: adequacy of the concepts involved, their validity and their reliability.

a. Adequacy of the concepts involved.

The concept of manufacturing flexibility has not been sufficiently explored in the literature (Correa, 1992). Although some drivers of volume flexibility have been identified in the literature, there is a need to identify other drivers and the different operating contexts in which these drivers are applicable to manufacturing plants. There also exists the need to identify the factors that enable and inhibit the achievement of volume flexibility in manufacturing plants and to provide insights into how these factors differ with different operating contexts. Resolving these queries requires an exploratory type of research method.

b. Validity

Bryman (1989) and Yin (1994) list three types of validity

Construct validity – the method chosen should establish the correct operational measures for the concepts being studied. This implies that it should be possible to test the adequacy of the measures chosen.

Internal validity – with the method chosen, it should be possible to establish a causal relationship whereby a direct causality can be established between two variables without the influence of other variables. This is better achieved with a method that consists of multiple cases (for case based research), where it should be possible to ascertain true causal relationships by comparing relationships between variables across many cases.

External validity – it should be possible to extend the findings of the study to wider contexts. This is better achieved in survey-based research where statistical inference can be made over a larger sample although analytical generalisation is also possible in a case based research.

c. Reliability

With the method chosen it should be possible to repeat the empirical study and arrive at the same findings and conclusions. This has an implication for a research method, which can be carried out systematically and is auditable.

5.3 Methodological Considerations

According to Bryman (1988a & 1989) the two general approaches to organisational research are concerned with quantitative or qualitative methodologies. Gill and Johnson (1991) argue that the type of data and information, its source and the means by which it is to be analysed, provide the differentiation between quantitative and qualitative approaches.

Quantitative research

At its extreme, quantitative research adopts a deductive approach. It is primarily concerned with identifying broad patterns, testing and refining theory and making predictions (Ragin, 1994). One of the main characteristics of quantitative research is the demonstration of causality. In survey research, causal relationships have to be inferred. In experimental research causal relationships between variables are more readily established because of the control that the investigator has over the dependent and the independent variables. Quantitative methods are also characterised by generalisation. Findings can be generalised and extended beyond the boundaries of the sample being investigated.

The analysis undertaken in quantitative research is usually static, involving the exploration of the relationships between variables (Eisenhardt, 1989). Quantitative studies tend to give less attention to context than qualitative research. For instance, one would not obtain the feel for the organisations under investigation in quantitative studies. Mintzberg (1979) argues that quantitative research would not be an appropriate method for theory building research because *"creative insight seems to require the sense of things - how they feel, smell, seem."*

Qualitative research

Qualitative research is an umbrella term that covers an array of interpretative techniques. Qualitative methods attempt to interpret significance, exploring diversity and perception in the process of developing theories (Croom, 1996 and Harrison, 1997). In contrast to quantitative research, which is propelled by a set of prior concerns, the investigator in qualitative research should be the determinant and source of what is relevant and important in relation to the domain being investigated. Also, the qualitative researcher is much closer to the phenomena being investigated. Methods of data collection in qualitative research include participant observation, open or unstructured interviewing, and semi-structured interviewing which can be part of a case study.

The proximity of the qualitative researcher to the phenomena being investigated could be a disadvantage of the research method if not well managed as it may introduce bias into the results if there is undesired interference with the phenomena being investigated. Collection and interpretation of data in qualitative research may be affected by subjective judgements. Thus the reliability of the qualitative research method may be doubtful. Yin (1994) argues, however, that the development of semi-structured protocols is a tactic that can be used to increase the reliability of qualitative research.

Generally, it is difficult to define a clear distinction between qualitative and quantitative research approaches. This is because qualitative research itself may involve some quantification, such as counting procedures in investigations. Similarly, quantitative research, such as the use of survey questionnaires, may include open ended and semi-structured questions, which seek some qualitative evidence.

5.4 Research Method

Blaikie (1993) argues that the key issue for the researcher is how the Research Questions can be answered. The question as to which methodology (either quantitative or qualitative) to use should depend on the nature of the research enquiry. Bryman (1988b) argues that the two approaches, rather than being seen as antagonistic, can in fact be complementary.

Yin (1994) cites three conditions for choosing a research strategy. These are:

1. The type of Research Question posed
2. The extent of control an investigator has over actual behavioural events
3. The degree of focus on contemporary as opposed to historical events.

Using Yin's conditions, five major research strategies employed in social science research (i.e. experiments, archival analysis, histories, surveys and case studies) will be assessed for their suitability for this research project. Table 5.0 below summarises the suitability assessment of each strategy based on Yin's criteria.

Research Questions/Yin's criteria and applicable research strategies.	**The type of Research Question**	**Does research require control over actual behavioural events?**	**Does research focus on contemporary events?**	**Choice of Research Strategies**
RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?	*"What"(Exploratory) (Case study, Survey, Archival analysis, Experiment and History)*	*No (Case study, Survey, Archival analysis and History) Drop Experiment*	*Yes (Case-study, Survey and Archival analysis) Drop History*	**Case study, Survey and Archival analysis*
RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?	*"What" (Exploratory) (Case study, Survey, Archival analysis, Experiment and History)*	*No (Case study, Survey, Archival analysis and History) Drop Experiment*	*Yes (Case-study, Survey and Archival analysis) Drop History*	*Case study, Survey and Archival analysis*

Table 5.0: Choice of Research strategies (After Yin, 1994).

* 'Case study is in effect a detailed description of an organisation, incident or phenomena', a hybrid form of research method (Croom, 1996). It can contain both quantitative & qualitative (e.g. in-depth interviews) data (Eisenhardt, 1989).

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

The first and the second Research Questions focus on "what" questions. The type of "what" questions that are implied in the Research Questions are exploratory in nature, the goal being to develop propositions for further inquiry. As such, Yin (1994) argues that any of the five listed research strategies can be used (Table 5.0, Column 2).

The two Research Questions require no control over actual behavioural events and contextual factors. Experiments require a closed system, where an investigator can manipulate behaviour directly. This can occur in a laboratory setting where the focus is on one or two variables or in a field setting (social experiment) where for instance a certain kind of treatment is applied to one group of people, and the other group is kept as a control. Experiments are best used in situations where there is a requirement to determine the effects of changes or intervention in a particular system or variable. For this reason, this research method (Experiment) is not judged to be suitable for the two Research Questions (Table 5.0, Column 3).

The two Research Questions deal with contemporary issues. The study intends to examine a current situation. Many of the empirical based studies on flexibility have been based on historical data (e.g. Fiegenbaum and Karnani, 1991 and Suarez *et al*, 1996). Historical method deals with the "dead" past where the researcher relies on documents (primary, secondary, cultural and physical artefacts) as the main sources of evidence (Yin, 1994). Therefore, the historical method is judged not to be suitable for the two Research Questions (Table 5.0, Column 4).

The implication of the above is that one can use any one of case study, surveys and/or archival analysis to investigate the two Research Questions (Table 5.0, Column 5).

5.4.1 Survey versus Case - Study

Survey is a method of social research, which like any other method has its advocates and critics. Survey research seeks to achieve an understanding of what causes some phenomenon by comparing cases (de Vaus, 1996). Surveys have been used extensively in Operations Management research. For example, the manufacturing futures survey (de Meyer *et al*, 1989), the global manufacturing research group (Whybark, 1995), the world class manufacturing project (Schroeder *et al*, 1995), the practice/performance study of European world class manufacturing (Hanson and Voss, 1995) and the Best Factory Awards (New and Szwejczewski, 1995). To this extent, the use of surveys is considered to be well grounded in Operations Management research and, therefore, suitable for this study.

There have been some calls for a more empirically based research method such as case-oriented research in Operations Management research (Mintzberg, 1979; Meredith *et al*, 1989; Swamidass, 1991). This is because of the dichotomy that is perceived to exist between surveys (variable-oriented) and case study (case-oriented) research. Ragin (1987) provides the distinction between the two methods. His views are summarised by Harrison (1997) as shown in Table 5.1.

Issue	Variable Oriented	Case Oriented
Basis of Research	*Quantitative* *Multivariate statistical techniques* *Many data sets*	*Multiple methods to establish different views* *Qualitative and quantitative*
Scope	*Wide categories* *Broad empirical generalisations based on heterogeneous samples* *Comparability ignored/skirted*	*Narrow classes of phenomena* *Several combinations of conditions may yield a certain outcome*
Causality	*Disaggregated into variables & distributions* *Based on analysis of entire population or sample*	*Probabilistic relationships not accepted* *Must account for all deviating cases*
Conclusions	*Vague & abstract* *'Unreal quality' of conclusions* *More concrete questions do not receive the attention they deserve*	*Few general conclusions* *Separate contexts*
Theory/data link	*Radically analytic* *Strictly a priori* *Link between research & actual empirical processes strained*	*Rich & elaborate dialogue* *Strong link between research & actual processes*
Aggregation	*Breaks into parts - variables which are difficult to reassemble into wholes. Not combinatorial.*	*Holistic: parts related to context of whole*
Complexity	*Average influence across a variety*	*Sensitive to complexity & historical specificity. But difficult to sustain attention to complexity across a large number of cases.*
Relevance	*Broad : general statements linked to abstract theoretical ideas about generic properties*	*Narrow : findings specific to few cases examined*

Table 5.1: The Dichotomy between Variable-Oriented and Case-Oriented Research in the Social Sciences
Source: Harrison, 1997 (after Ragin, 1987).

The above table highlights the main strengths and weaknesses of variable-oriented research and case-oriented research typified by survey based and case study research strategies respectively. Walker (1985) argues that the type of question asked determines the methods to be employed. Warwick and Lininger (1975) argue that each is useful for some purposes, and useless for others. These two methods, when used together in a research project, can provide the benefits of using the strengths of one to balance the weaknesses of the other. This process is known as triangulation.

5.4.2 Triangulation

The most important advantage of using multiple sources of evidence is the development of converging lines of inquiry (Yin, 1994). Methodological triangulation is achieved when different methods of approaching a social enquiry are used, such as combining both qualitative and quantitative approaches. In this case, the qualitative study attempts to overcome the limitations of the quantitative approach and vice versa. Multiple and independent measures, if they reach the same conclusions, provide a more certain portrayal of the phenomenon under investigation (Jick, 1979). Vidich and Shapiro (1955) argue that *"without the survey data, the observer could only make reasonable guesses about his area of ignorance in the effort to reduce bias"*.

Jick (1979) notes that survey research may contribute to greater confidence in the generalisability of results. Reiss (1968) argues that surveys can be used to exploit *"the potentialities of social observation"*, while Sieber (1973) suggests that field studies such as case studies can contribute to survey analysis in terms of validation of results and interpretation of statistical relationships. According to Diesing (1971), survey research and fieldwork are better viewed as two ends of a continuum rather than as two distinct kinds of method. Yet, research designs that extensively integrate both methods are rare, as journals tend to specialise by methodology, thus encouraging purity of method (Jick, 1979).

Good examples of studies which employed the triangulation approach (cited in Jick, 1979) include LaPiere's (1934) seminal investigation into the relationship between attitudes and behaviour, Reiss' (1968) study of police and citizen transactions, Sales' (1973) study of authoritarianism and Van Maanen's (1975) data on police socialisation.

This research project follows the above examples and employs a methodological triangulation approach (combining survey and case studies) as well as a data triangulation approach (multiple sources of data within a research method). This is intended not only to examine the issue under study from different perspectives but also to enrich our understanding by allowing for new and deeper dimensions to emerge (Jick, 1979).

5.4.3 Level and Unit of Analysis

The requirement for flexibility at each level in an organisation may be different. As such it is necessary in researching a concept such as flexibility to define the level of analysis. Gerwin (1987) suggests four classifications of levels in an organisation:

1. Individual machine or manufacturing system level
2. The manufacturing function, i.e. forming, cutting or assembling
3. The manufacturing process
4. The factory

Slack (1990a) defines four levels of analysis:

1. The level of the firm
2. The level of the function (i.e. the manufacturing function as a whole)
3. The level of the cell
4. The level of the particular resource

The terms *level* and *unit* of analysis have most often been used in the literature interchangeably. In most cases, they tend to represent the same thing. The level of analysis deals with the level at which the research is carried out or administered, such as the *level of the cell,* as classified by Slack above. However, if there is a requirement to compare the phenomenon being studied within the cells in different plants, then the unit of analysis is the *manufacturing plant.*

Yin (1994) notes that the definition of the unit of analysis should be related to the way the initial questions have been defined. Thus, the unit of analysis provides a basis for the comparison of results or for aggregating reports on the phenomena being investigated. The Research Questions for this project focus on the issue of volume flexibility (a strategic flexibility type) in manufacturing plants. Thus, a common unit and indeed the level of analysis adopted for the empirical phase of the research is *"a manufacturing plant"*. This is similar to Gerwin's (1987) *'factory'* level and Slack's (1990a) *'level of the function'* (given that the manufacturing function is dominant).

New and Szwejczewski (1995) have defined a manufacturing plant as:

"..a relatively self-contained unit with its own management staff which can be identified by separate facilities, by separate products, or by a separate management structure."

The definition above has been adopted for this research and all data are collected in reference to a manufacturing plant as defined by New and Szwejczewski.

5.4.4 Empirical Research Design

The empirical phase of the research project has been carried out in the following sequence.

1. Pilot study
2. Survey
3. Case-study

The pilot study is exploratory in nature. It has been used to identify variables that are relevant to the Research Questions, such as the drivers, enablers and inhibitors of volume flexibility in manufacturing plants. These variables are compared with those identified in the literature and are then used to design a survey questionnaire. The survey research is also exploratory. It was necessary to investigate the applicability of the variables identified in the pilot study over a larger sample of manufacturing plants. Thus, broad patterns of established variables are identified resulting in new questions, which required investigation. Investigating these questions required the use of a research method such as a case study research that helps in providing deeper understanding of the phenomenon under investigation. Thus, the analysis of the survey research is followed by an explanatory case study research. The case study research has been used to add richness to the investigation of volume flexibility issues in this project by seeking to explain the observed trends and patterns from the survey research. A brief description of each of the research method is given below.

1. Pilot Study

The pilot study helps to refine data collection plans with respect to both the content of the data and the procedures to be followed (Yin, 1994). The pilot study undertaken in this research has been used to explore and provide insight into the basic issues of volume flexibility in manufacturing plants. Four manufacturing plants were selected from the Food, Electronics, Process and Household goods sectors of the Best Factory Awards (BFA) database†. Variables identified from the pilot study in respect of the Research Questions are used in designing the survey questionnaire (Chapter 6 outlines the detail of the pilot study).

2. Mail Survey

Exploratory survey research is undertaken to explore and identify the drivers, the enablers and inhibitors of volume flexibility in manufacturing plants (Research Questions One and Two). A questionnaire consisting of a mixture of structured questions and an open-ended question is employed and administered in 529 manufacturing plants that are past entrants into the BFA competition. These plants belong to the Food, Electronics, Process, Engineering Consumer, Engineering Capital and Household goods sectors. The survey is analysed in order to confirm the concepts identified from both the literature and the pilot study and to identify other drivers, enablers and inhibitors of volume flexibility (Chapters 6, 7 and 8 outline details of the survey administration and analyses respectively).

3. Case Study

The case study is undertaken to identify the drivers, enablers and inhibitors of volume flexibility in manufacturing plants (triangulation for survey). The second objective of the case study is to explain the trends observed in the survey analyses, thereby providing insights into new Research Questions generated from the survey analyses.

Case Study Design

Figure 5.3 below is a 2 X 2 matrix developed by Yin (1994) to describe different types of case study design. The matrix shows that, generally there are two types of case study design (i.e. single and multiple-case designs). Within these types, case study designs can be based either on a single or on multiple units of analysis. The choice of the unit of analysis depends on the basis chosen for reporting or comparing the results of the case

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† The Best Factory Award is a yearly competition amongst Britain's factories to select and reward factories with best practices. Cranfield School of Management manages the Best Factory Award (BFA) database. The database consists of over 1000 UK manufacturing plants that have entered for the BFA competition since its inception in 1992.

study analysis (see Section 5.4.3). A single case design is preferred where the case represents an extreme or unique case (Yin, 1994).

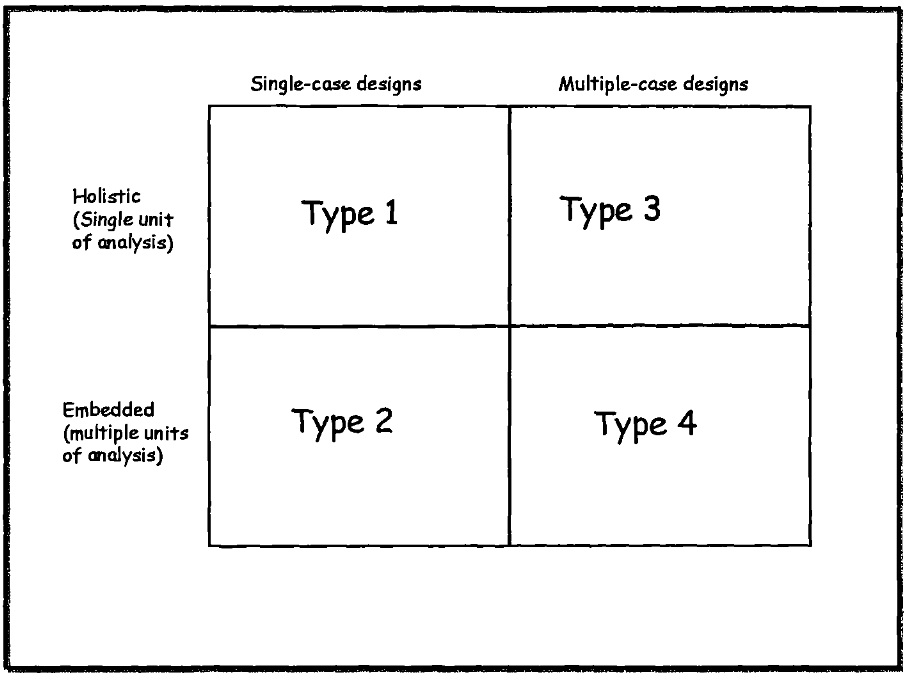

Figure 5.3: Basic types of design for case studies
Source: Yin (1994) after Cosmos Corporation

This research adopts the holistic, multiple-case design approach for the case study (located in the type 3 quadrant of the figure above). This consists of a single unit of analysis (a manufacturing plant) and eight manufacturing plants across different industrial classifications. Multiple case design is considered suitable for this research project because the nature of the research objectives requires insights into flexibility issues in different operating contexts. This is intended to partially fill yet another gap in the literature on manufacturing flexibility. For instance, the results of Suarez *et al*'s (1996) study on the implementation of flexibility is limited because it is survey based and it focuses only on a particular manufacturing sector (i.e. printed circuit board assembly plants). Herriot and Firestone, (1983) argue that multiple cases' evidence is often more compelling and gives the overall study more robustness.

The multiple-case design in this project follows the '*replication logic*' rather than the '*sampling logic*'. Sampling logic commonly used in surveys demands an evaluation of a population of say manufacturing plants such that samples of surveyed plants are selected using some sampling techniques such as stratified sampling, random sampling and the like. The results of the analyses of the selected subset of the larger population are then inferred onto the entire population using some statistical techniques. In replication logic, a particular concept or phenomenon is investigated in different operating contexts or cases. Where similar results are obtained, the results are said to produce a *literal replication*. Where the analyses produce contrasting results but for predictable reasons, the results are said to follow a *theoretical replication* (Yin, 1994). Both the literal and theoretical replication logic are sought in this research project.

The cases are selected from the respondents of the survey based on the richness of the information supplied. Details of the selection criteria are discussed in Chapters 7 and 8. Selection is made across all the six industrial classifications defined earlier (i.e. six manufacturing plants, one from each sector). Two other manufacturing plants that provided other interesting insights in respect of the phenomena being studied are also chosen to add richness to the analyses. Thus, eight plants are selected for the case study empirical phase of the project (Chapters, 9, 10 and 11 outline the details of the within-case and cross-case analyses).

5.5 Chapter Summary

Figure 5.4 below summarises the issues covered in this chapter.

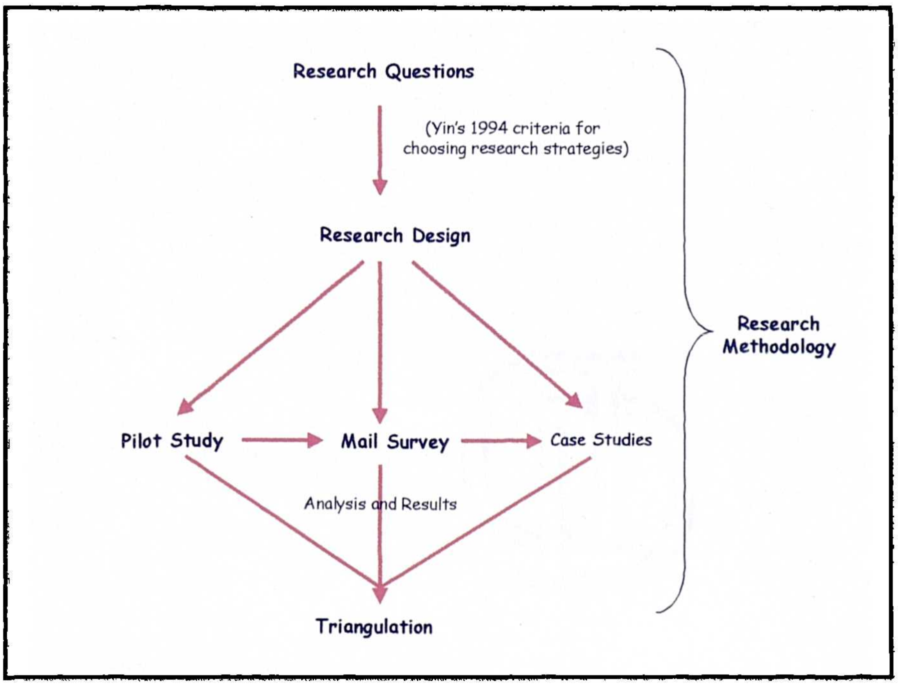

Figure 5.4: Summary of chapter coverage

The chapter has reviewed various research methods available in management research. Due to the nature of the Research Questions, the survey research and case study research methods are chosen for the empirical phase of the research. The unit of analysis for the research is *'a manufacturing plant'*. A pilot study, which provides insights into the basic issues of volume flexibility and tests the data collection strategy, precedes the survey research. The selection of the case study plants is based on the analyses of the survey. The case study research design chosen is a holistic multiple case design consisting of eight manufacturing plants with at least one plant belonging to each of the six industrial classifications described earlier. The multiple-case design consists of a replication logic whereby, for instance, a particular concept (e.g. an enabler of volume flexibility) is investigated in different operating contexts (such as sectors) to achieve either a literal or theoretical replication.

The next chapter will describe the pilot study protocol and analysis, and the survey research design and administration.

Chapter 6 – The Pilot Study and Survey Research

6.0 Introduction

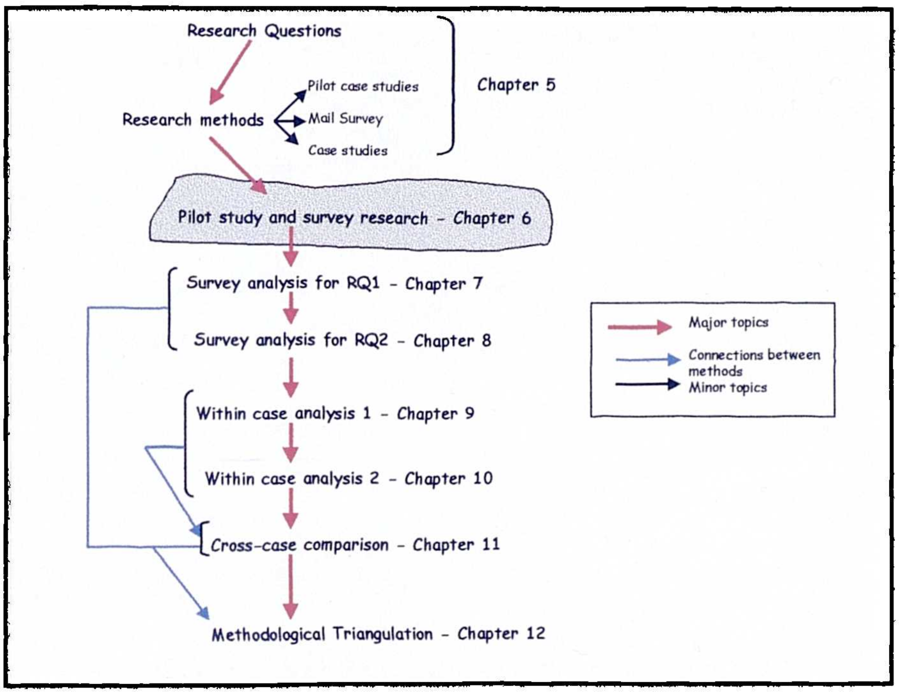

Figure 6.0: Empirical research road map. Chapter coverage shaded

The research design described in Chapter 5 proposed the execution of the empirical stage of the research in three phases. Phase one involves carrying out a pilot study in selected manufacturing plants to provide insight into the basic issues of volume flexibility. Phase two involves carrying out survey research to explore and provide insights into the Research Questions. Phase three involves carrying out case study research to validate the results of the survey and to enrich our understanding of the emerging trends identified in the survey.

This chapter describes the first phase (pilot study and analysis) and part of the second phase (survey administration) of the empirical research. Four manufacturing plants were selected for the pilot study. The analysis of the pilot study is done in line with the two Research Questions under investigation. Concepts identified from the pilot study analysis are used to design a survey questionnaire. This chapter presents a justification matrix for the questions asked in the survey questionnaire as well as the operationalisation of the Research Questions.

6.1 Pilot Study

The aim of the pilot study was to provide insight into the basic issues of volume flexibility. The information obtained in the pilot study is used in parallel with the information obtained from the review of relevant literature to carry out the survey research. The Research Questions were also investigated in the pilot study. This was done to refine the data collection strategy and to identify variables, which are then explored in the survey stage of the research. Thus the final Research Questions and design are informed both by prevailing theories and by a fresh set of empirical observations. This dual sourcing of information helps to ensure that the study reflects significant theoretical issues as well as questions relevant to contemporary cases (Yin, 1994).

Four manufacturing plants were selected for the pilot cases. In general, convenience, access, geographical proximity and their willingness to co-operate in the study were the main criteria for selecting these plants as pilot cases. More importantly, these manufacturing plants belong to four sectors (Food, Process, Electronics and Household) which are similar to the *sectors of the plants targeted for the survey research. The plants are identified by the letters A, B, C and D. The research design for the pilot study involves:

1. Factory tour of operations to understand the operations process and plant characteristics that may affect volume flexibility.
2. Interviews with relevant managers in the plants (i.e. factory or production manager, production planning manager and quality control manager) lasting on average about 2 hours each over two days in each plant. The format of the interview is semi-structured. Interviews are audio taped to provide transcripts for subsequent analyses.
3. Collection of relevant production data.
4. Transcription of interviews and analysis of data in line with Research Questions One and Two to identify emerging themes (Miles and Huberman, 1994; Yin, 1994). These themes and concepts are constantly compared with themes from the literature to develop a conceptual framework used for the survey and case study phases of the research.

* The sample for the survey is discussed in Section 6.3.1. Entrants into the Best Factory Award (BFA) from 1995 to 1998 are targeted. The sample consists of plants in the Food, Process, Engineering and Household sectors.

Plants	Sector	Product/Service	Major Clients/Market	Description of operations
Plant A	Food	Washed and bagged potatoes.	Major UK supermarket chains	Highly seasonal demand. Largely make to order. Simple production process consisting of grading of potatoes to the required sizes, washing, further grading and bagging. Labour skill level: low to medium
Plant B	Process	Construction material	Construction, DIY and decorative markets	Operations can be divided into upstream and downstream. Upstream operation is largely make-for-stock. Releasing a blowing agent to them expands the raw materials beads. These are stored and allowed to mature in a silo for 24 hours. The matured pre-expanded materials are loosely charged into a block mould where they are treated with heat to expand further. The finished products are then formed in blocks and stored as stock for about 5 days on average. The downstream operation is largely make-to-order. The blocks are cut to required sizes for dispatch. Labour skill level - medium
Plant C	Electronics	Capital kits required for telecommunication solutions	British Telecom	Operations can be divided into upstream and downstream. Upstream operation is largely make-for-stock. Consist of the assembly of printed circuit boards (PCB). Have two manufacturing sections for the PCB assembly. A cell layout and a batch manufacturing section. The former is faster and uses surface mount technology. The downstream operation consists of the building of the capital kits (i.e. configuration & customisation using the PCB and racks) to the required specifications. The operation is only activated on the receipt of an order, hence largely make-to-order. Labour skill level: medium to high.
Plant D	Household goods	Wallpapers	Sister marketing company and third party customers (Hotels, private and the like).	Three types of printing processes: Gravure, Flexo and Surface prints. Type to be used depends on product type required. Four major stages involved for all types of prints. (1) Make ready: prepare materials (ink, paper, bases, cylinders) and installation. (2) Print: done on the type of machine required. (3) Heat Emboss: gives the paper the type of surface required. Not required on all jobs especially Surface prints. (4). Winding, wrapping & packing, ready for dispatch. Labour skill level: medium

Table 6.0: Descriptions of Pilot Case-Study Plants

The first Research Question was explored in each of the plants. Generally, in-depth interviews were carried out with the Manufacturing Managers and other selected personnel in the plant (i.e. Planning Manager and/or Production Manager). The positions vary across the plants. All the managers interviewed are directly involved in the supervision of at least one aspect of the production operations.

6.1.1 Analyses for Research Question One

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

Questions asked include:

What do you understand by volume flexibility?...
Is volume flexibility a major issue for you?...
Why does your plant require volume flexibility?
How variable is the demand pattern for your products?
How do you fill orders, i.e. ex-stock etc.?.....

The excerpts of the interview are summarised in Table 6.1. Relevant responses to some of the above questions are tabulated. Variables have been identified to enable the classification of responses.

Variables	Plant A	Plant B	Plant C	Plant D
Demand Pattern	*"..mainly seasonal, total demand is fairly predictable and stable up to about 80%, but high variability exists on a daily and weekly basis during peak periods".*	*"Demand from major customers does not vary very much. We are pretty close to our customers, so they can easily warn us in advance of their requirements.."*	*"...our business is seasonal. The volume forecast is not bad, though it varies slightly, but the mix within a product forecast is more difficult and more variable".*	*"For supplies to our sister marketing companies, we are sort of insulated from the direct market effect. So to some extent the demand has not been so variable". "For third party business, the demand is relatively more variable*
Product type and Order-filling mechanism	*"We cannot afford to fill orders from stock as our products have very short life span. Once washed, the life-span of potatoes is drastically reduced. We stock only the unwashed potatoes".*	*"We produce the blocks to stock and start to cut to the required sizes as soon as orders are received. We usually have about six days worth of stock. The length of time the blocks stay in stock actually depends on the purpose for which it is required."*	*"We produce part of the process to stock which we call the 'supermarket'. On receipt of orders we do mass customisation and configuration to fill our orders. Our stock products are generally durable but may be threatened by obsolescence."*	*"Generally, we make to order. By their nature, our wallpapers are durable otherwise we would be out of business. But specific designs may become obsolete with time".*
Customer lead time	*"....we supply big supermarkets in the UK. We are heavily dependent on them. They determine when they want the produce and are somewhat unsympathetic to our needs"*	*"..our customers specify the lead time but we are sometimes able to negotiate the delivery time with them if we run into difficulties. We work very closely with them and it is not such a problem once we let them know in advance of potential problems or delays to delivery..."*	*"...we have two kinds of businesses. The first is where the customers come to us for a particular need which we then translate into capital kits. In this case, we specify the customer lead time. Also, we have technical customers who come to us directly asking for a particular product type, they specify when they want it, but we can still negotiate to some extent on the lead time".*	*"..for repeat orders, we do automatic stock replenishment for our customers based of course on a pre-determined lead time. For "striking" jobs (new collections), we usually have sufficient lead time to deliver. In both cases, our customers are somewhat flexible about the lead time which of course depends on their end users"*
Volume flexibility requirement	*"..our major problem is to be able to meet volume requirements profitably and on time within the peak demand period as these are highly variable"*	*"..we need to be able to satisfy any quantity of order required by our customers. I believe we possess this ability".*	*"..we need volume flexibility, but this is not sufficient for our business. More importantly, we have to be able to accommodate changes in the mix of the products that we supply"*	*"I believe we require high levels of volume flexibility. Future orders are going to be in a variety of forms, i.e. smaller batches and so on".*

Table 6.1: Excerpts from pilot interviews (RQ1- Drivers of volume flexibility)

Analyses of the interview transcripts reveal that relatively, Plant A appears to have more need for higher levels of volume flexibility than the other plants. The reasons they gave for this include:

1. High short term variability in demand levels
2. Short life span of product
3. Heavy dependence on customer (see circled comments in Table 6.1)

The above concurs with Slack's (1987) argument in which he suggested that turbulent trading conditions, particularly large fluctuations in demand, have highlighted the need for flexibility in manufacturing.

The insights gained from Plant A with regard to the first Research Question were investigated in the other plants. The analyses of the transcripts of the other plants reveal that generally:

1. The plants do not experience as much variability in demand levels as Plant A
2. The plants have relatively more durable products
3. Product obsolescence is an issue in some of the plants
4. The plants have flexible and understanding customers
5. Having high levels of volume flexibility is an issue but not as pressing as for Plant A.

Table 6.2 identifies and summarises the conditions that drive the needs for volume flexibility in the plants, as well as their perceived need for volume flexibility.

	Demand variability	**Product Shelf-life**	**Customer's influence in lead-time determination**	**Product life-cycle**	**Demand uncertainty**	**Perceived need for high levels of volume flexibility**
Plant A	• Very high	• Short	• High, non-negotiable	• Not applicable	• High	• High
Plant B	• Medium	• Long	• Negotiable	• Not applicable	• Medium	• Medium
Plant C	• Medium	• Long	• Negotiable	• Short	• Low	• Medium
Plant D	• Medium	• Long	• Negotiable	• Short	• Medium	• Medium but increasing

Table 6.2: Summary of findings from pilot study with regards to RQ1 (Drivers of volume flexibility).

The results of the analyses highlight the need to investigate the first Research Question of the project. In fact Slack (1991) notes that in order improve flexibility it is important to clarify why flexibility is needed. For instance the pilot study reveals that not all the manufacturing plants require high levels of volume flexibility. Conditions, which drive the need for volume flexibility, were identified:

1. *High variability of actual demand levels* – demand variability exists when expected demand varies significantly from period to period over the relevant planning period, but the total demand over the planning period is relatively predictable.
2. *Short product shelf-life* – refers to the perceived limited elapsed time period between the date the product manufacture is completed and the 'use-by' date of the product.
3. *Short product life-cycle* (expressed as obsolescence in the interview) – refers to the perceived elapsed time period that the product is in use for before it becomes obsolete or modified.
4. *Customer's influence in lead-time determination* – refers to a situation whereby a customer has more power or influence in the determination of customer lead time (customer lead time refers to the elapsed time from the time an order is placed to delivery to the customer).
5. *High unpredictability of demand levels* – exists when the actual demand experienced in a given period is highly unpredictable from period to period.

6.1.2 Analyses for Research Question Two

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

Questions asked include:

How did you cope with variability in demand levels in the past?...
Have you ever failed to meet scheduled delivery dates or demand requirements in the past? If so why?
Has your inability to meet demand requirements in the past been due to problems with suppliers, distribution and insufficient capital equipment capacity?
What other problems have in the past inhibited your ability to meet demand requirements?
How did you overcome these problems?
Excerpts of interview are displayed in Table 6.3.

Variables	Plant A	Plant B	Plant C	Plant D
Coping mechanism for demand variability (or enablers)	*"...through the use of overtime hours and employing 'gang labours' which results in high production cost since labour content represent a high proportion of our cost".*	*"..we rarely get caught out. We operate normally on a single shift, hence we have sufficient slack to increase production if we have to by using overtime. We can also transfer work to our sister factories, but we rarely do this. Our customers usually agree to re-schedule delivery dates if necessary".*	*"..we operate 3-shifts, 5-day working, so we have slack to introduce overtime in the weekends. We employ contract and temporary staff when we need to. We are trying to introduce a system of 'banked hours', which should cut cost of overtime. We are also able to offload work to our sister factory in Liverpool if we have to".*	*"we normally operate well below our capacity, so we have slack for overtime. For instance, we run a 12-hour, 3-day shift. The remaining days are available for overtime. We can negotiate the delivery dates with our customers. We also use sub-contractors but it is not a preferred option".*
Constraints to coping (or inhibitors)	*"..difficult to get gang labours when we need them. Notice is usually very short and the work is relatively unattractive in terms of pay. We also have problems of low yield. The lower the yield, the more the hours needed to get the required quantity of output through the door, the higher the cost".*	*"..sometimes we have power cuts. Three things are vital to our operations, the electric, the boiler and the compressor. If any of these is out of order for 3 days or more, we start to panic".*	*"about two years ago, when we were launching a new product, one of our suppliers couldn't produce the required volume for a particular component. This affected us badly. It was a one-off incident though. Apart from that, there is the overtime premium that we pay, and we also find it difficult getting good people to work on contract and temporary basis because of the level of skills required".*	*"we have about 400 cylinders on the move regularly, so they get spoilt and this could delay production. Our machines are old so the production process is not as sleek as it should be, we could do a lot to improve change-over times".*
Overcoming constraints	*"..we are looking at new labour strategies to employ, but in the main the problem with gang labours is still there. As for the yield, we increase the order requirement by a reasonable percentage to cover losses. We have formed a growers club which improves our relationship with our growers. We source much of the seeds for them to increase quality".*	*"..when we had a long power cut in the past, we shifted orders to our sister factories and discussed the problems with our customers. This is not a regular occurrence, but we will probably take the same action if it happens again".*	*"the introduction of the banked hours system should reduce the cost of overtime. we communicate better with our suppliers through EDI and video conferencing. Our order planning system, the MFG Pro requirements are automatically displayed on the screen of our suppliers at the same time we see them, so we have almost eliminated completely potential supply problems".*	*"we will be investing in new machinery for a long-term solution to our long lead time. At the moment we have introduced swot teams which have helped to improve our downtime. We are close to our customers. We talk to them to re-negotiate delivery dates. This has always worked".*
Efficiency of the supply chain	*"..apart from the quality issue, we have no problems getting our supplies through. We actually supply 10% of our requirements. We hold large stock of raw materials and we own 100% of the distribution fleet, so we have no problems with moving the produce to our customers".*	*"our suppliers belong to the same group as ourselves. We can get supplies within 24 hours if we wanted. We have a very good relationship with our distributors. They are based on site so we can easily track the movement of our deliveries".*	*"we consume about 800 million components a year from about 250 suppliers. About 80% of our supplies come from 20% of the suppliers. Our suppliers are scattered around the world but many of them now have subsidiaries in the UK. With the technology we now have in place, we don't expect major problems with getting our components on time".*	*"we have two suppliers for each printing process materials. They are very reliable, if I order for a base material before 11 am, I will get the delivery the next morning. We have limited space for stock, so we require this kind of response. We have no problems with distribution either. The haulage company we use does very well".*
Equipment efficiency and slack availability	*"..we have enough lines to cover all our demand requirements. In the long term, if we secure more accounts, we may install more lines".*	*"we have invested a lot of money on modern machinery. We can handle about 50% more capacity than our current peak. we also have a good maintenance crew on site".*	*"since the installation of the 1-day manufacturing cell, we have seen a vast improvement in the capacity of our production process".*	*"we have enough capacity on our machines, the only problem is the set-up and change-over times".*

Table 6.3: Excerpts of interviews relating to RQ2.

Table 6.4 below summarises the findings in relation to RQ2.

Enablers	**Overtime hours**	**Sub-contracting**	**Temporary Labour**	**Contract staff**	**Banked hours**	**Work transfer**	**Varying lead-times**
Plant A	• Used	• Not used	• Used	• Not used	• Not used	• Not used	• Can't use
Plant B	• Used occasionally	• Not used	• Not used	• Not used	• Not used	• Used	• Used occasionally
Plant C	• Used	• Not used	• Used	• Used	• Used	• Used	• Used occasionally
Plant D	• Used	• Used	• Used occasionally	• Not used	• Not used	• Not used	• Used occasionally

Table 6.4: Summary of findings with regards to RQ2.

The variables below (also in Table 6.4 above) are identified as coping mechanisms (enablers) when fluctuations in demand levels are experienced (see circled texts in Table 6.3).

• *Use of overtime hours* – provides for longer hours of work than the standard week worked normally by full time employees.

• *Use of sub-contractors* – out-sourcing all or part of the production process to absorb some of the fluctuations faced by the company.

• *Use of temporary labour* – includes the use of casual, freelance or short-term cover. Generally, temporary employees for manufacturing operations jobs are likely to be of a lower calibre than permanent employees.

• *Use of contract staff* – usually skilled and employed for a fixed term, work full hours as company staff within the contractual period but may not be entitled to full company benefits.

• *Use of banked hours (a variant of annualised hours contract)* – a contract which enables the employer to vary the number of hours worked in a given period within the context of the agreed total working hours over the relevant planning period.

• *Transfer of work to sister plants* – similar to subcontracting, but transfer is done to a sister plant rather than externally.

• *Negotiating or varying customer lead-time* – balancing capacity with load by quoting, say, a longer lead-time, when demand is high, and a shorter lead-time when demand is low.

Table 6.5 summarises the findings of the second part of RQ2. That is the identification of inhibitors to volume flexibility.

Inhibitors	**Securing temporary labour**	**Low yield**	**Securing contract staff**	**Old equipment and power cuts**	**Supplier problem**
Plant A	• Problematic	• Problematic	• Not applicable	• Not applicable	• Not applicable
Plant B	• Not applicable	• Not applicable	• Not applicable	• Occasional power cuts	• Not applicable
Plant C	• Problematic	• Not applicable	• Problematic	• Not applicable	• A one-off problem.
Plant D	• Not problematic	• Not applicable	• Not applicable	• Equipment age, an issue	• Not applicable

Table 6.5: Summary of findings with regards to RQ2.

Tables 6.4 and 6.5 display predominantly the labour-based enablers and inhibitors of volume flexibility in manufacturing plants.

Due to its small sample size, the pilot study could not have identified all the drivers, enablers and inhibitors of volume flexibility in manufacturing plants. Therefore, rather than carrying out explanatory survey research, exploratory survey research was preferable. This type of survey is more suitable for investigating issues that are novel in nature such as this research project. As such, exploratory survey research is required to do the following:

1. Investigate the applicability of the factors identified in the pilot study and literature over a larger sample of plants
2. Identify other conditions that drive plants to require high levels of volume flexibility and
3. Identify other enablers and inhibitors of volume flexibility in manufacturing plants.

6.2 Survey Research

According to Kerlinger (1986), there are two major types of survey research. These are:

1. Exploratory (where the objective is to become more familiar with the topic) and
2. Explanatory (where the research is devoted to finding causal relationships among variables).

The manufacturing flexibility literature is a growing one. As argued previously, the literature review of the subject area reveals that many of the studies have focused on the development of manufacturing flexibility taxonomies. Very few studies have been done on the issue of manufacturing flexibility analysis and implementation, hence the motivation for this research. As such, exploratory survey research appears to be most suitable for this research. Exploratory and descriptive surveys can help to identify the concepts and the basis for measurement, and are very appropriate for early stages of the research (Malhotra and Grover, 1998).

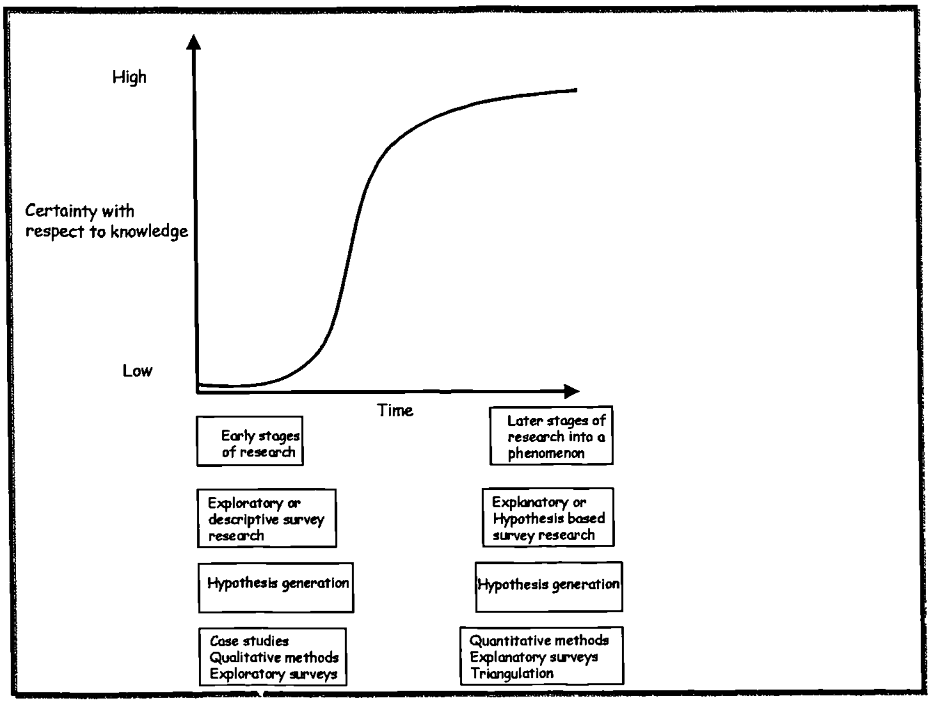

Figure 6.1: The maturity cycle of research
Source: Malhotra & Grover, 1998.

Figure 6.1 above shows that when the certainty with respect to knowledge of a particular phenomenon is low (i.e. novel research), exploratory or descriptive surveys are the more suitable type of survey research to be applied. As the certainty with respect to knowledge of the particular phenomenon increases, explanatory or hypothesis based survey research can be applied.

6.2.1 Questionnaire Design

The process of questionnaire design starts with the identification of concepts for the phenomenon under investigation. Some of the concepts have been identified from the pilot study while others have been identified from the literature. Suitable indicators which best capture the concepts are developed for these concepts, a process known as operationalisation. de Vaus (1996) defines operationalisation as the process of how to translate abstract concepts into something more concrete and directly observable (i.e. indicators). Table 6.6 summarises the concepts identified, presents typical questions designed (the operationalisation process) as well as the justification for the questions asked in the questionnaire. The questionnaire itself is included in Appendix 1.

Scaling

The research on the concept of flexibility is still at an early stage. Measurable constructs have not been clearly defined for the concept. For instance, although some authors have proposed objective measures for demand uncertainty based on physical attributes of the environment, other authors have argued for the perceptual measures of uncertainty (Downey *et al,* 1975 and Huff, 1978). Huff argues that given the same environmental factors, what is certain to one person may be uncertain to another.

Swamidass and Newell (1987) propose that the role of the manufacturing manager is significant in the formulation of manufacturing strategy. This suggests that the perception of the manufacturing manager can be relied upon when investigating manufacturing strategy issues in organisations. As such, managers' perceptions are used to explore the issues in this research. The scaling technique used for the exploratory survey is the horizontal, numeric interval scale. This scaling technique applies a single question and rating scale to many items (Flynn *et al* 1990). It is thus very economical in terms of space utilisation and respondents have little or no difficulty understanding the task. Flynn *et al,* (1990) also argue that of the other available interval rating scales (such as semantic differential, comparative and Likert), the horizontal numeric interval scale has the fewest limitations. The horizontal numeric interval scale is thus adopted for this study (see Appendix 1).

Table 6.6 presents the justification for each of the questions (based on design before pilot testing) asked in the questionnaire. A copy of the questionnaire is included in Appendix 1 (before pilot testing) and Appendix 2 (after pilot testing).

Theoretical Support	**Research Questions**	**Concepts (identified from literature and pilot studies)**	**Survey Questions (see appendix 1)**	**Comments**
De Meyer (1986), Jaikumar (1986), Slack (1987, 1991), Swamidass and Newel (1987).	RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?	•High customer demand level variability. •Short product shelf life •Customers influence on lead time determination. •Short product life cycle. •High demand unpredictability.	Q2: Which of the following characteristics drive your plants to require high levels of volume flexibility? (please circle one for each item): e.g. Insignificant Highly Sig. Short product shelf life 1 2 3 4 5	Perceptual question is asked to capture the extent to which each of the identified variables drive the need for volume flexibility in manufacturing plants. Because this is an exploratory survey, respondents are given opportunity to identify other variables that drive the need for higher levels of volume flexibility in their plants. (See appendix 1 for definitions of variables). Any condition that is perceived to be significant by at least one responding plant qualifies as a likely driver of volume flexibility (vf) needs. ***Analyses of Q2 reveal these drivers. To this extent, RQ1 will have been answered.*** The reasons for different patterns (if any) observed in the driving ability of each of these conditions can be explored using explanatory research methods such as interviews and case studies.
Kossoris and Kohler (1974), Atkinson (1985), Suarez *et al* (1996).	RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?	<u>**Enablers**</u> •Overtime by full time employees •Increased hours worked by part-time employees •Temporary labour •Job sharing •Annual hours contract •Sub-contracting •Contract employees •Rejecting orders	Q10: How did you cope with the actual fluctuations in demand levels in the past year? Please circle one number for each strategy. e.g. Not used Used extensively Temporary labour 1 2 3 4 5 Q11: In coping with actual demand level fluctuations in your plant, how would you assess the relative economics of the use of each of these strategies? (please circle one number for each). Your perceptions for strategies 'not used' are also sought. e.g. Not costly Very costly Temporary labour 1 2 3 4 5 Q12: Which of the above strategies (in Q10) do you think was the most successful in your plant and why?	Q10 is asked to determine the usage level of each of the variables. Opportunity is given for identification of other variables not listed. Any variable that is used extensively by at least one plant qualifies as a likely enabler of vf. Q11 is asked to determine the relative cost (monetary terms) of using the strategies. More costly strategies are less likely to be enablers if they have the same usage level with less costly strategies. This is line with the working definition of vf. Q12 is asked to determine specifically which strategy the respondents considered as enablers in their plants. It is an open question and provides insight into why respondents consider the enabler as the best.

Theoretical Support	Research Questions	Concepts	Survey Questions (see appendix 1)	Comments
		Enablers continued	Q13: In your opinion, what will the desirability of each of the listed strategies (in terms of suitability and relative economics) be in coping with demand fluctuations in your plant in the future? (Please circle one for each). e.g. Not desirable Highly desirable Temp. labour 1 2 3 4 5	Q13 is asked to determine certain factors, which the respondents consider as enablers and are or may not presently being used in their plants. A strategy that is highly desirable by at least one plant qualifies as a likely enabler. ***Analyses of Q10, Q11, Q12 and Q13 reveal various enablers of volume flexibility and the frequency of use. To this extent, the first part of*** **Research Question** ***two will have been answered.*** The issues of why certain enablers are preferred or why others are not used and how they are used can be explored with explanatory research methods such as interviews and case study.
		<u>**Inhibitors**</u> •Hiring full time employees •Getting full-time employees to work overtime hours •Getting part-time employees to work increased hours •Securing temporary labour •Implementing job sharing •Implementing annual hours contracts •Sub-contracting •Securing contract employees •Getting customers to agree to variations in lead time •Rejecting orders	Q14: How problematic has each of the listed factors been to your plant's ability to meet production requirements during the period of demand fluctuations? (Please circle one for each item used. Ignore strategies not used). e.g. Not problematic Very prob. Securing temp. labour 1 2 3 4 5 Q15: How problematic do you think each of the listed factors will be to the ability of your plant to cope with demand fluctuations in the future? (Please circle one for each item).	Q14 is asked to determine the inhibiting nature of the identified inhibiting factors. Any factor that is very problematic to at least one plant qualifies as a likely inhibitor. Q15 is asked to fill the gaps in Q14. That is, while certain factors may not be inhibiting to the achievement of vf at present (probably because it is not being used), perceptions of respondents are sought to determine the inhibiting nature of these factors. Again, any factor that is perceived to be very problematic qualifies as a likely inhibitor of vf. Analyses of Q14 and Q15 answer the second part of RQ2. Determining why these factors are inhibitors and how they can be or have been overcome can be explored using explanatory research methods such as interviews and case studies.

Table 6.6: Questionnaire design justification

Pilot Testing of Questionnaire

Pilot testing or pre-testing provides a way of evaluating questionnaires. The aim of pilot testing the questionnaire in this research was generally to use respondents' experience to refine the questions and to check the reliability and validity of the measures devised in the questionnaire. de Vaus (1996) identifies two ways by which pilot testing can be carried out. The first is called *'declared or participating'* pre-test. Here, respondents' help and advice are explicitly sought about clarity of the questions and how the questions might be improved. The second type is referred to as *'undeclared'* pre-test, where respondents are not told that the questionnaire is under development. The 'declared' pre-test method was employed in this research. The process of pre-testing included:

1. Internal pre-testing
2. Pre-testing with pilot case study plants and other plants selected from the Best Factory Award (BFA) database [the criteria for choice being (a) close fit with sample characteristics in terms of sector and (b) access]

Internal pre-testing was done mainly within the Cranfield University environment. Several amendments were made as a result of meetings held with my supervisor. The questionnaire was administered to two colleagues within the school of management, both of whom were involved in research studies related to this project's area of study and one colleague from the school of mechanical engineering who was also carrying out survey research in operations management at the time. The time for completing the questionnaire was on average about 20 minutes. Their comments were considered, and the questionnaire was further refined. The views of three senior academics in the Operations Management and Logistics and Transportation research centres were sought. Their comments resulted in further refinement of the questionnaire. The final draft was discussed with my supervisor and then dispatched to the plants.

Seven plants were targeted. Four of the plants participated in the pilot case studies while the other three were chosen from the list of past entrants into the BFA. The breakdown of the plants and sectors is shown below:

Plants	Sector	Past BFA entrant?	Participated in pilot study?
A	Food	Yes	Yes
B	Process	Yes	Yes
B1 (sister plant to B)	Process	Yes	No
B2 (sister plant to B)	Process	Yes	No
C	Electronics	Yes	Yes
D	Household	Yes	Yes
E	Engineering	Yes	No

Table 6.7: Plants used for pre-testing of questionnaire

Three questionnaires (with pre-paid self-addressed envelopes) were sent to each of the plants except plants B, B1 and B2, which received one questionnaire each. A total of 15 questionnaires were sent out. The reason for sending three questionnaires to each plant was to enable the reliability of the questions to be assessed. Questionnaires from the same plant (or sister plants in the case of B, B1 & B2) are expected to have highly similar responses. This is because the unit of analysis for the research is the 'plant'. So in theory, three respondents are providing information about the same issues within the same plant. However, differences may exist due to differing perceptions of the respondents concerning the phenomenon being investigated. For instance, Downey and Slocum (1975) propose that an individual's perception of uncertainty can be expected to vary with "*individual differences in cognitive processes, social expectations for the perception of uncertainty and individual behavioural responses repertoires*". There may also be differences in their understanding of the questions. In each of the plants, the recipient of the questionnaires (the original contact personnel) was advised to distribute the questionnaires amongst senior members of staff in the production department such as the factory manager and the planning manager. There was to be no collusion amongst the respondents.

13 questionnaires were returned. All the plants returned the three questionnaires sent to them except plants A & E, which returned two each. After receiving the completed questionnaires, telephone conversations were carried out with each of the respondents to clarify some issues (where comments and suggestions were made). Enquiries were also made about possible ambiguities of the questions, the ease of completing the questionnaire, their understanding of the questions asked and the timing of completion. Many of the questions were perceived to be very clear and it took about 15 minutes on average to complete each questionnaire. Most importantly, respondents felt that they would feel able to participate in such an exercise because of the perceived mutual benefits that could be gained from the research.

Reliability

A reliable measure is one where the same result is obtained on repeated occasions (de Vaus, 1996). The indicators used in the questionnaire design were obtained both from the literature and the pilot study. A single question is asked in each case to cover these indicators. The test-retest method is the only way to check on the reliability of single questions (de Vaus, 1996). The same people are asked the same questions at intervals of two to four weeks and the correlation coefficient between the two answers on both occasions is calculated to assess the reliability. This method is difficult to implement, as it is often difficult to give the same test to the same sample twice. Also, people may give consistent answers where they remember their answers on the first occasion, thereby inflating the apparent reliability of the question.

The above problems of the test-retest method were eliminated in this research by giving the questionnaire to different people working in the same plant within the production department. Collusion amongst the respondents was strongly discouraged. Since the questionnaire addresses mostly non-objective measures, it is believed that the analysis of the correlation coefficient between the responses of people working for the same plant would provide a good assessment of the reliability of the questions (item-item reliability). The rule of thumb for a reliable question using this method is that the Cronbach's alpha must be equal to or greater than 0.7 (de Vaus, 1996). The result of the reliability analysis is summarised below (SPSS output in Appendix 3):

Plants	**No. of responses**	**Cronbach's alpha**
Plant A	2	0.92
Plants B, B1 & B2	3	0.80
Plant C	3	0.86
Plant D	3	0.85
Plant E	2	0.87

Table 6.8: Item-Item reliability

The results in the above table indicate that the questions are generally reliable.

Validity

A valid measure is one which measures what it is intended to measure. de Vaus (1996) defines three ways of assessing validity in survey research. These are:

1. *Criterion validity* - comparing how respondents answer our new questions to measure a concept with existing well-accepted measures of the concept.
2. *Content validity* - the extent to which the indicators measure the different aspects of the concept.
3. *Construct validity* - how well the measure conforms to theoretical expectations.

Due to the novel and unique nature of the research and the attendant exploratory survey research method, it is not possible to assess criterion validity of the questions. The content validity was assessed through the interviews carried out with the respondents (face validity). Generally, respondents' understandings of the questions were similar within and across the cases. Most importantly they understood the information that the questions were designed to obtain. Two questions appeared to create ambiguities and thus have low content validity. The first is question 1 (see Appendix 1) which was subsequently removed from the final questionnaire. This question was found to add no real value to the objective of the research. Furthermore, the information it seeks to obtain is available in the Best Factory Award database, if needed. The second area is the question relating to employee headcount (questions 3-9, Appendix 1). Respondents were unsure of the period of time the questions were referring to. This ambiguity was corrected in the final questionnaire by including a new question 2 (see Appendix 2).

Other minor amendments to the questionnaire were made and the questionnaire was made ready for the survey administration (See Appendices 1 and 2).

6.3 Survey Administration

This section discusses the survey methodology in the following sequence:

1. Sampling
2. Method of questionnaire administration
3. Response rate analysis

6.3.1 Sampling

The study focuses on the issue of volume flexibility in manufacturing plants in the UK. One would, therefore, have expected that information be collected from all the manufacturing plants in the UK. This would clearly be expensive and impractical. There is also the problem of defining a relevant population. For instance, manufacturing plants could range from those having less than 100 employees to those having more than 1,000 employees. The issue of volume flexibility may not be of particular relevance to the entire population of UK plants. Sampling involves the selection of only some plants from the entire population of UK manufacturing plants such that their responses and characteristics reflect those of the other plants in the UK. It is much cheaper, easier and faster to concentrate the study on a sample of plants than to survey all manufacturing plants in the UK.

Ideally, the sample of plants required for this project should be a sample, which contains manufacturing plants, for which the issue of volume flexibility appears to be of some relevance. Flexibility is an attribute that gives some plants an added competitive advantage. This research enquiry will benefit from plants that have either achieved relatively high levels of volume flexibility, have attempted to achieve it or are considering implementing volume flexibility in their operations. It was not possible to pre-select the sample based on these criteria. Sample selection was made from the Best Factory Award database. The database for the Best Factory Award (BFA) managed by Cranfield School of Management consists of over 1000 manufacturing plants in the UK which have participated in the past in the BFA award process. The BFA database consists mainly of plants employing more than 100 employees. For this research, plants that entered for the award between 1995 and 1998 were targeted. The database serves as a source for obtaining the names and addresses of the sample of manufacturing plants to be surveyed. The research has not made use of any specific data in the database.

The figure below has been drawn to show the relationship between the sample for this research and the wider context of UK manufacturing plants.

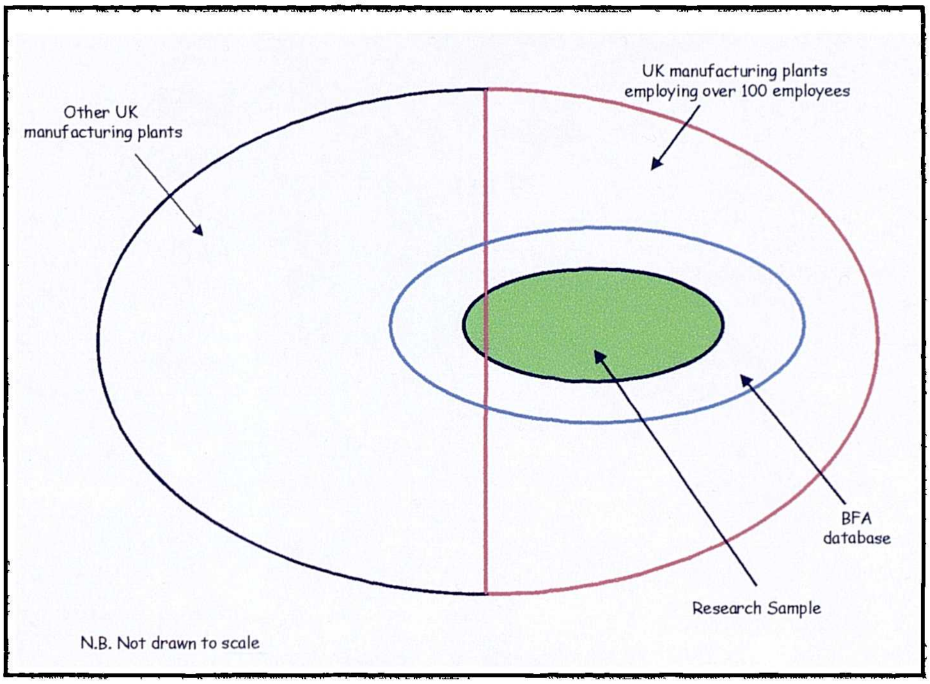

Figure 6.2: Choosing the sample from a population of UK manufacturing plants

The sample of plants within the BFA database is non-random and self-selected. This is because entry to the award is on an open, voluntary basis. The implication of this is that the sample may be biased towards plants in which:

a. The management team believes that the plant has a chance of winning an award and/or
b. Have a management team which knows about the awards and are sufficiently motivated to complete the 14-page questionnaire (Baker, 1996).

Regarding point (a) above, New and Szwejczewski (1995) argue that *"...many entrants do not expect to win at all but enter solely for the feedback report."* This suggests that to some extent, point (a) above can be mitigated.

Motivation factors always play a part in involving practitioners in academic research. Thus it is impossible to mitigate point (b) above. Above all, "social-practical reasons" (Rose, 1982) such as those of convenience and need for collaboration (Baker, 1996) provide the incentive for the use of this established database.

From the above discussions, one could see that the sample of plants within the BFA database may not be representative of UK manufacturing plants having more than 100 employees. The question now is, *does one really need a representative sample in exploratory survey research such as this?*

It has been argued that having a representative sample in an exploratory survey is of less significance than in an explanatory survey (Malhotra & Grover, 1998). This is because, exploratory surveys are generally used to formulate propositions which can be tested in further research. The objective of an exploratory survey such as in this study is not to make a generalisable conclusion about the phenomenon being investigated.

In spite of the above argument, caution needs to be exercised in drawing conclusions from the study. Conclusions will be drawn only about that part of the universe (Simon and Burstein, 1985), represented by the sample and not about the whole universe (UK manufacturing plants employing more than 100 employees). So, conclusions are limited to UK plants with 100 or more employees, run by management teams with the awareness of and motivation to enter for the BFA exercise and the ability to complete this project's questionnaire.

6.3.2 Sample Size

Details of about 800 manufacturing plants in the UK were obtained from the BFA database. This number represented plants that entered for the competition in the years 1995, 1996, 1997 and 1998. Filtering was done to remove plants that entered more than once during these periods, plants whose addresses cannot be located and other plants not based in the UK. The effective number of plants targeted for the survey after the filtering was 529 manufacturing plants. See Table 6.9 for breakdown by sector.

Year	**Process**	**Engineering**	**Electronics**	**Household & General Products**	**Total**
1995	20	45	19	46	130
1996	22	46	26	43	137
1997	17	45	19	54	135
1998	16	49	23	39	127
Total	**75 (14.2%)**	**185 (35%)**	**87 (16.4%)**	**182 (34.4%)**	**529**

Table 6.9: Survey sample size: sector by latest year of BFA entry.

6.3.3 Questionnaire administration

There are three main methods of questionnaire administration. These are the facc-to-face interview method, the telephone interview method and the mail method. Table 6.10 summarises the relative merits of the three approaches by focusing on six broad considerations:

- Response rates;
- Ability to produce representative samples;
- Limitations on questionnaire design;
- Quality of responses;
- Implementation problems and;
- Cost/time

Considerations	face-to-face Interview	Telephone Interview	Mail Surveys	Methods, in order of preference.
Response rate	*•Seen as most effective in general population samples*	*•Relatively more effective than mail surveys*	*•Not so effective in general population samples, but may be effective in surveys of specific, more homogeneous group. e.g. UK plants.*	*1. Face-to-face 2. Telephone 3. Mail surveys*
Obtaining representative samples	*•Less prone to this type of bias •samples can be drawn by the cluster sampling techniques hence better representation.*	*•May be prone to this type of bias since some categories of respondents may be under-represented.*	*•Relatively more prone to this type of bias because of less control over who completes the questionnaire*	*1. Face-to-face 2. Telephone 3. Mail surveys*
Effects on questionnaire design	*•Provides the greatest flexibility in terms of question design. •Best for complex and open-ended questions.*	*•Suited to complex and open-ended questions.*	*•Unsuitable for complex and open-ended questions.*	*1. Face-to-face 2. Telephone 3. Mail surveys*
Quality of responses	*•Performs less well in obtaining accurate answers. Respondents are more likely to give acceptable rather than true opinion answers. •Observable characteristics of interviewer can affect responses.*	*•Performs better than face-to-face method in terms of interviewers' influence on responses.*	*•Performs best in obtaining accurate answers. •far removed from interviewers' influence.*	*1. Mail surveys 2. Telephone 3. Face-to-face*
Implementation problems	*•May require careful training of staff •Requires many staff*	*•Less demanding in terms of staffing requirements.*	*•Least demanding in terms of staffing requirements.*	*1. Mail surveys 2. Telephone 3. Face-to-face*
Cost/Time	*•Most expensive and time consuming.*	*•Less expensive in terms of cost, but more time consuming than mail surveys.*	*•Least expensive and time consuming.*	*1. Mail surveys 2. Telephone 3. Face-to-face*

Table 6.10: Comparisons between methods of questionnaire administration (after de Vaus, 1996).

From the table above, it can be observed that the mail survey method is preferable to the telephone and the face-to-face interview methods in terms of the quality of responses obtained, implementation problems and cost and time considerations. It is, however, less preferable in terms of response rate (which may be poor), obtaining a representative sample and the effects on questionnaire design. In spite of the drawbacks of mail surveys, it was the preferred method of questionnaire administration for this research. This is because its drawbacks can be limited if not totally overcome. For instance, a fairly good response rate was expected for the following reasons:

- The study is focused on a specific and more homogeneous group, i.e. UK manufacturing plants, for which the issue of volume flexibility appears to be of particular relevance (as confirmed from the literature review and pilot study).
- Feedback reports were promised to all participating plants providing an incentive for participation
- Follow-up calls (by telephone) were made to non-responding plants.
- The sample consists mainly of UK manufacturing plants which have participated in the past in the Cranfield School of Management/Management Today's Best Factory Award competition, an exercise many plants in the UK find rewarding in terms of the quality of the feedback they get.
- Low response rate is not a critical issue for exploratory survey research.

The issue of obtaining a representative sample has been discussed in the previous section. The questions are made very simple and there is only one open-ended question. Thus, the drawbacks of mail survey, as highlighted in the table, were minimised.

6.3.4 Response Rate

A total of 529 questionnaires (see Table 6.9) were sent out on October 23, 1998. Of these, 134 questionnaires were returned, representing about 25.3% response rate. Of the 134 responses, 14 were returned unanswered for various reasons, including declining to participate in the survey, factory closed down and change of business. The cut-off level used for the analyses is 120, representing about 23% response rate.

Sector	Frequency	Percent
Process	24	20
Engineering	38	32
Electronics	22	18
Household & Gen. Products	36	30
Total	120	100

Table 6.11: Breakdown of responses by sector.

The table above gives a breakdown of responding plants by sector. A chi-square test was done to check whether the proportion of respondents is similar to the sample with regard to industry split. The result of the test is shown in the table below:

Sector	Cases observed	Expected	Residual
Process	24	17.04	6.96
Engineering	38	42.00	-4.00
Electronics	22	19.68	2.32
Household Products	36	41.28	-5.28

Table 6.12: Comparing the responding plants proportion with the sample size.

Chi-square value = 4.1726, and Significance level $p = 0.2434$. Because the chi-square value is less than the critical value (7.815), and $p > 0.05$ (at 5% significance level), it could be concluded that there is no difference between the distribution of responding plants and the survey sample composition. Hence, the responding plants are representative of the sample size in terms of industry split.

The sector classification used in the BFA has been adopted. However, these classifications are considered too broad especially for the Engineering and Household/Food sectors. These are, therefore, broken down respectively into:

(1) Engineering Consumer products and (2) Engineering Capital products.
And, (1) Household/other products (2) Food consumables.

Sector	Frequency	Percent
Process	24	20.0
Engineering Consumer	26	21.7
Engineering Capital	12	10.0
Electronics	22	18.3
Household/Other products	21	17.5
Food Consumable	15	12.5
Total	**120**	**100**

Table 6.13: Breakdown by sub-sectors of respondents.

6.4 Chapter Summary

A pilot study was carried out in four selected manufacturing plants to identify the drivers, enablers and inhibitors of volume flexibility in manufacturing plants. The identified concepts are used to design a questionnaire for an exploratory mail survey. Exploratory mail survey is preferred to an explanatory survey because of the low certainty with respect to knowledge regarding the issue of volume flexibility in manufacturing plants. The questionnaire was pilot tested internally within the Cranfield School of Management and also administered to the pilot study plants and other selected plants from the BFA database.

The analyses of the pilot testing reveal that the questions are highly reliable, as indicated by the high values of the Cronbach alpha. The analyses also reveal the need to make some amendments to the original questionnaire. The revised questionnaire was administered by mail to 529 UK manufacturing plants (covering all industrial sectors) selected from the past entrants into the Britain's Best Factory Award competition. The response rate was 23%. A chi-square test of the distribution of differences between the responding plants and the sample reveal that the responding plants are representative of the sample size in terms of industry split.

The next two chapters (Chapters 7 & 8) will describe and present the results of the analyses done to answer the first and the second Research Questions respectively.

Chapter 7 – Survey Analyses: Research Question One

7.0 Introduction

Chapters 7 and 8 describe the procedure of the analyses and present the results of the survey analyses with respect to the two Research Questions. This chapter focuses on the first Research Question.

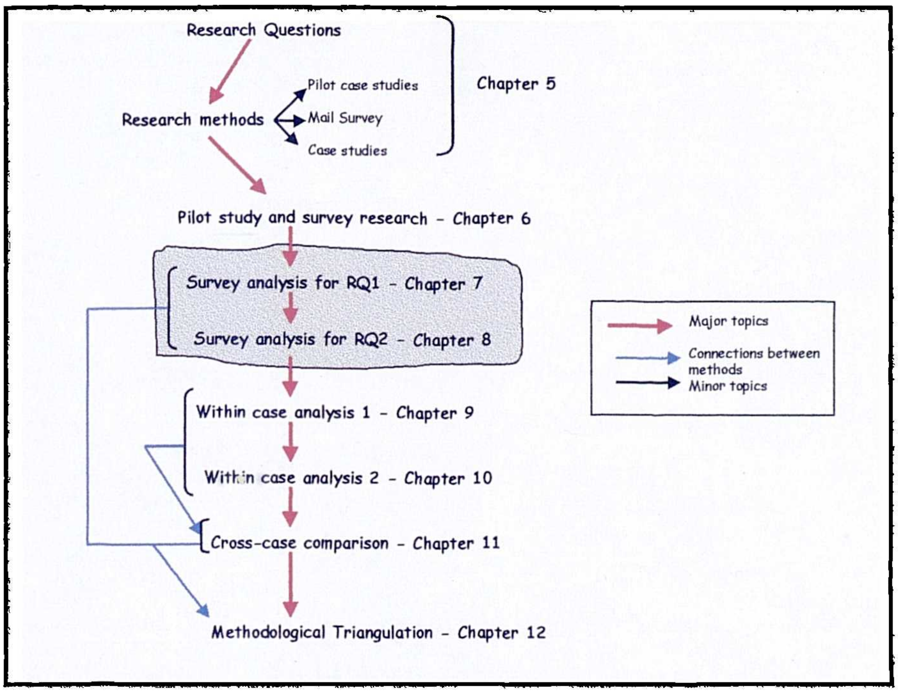

Figure 7.0: Empirical research road map. The survey analyses chapters' coverage are shaded

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

The question that addresses RQ1 is question 1 in the questionnaire (see Appendix 2).

Certain conditions that drive a plant to require high levels of volume flexibility were identified from the literature and the pilot case studies. Respondents were asked to rate on a 5-point scale (1 = insignificant, 5 = Highly significant) how these conditions drive their requirements for high levels of volume flexibility.

7.1 Steps for Analyses

1. Overall frequencies for all responding plants were obtained. This determines in general how the responding plants rate the conditions that drive their plants to require high levels of volume flexibility.
2. Frequencies of responding plants by sector were obtained. This shows the number or proportion of plants in each sector and how they rate the different conditions.
3. The chi-square test was performed. This determines whether conditions that drive plants to require high levels of volume flexibility depend on the sectors to which the plants belong.
4. Other conditions identified by responding plants were obtained and classified by sector.

The above analyses were performed for each condition. A condition qualifies as a driver for high levels of volume flexibility where responding plants perceive its influence as highly significant.

Combining Questionnaire Scale Categories

In order to perform the analyses, it was necessary to collapse the 5-point scale on the questionnaire to a smaller scale point (i.e. a 4-point, a 3-point or a 2-point scale). This is because there are many cells having very few cases on the 5-point scale. Performing the analysis using the 5–point scale thus leads to very low frequencies which can produce misleading tables and distort some statistics (de Vaus, 1996). Also, the chi-square test, which is used to explore differences between the variables, produced results that are unreliable. The trial test performed based on the 5-point scale reveals that in most cases, more than 20% of the expected frequencies are smaller than 5, a situation, which leads to unreliable chi-square test results (Brymer and Cramer, 1998). Bryman and Cramer argue that it may be possible to increase the expected frequencies in a category by combining it with those of another. Therefore, the 5-point scales used to measure the variables required to answer the two Research Questions were collapsed for the analyses covered in Chapters 7 and 8, as explained below.

In combining the categories, it is important to have a fairly equal number of categories to form a new category, so as not to create a bias (Bryman and Cramer, 1998). The category '1' means insignificant, hence, cannot be diluted or combined with any other category. The other categories 2, 3, 4 and 5 represent varying degrees of significance. For instance, 2 =

less significant; 3 = significant; 4 = more significant; 5 = highly significant. It is only possible to have an equal number of categories using a 3-point scale. For a 3-point scale, the possible combinations are:

a. 1 / 2+3 / 4+5
b. 1 /2 / 3+4+5
c. 1 / 2+3+4 / 5

Clearly, option 'a' (1 / 2+3 / 4+5) provides the best option for collapsing the original 5-point scale to a 3-point scale, since it provides at least 2 new fairly equally weighted categories. Thus, using a SPSS Syntax programme, the 5-point scale was collapsed into a 3-point scale (1 = 1 = insignificant; 2+3 = 2 = Moderately significant; 4+5 = 3 = Highly significant). This increased the number of observed cases, which was required for meaningful statistical analysis. An example has been used below to show that, collapsing the scale does not significantly affect the outcome of the analyses. Table 7.0 summarises the frequency distribution of respondents' responses with regard to conditions that drive their plants to require high levels of volume flexibility based on the uncollapsed scale.

Drivers of volume flexibility	Insignificant	Less Significant	Significant	More Significant	Highly Significant
High variability in demand levels	0.8	5.0	11.7	40.8	41.7
Short product shelf life	62.5	21.7	5.0	9.2	1.7
High influence of customers in the determination of lead time	5.0	7.5	32.5	35.0	20.0
Short product life cycle	50.8	26.7	12.5	7.5	2.5
High unpredictability of customer demand levels	2.5	11.7	19.2	48.3	18.3

Table 7.0: Overall frequencies of responding plants (uncollapsed scale)

The data in the above table reveals that most of the responding plants perceive *high variability in demand levels* to be a driver of volume flexibility in their plants. Also, *demand unpredictability* and *high influence of customers in the determination of lead-time* are perceived as volume flexibility drivers by a high proportion of responding plants. On the other hand, the majority of responding plants do not regard *short product shelf life* and *short product life cycle* as major drivers of volume flexibility in their plants.

Table 7.1 summarises the analyses of the distribution of respondents' responses with regard to the conditions that drive their plants to require high levels of volume flexibility based on the collapsed scale. It is pertinent to note that, the general nature of the data in the uncollapsed scale analysis is similar to the nature of the data in the collapsed scale analysis. Thus, the description of the frequency distribution in the main is common to both Tables 7.0 and 7.1.

Drivers of Volume Flexibility	**Insignificant (%)**	**Moderately Significant (%)**	**Highly Significant (%)**
High variability in demand levels	0.8	16.7	82.5
Short Product Shelf-life	62.5	27.7	10.8
High influence of customers in the determination of lead time	5.0	40.0	55.0
Short Product Life-cycle	50.8	39.2	10.0
High unpredictability of customer demand levels	2.5	30.8	66.7

Table 7.1: Overall frequencies of responding plants (collapsed scale).

The breakdown of the responses by industry is displayed in Table 7.2 below.

	Demand variability	Short Product shelf life	Customers' influence on lead time	Short Product life cycle	Demand unpredictability
Process	87.5 (1)(1)	4.2 (4)(4)	50.0 (3)(3)	4.2 (4)(4)	54.2 (2)(2)
Engineering (consumer)	88.5 (1)(1)	7.7 (5)(4)	57.7 (3)(3)	11.5 (4)(4)	80.8 (2)(2)
Engineering (capital)	58.3 (1)(1)	0.0 (4)(4)	25.0 (3)(2)	0.0 (4)(4)	58.3 (1)(3)
Electronics	72.7 (2)(1)	9.1 (4)(5)	54.5 (3)(3)	13.6 (4)(4)	81.8 (1)(2)
Household	90.5 (1)(1)	9.5 (4)(4)	61.9 (2)(2)	9.5 (4)(4)	61.9 (2)(3)
Food	86.7 (1)(1)	40.0 (4)(5)	73.3 (2)(2)	20.0 (4)(5)	53.3 (3)(3)

( ): ranking of the % of plants rating this driver as highly significant in this sector based on the collapsed scale
( ): ranking of the % of plants rating this driver as highly significant in this sector based on the uncollapsed scale

Table 7.2: Drivers of volume flexibility by sector. Figures represent the % of responding plants in the particular sector rating this factor as highly significant as a driver for volume flexibility (collapsed scale).

The above Table 7.2 shows the ranking of each of the drivers when analysed using the collapsed and the uncollapsed scales. For instance, in the process sector, the highest proportion of plants ranked *demand variability* as highly significant in both the uncollapsed and collapsed scale data. As the comparison reveals, the rankings on both scales are generally similar. Thus, in terms of identifying drivers of volume flexibility, and the general distribution of the proportion of plants that rated these drivers as important, the use of the collapsed scale data will not distort the information that the uncollapsed data would have revealed.

Table 7.2 shows that *demand variability* is a major driver for achieving volume flexibility in all industrial sectors. Relatively, *demand unpredictability* is also seen as a significant driver by a greater proportion of plants in the two engineering sectors and electronics sector. In the case of the engineering capital sector, this is hardly surprising since in many cases orders might be won on the basis of bids which have highly uncertain success rates. *Customer's influence on lead times* is seen as a significant driver for achieving volume flexibility in the food industry but seen as relatively unimportant for the engineering capital goods sector. Plants in the food industry typically supply the big UK grocery retailers who are dominant and have more clout in the supply chain because of their relatively bigger size and their ability to switch easily from one supplier to another. It is, therefore, difficult for the food manufacturers to influence the customer lead-time (Buyer's power – Porter, 1986).

In the engineering capital goods sector, lead-times are often used to balance load with capacity, hence, plants find it relatively easier to negotiate lead-times with their customers, and the influence of customers on lead-time determination is minimal.

Short product shelf life is found to be a key issue for the food industry but not usually elsewhere. This is not surprising and is due to the nature and characteristics of products of most plants in this sector. Some of the products are perishable. For other products, the requirement to specify 'use by' dates for the products further reduces the effective shelf lives of the products.

Additionally, chi-square tests were performed in order to explain further some of the differences observed in the applicability of the conditions that drive plants to require volume flexibility. This helps to determine whether the differences observed in the frequency distribution depend on the sector to which the plants belong. The results are summarised in Table 7.3 below.

Conditions (Volume flexibility drivers)	Overall Frequencies of responding plants.	Frequencies by sectors. See appendix	*Chi-square test.	Comments
High variability in demand levels	Highly sig. – 82.5% Moderately sign. – 16.7% Insignificant – 0.8% (1 plant)	Pattern of rating highly skewed towards highly significant score for all the sectors except Engineering capital kits which have a more even pattern between highly and moderately significant. The one plant that recorded insignificant belongs to the Process sector.	P = 0.301 Chi-square value = 11.8 Accept the null hypothesis.	High variability in demand levels drives the need for high levels of volume flexibility in most of the plants. This condition however does not depend on the sector. That is, demand variability is equally likely to drive the need for volume flexibility in at least plants in the sample irrespective of the sectors to which the plants belong. **(Sector independent driver)**
Short product shelf life	Highly Sig.- 10.8% Moderately sig. – 27.7% Insignificant – 62.5%	Apart from the food sector, most of the responding plants in the others sectors consider the influence of this condition as insignificant.	P = 0.013 Chi-square value = 22.3 Reject the null hypothesis.	Short product shelf life drives the need for high levels of volume flexibility mostly for plants in the food sector. The influence of this condition as a driver for the need for high levels of volume flexibility, at least for the sample, depends on the sector to which the plants belong. **(Sector dependent driver)**
Customer's influence on lead time determination	Highly significant – 55% Moderately sig. – 40% Insignificant – 5%	Pattern of rating is skewed generally towards moderately & highly significant for all sectors. More pronounced however in the food sector.	P = 0.22 Chi-square value = 12.9 Accept the null hypothesis.	High influence of customers in the determination of customer lead-time drives most plants in the sample to require high levels of volume flexibility. Although some differences are observed, the influence of this condition on plants in the sample is not significantly dependent on the sector to which the plants belong. **(Sector independent driver)**
Short product life cycle	Highly significant – 10% Moderately sig. – 39.2% Insignificant – 50.8%	A higher proportion of responding plants in the process sector felt that the influence of this driver is insignificant. Otherwise the pattern is generally skewed for all plants towards 'insignificant' influence of life cycle on the need for volume flexibility.	P = 0.15 Chi-square value = 14.5 Accept the null hypothesis.	Short product life cycle drives a smaller proportion of the responding plants in the sample to require high levels of volume flexibility. The influence of this condition on plants in the sample is not dependent on the sector to which the plants belong. **(Sector independent driver)**
Demand unpredictability	Highly significant – 66.7% Moderately sig. – 30.8% Insignificant – 2.5%	Except for 3 plants belonging to the Engineering consumer and Household sectors, the pattern of responses is generally skewed towards moderately & highly significant influence of this driver.	P = 0.11 Chi-square value = 15.7 Accept the null hypothesis.	High unpredictability of customer demand levels drives most of the plants in the sample to require high levels of volume flexibility. The effect of this condition does not depend on the sector to which the plants belong. **(Sector independent driver)**

Table 7.3: Summary of results: Conditions that drive plants to require high levels of volume flexibility

* *Null Hypothesis: The condition is equally likely to drive at least the plants in the sample in different sectors to require high levels of volume flexibility.*
Alternative Hypothesis: The effect of the condition on at least the plants in the sample depends on the sectors to which the plants belong. ***Reject null hypothesis if $P \leq 0.05$ & Chi-square value > critical value (18.307) at 5% significance level.***

7.2 Other Variables Identified by Respondents.

Respondents were given the opportunity to identify other conditions (which were not listed in the questionnaire specifically) that drive their plants to require high levels of volume flexibility. These conditions are tabulated in Table 7.4. The number of plants that identified each condition is insignificant in the analysis because it may be the case that these conditions actually apply in other plants but were not thought of by the respondents at the time of completing the questionnaire. It may, however, also be the case that these conditions are not applicable to other plants. However, what is worth noting is the sector to which the identifier of each condition belongs.

Other conditions that drive plants to require high levels of Volume Flexibility (identified by respondents)	Frequency (No. of respondents)	Sectors of identifying plants
Need to avoid stock holding (stockhol)	3	Process, Engineering consumer, Household/General products
Need to optimise throughput and yield (throuput)	2	Process and Electronics
Need for process capability (procapab)	1	Process
Focusing on orders from key customers (keycusto) i.e. when orders from key customers (or high volume customers) are required urgently. These take priorities hence drive the need for high levels of volume flexibility.	3	Household/General products (2), Food consumables (1)
Material availability (mateava) i.e. raw materials shortages.	2	Process and Engineering consumer products.
Product mix changes/New product introductions (prodmix)	8	Process (2), Engineering consumer (2), Electronics (1), Household/Gen. Products (1), Food consumables (2).
Demand peaking at seasons (season)	3	Engineering consumer, Household and Food consumables.
Action of competitors (competit)	1	Electronics
Company policy/Growth ambitions (growth)	1	Electronics
Market overcapacity (overcapa)	1	Process
Poor communication with customers (comunica) i.e. between sales department and customers leading to wrong production schedule or unanticipated demand.	1	Process
Accounts engineering by sales (salesacc)	1	Food
Currency variations (currency)	1	Food
Mass customisation to maintain old product position (masscust)	1	Food
Small order runs (batchsiz)	2	Household/Gen. Products and Food.

Table 7.4: Other conditions that drive plants to require high levels of volume flexibility as identified by respondents, by sectors.

The total number of plants that identified the conditions in Table 7.4 is 10. It is not possible statistically to determine whether these conditions are sector dependent in the survey analyses because of the limited data available. The conditions identified are explored further in the case study analysis phase of the research to investigate how they actually drive the respondents' plants to require high levels of volume flexibility.

7.3 Summary of Analyses: Conditions that drive plants to require high levels of volume flexibility (RQ1).

Each of the conditions was regarded by at least one responding plant as significant in driving the requirement for volume flexibility in that plant. This shows that all the variables identified are valid as conditions that can drive plants to require high levels of volume flexibility, and that conditions which are drivers for some plants are not drivers for other plants.

Short Product Shelf Life

Out of all the variables identified, only the condition of *short product shelf life* is found to be dependent on the sector to which the plants belong. In other words, the type of sector to which plants belong (at least in the sample) determines whether this variable actually drives the need for high levels of volume flexibility in the plants. Although the majority of the responding plants in other sectors felt that this condition is insignificant, most of the responding plants in the food sector regarded the effect of this variable as significant. This result concurs with the [†]contextual framework described in Section 4.2, Chapter 4 (Oke, 1998). Products having a short shelf life are largely non-stockable (in this case probably because they are perishable). Hence, plants producing such are limited to the option of using volume flexibility. Some plants in sectors other than food (although not many) also regarded *short product shelf life* as a significant driver of volume flexibility. This may be because their products (although not perishable) are customised or "make to order". The reasons for this perception are explored in the subsequent case study research.

[†] The framework consists of two overlapping circles forming three areas A, B & C. Plants in group A have stockable products but continuous production system, hence are limited to responding to orders using stock. Products of group B plants can be stocked, have non-continuous production system and can either use stock levels or volume flexibility to meet demand requirements. Products of group C plants cannot be stocked and are therefore limited to using volume flexibility to meet fluctuations in demand levels (Oke, 1998).

High Variability in Demand Levels

All but one of the responding plants felt that a condition of high variability in demand levels drives their plants to require high levels of volume flexibility. Again this result is what one would expect and it concurs with Slack's (1987) argument in which he suggests that large fluctuations in demand have highlighted the need to adapt and respond to a less predictable environment. This driver is found to be *sector independent.*

Customers' Influence in the Determination of lead-time

The customer's influence on lead times is seen as a significant driver for achieving volume flexibility in the food industry but seen as relatively unimportant for the engineering capital goods sector. In the case of the food sector, the stronger influence of customers can be explained by the power dynamics that exist between the supplier and the customer (e.g. UK Groceries retailers: Howe, 1990 and, Ogbonna & Wilkinson, 1996). Plants in the food industry typically supply the big UK grocery retailers who are dominant and have more clout in the supply chain because of their relatively bigger size and the availability of substitute products. It is, therefore, relatively difficult for the food manufacturers to influence the customer lead-time (Buyer's power – Porter, 1986). In the engineering capital goods sector, lead-times are often used to balance load with capacity, hence, plants find it relatively easier to negotiate lead-times with their customer, and the influence of customers on lead-time determination is minimal. The analyses further reveal that this driver is *sector independent.*

Short Product Life Cycle

Many of the responding plants felt that *short product life cycle* does not drive their plants to require high levels of volume flexibility (the highest percentage coming from the process sector). Although the chi-square test reveals that this condition is *sector independent*, it is interesting to note that the majority of responding plants in the electronics sector (about 52.7%) felt that the influence of this condition is significant. Again this is not surprising considering that the electronics (especially the IT) industry in today's market is experiencing rapid change. There are also a few exceptions in the other sectors where the responding plants felt that the effect of this variable on their need for high levels of volume flexibility is significant. The reasons behind the applicability of this driver are also explored in the subsequent case study research.

High Unpredictability of Demand Levels

The majority of the responding plants felt that a condition of *high unpredictability of customer demand level* drives the need for high levels of volume flexibility in their plants. The distribution (between moderately and highly significant) is, however, more even in the engineering capital products sector. It is important to recall at this point that a distinction was not made between short-term and long-term demand uncertainty in the survey research because of the potential problems of understanding and distinguishing between the two terms, which respondents were likely to face. The two terms are treated as separate in the subsequent case study research.

Other Drivers of Volume Flexibility

A total of 10 plants belonging to various sectors identified additional variables as conditions that drive their plants to require high levels of volume flexibility (Table 7.4). The applicability of these conditions to various plants is explored in the subsequent case study research.

The conditions that drive the need for volume flexibility in manufacturing plants are referred to as volume flexibility *drivers*. These conditions can be classified as either *sector independent drivers* (common to all sectors except in a few cases) or *sector dependent drivers* (specific to a particular sector as it is for *short product shelf life*). The Figure 7.1 below shows the classification of the identified drivers.

The y-axis in the figure represents the percentage of plants rating the factors as highly significant drivers of volume flexibility. Thus, *high variability in demand levels* is rated highly by virtually all the plants because it is a characteristic shared by most markets. *Short product shelf life* is highly rated by a few plants, many of which belong to the food sector. These plants generally produce products that are perishable. The x-axis represents the chi-square test values for each of the conditions. They show the likelihood of the drivers to be either *sector independent or sector dependent.* It will be recalled from Table 7.3 that the test hypotheses are:

Null Hypothesis – the condition is equally likely to drive the plants in the sample in different sectors to require high levels of volume flexibility (i.e. sector independent)

Alternative Hypothesis – the effect of the condition depends on the sectors to which plants belong (i.e. sector dependent)

The test is to reject the null hypothesis if the observed significance level is less than 0.05 (or the chi-square value is more than the critical value of chi-square at 5% significance level). That is, there is less than a 5% chance of obtaining such a large statistic if the null hypothesis is true.

At 5% significance level, the chi-square critical value is 18.3. Therefore, all the conditions having chi-square values (see Table 7.3) of less than the critical value of 18.3 are *sector independent*. A condition becomes *sector dependent* if its chi-square value is more than the critical value of 18.3. Thus, *short product shelf life* (chi-square value = 22.27) is *sector dependent*. The SPSS output for the tests is displayed in Appendix 5.

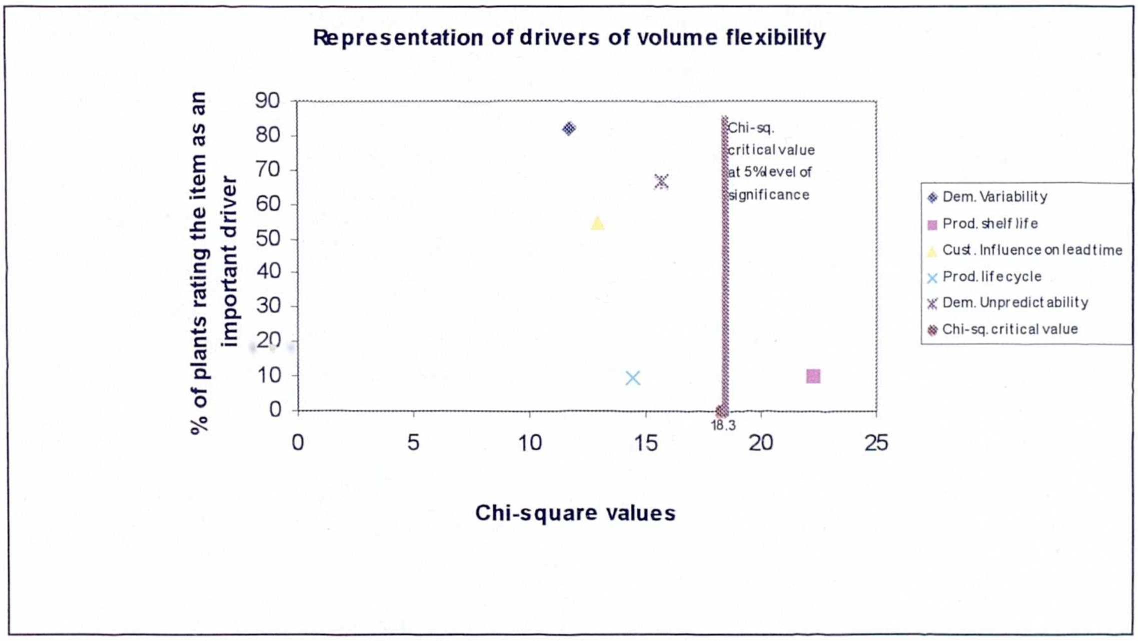

Figure 7.1: Representation of the conditions that drive plants to require high levels of volume flexibility

At this stage of the empirical research, it was not possible to place the additional variables identified by plants in the figure above. The subsequent case study research is used to confirm (or otherwise) the positions of both the existing variables (as above) and the newly identified variables.

To conclude, it is suggested that in so far as Research Question one is concerned (i.e. under what conditions does a manufacturing plant require high levels of volume flexibility?) the above analyses have been able to identify and classify the conditions. However, the analyses also reveal other interesting issues. For instance,

Are the conditions truly dependent on or independent of the sectors? And why?
Are there other plant characteristics (other than sector) that can explain differences in the effects of these conditions on plants?

These are new questions that are further explored in this research study. The case study phase of the empirical research is used to investigate these issues. This is because the research method for investigating the issues has to be an explanatory one. It should be able to answer the why questions stated above. Yin (1994) argues that case study research is most suitable for answering the 'why' question in a research enquiry.

A preliminary selection of cases is done here. It is preliminary because it is based only on the analyses of the first Research Question. At least six cases (one from each sector) are aimed at eventually. The cases selected here are then compared with those selected from the analyses of the second Research Question. Final selection should consist of the cases that provide the best insight into all the issues requiring investigation.

7.4 Case Study Selection

The aims of the case study are

1. To provide triangulation for the survey results and
2. To provide explanation for the effects of the identified conditions on the plants in the sample.

Possible cases (with regard to RQ1 only) are selected, as shown in Table 7.4. The focus is on plants that perceived the conditions as highly significant as drivers of volume flexibility in their plants. However, where most of the responding plants within a particular sector perceive the condition as significant, the outliers in that sector are selected. It is of course the case that once a plant is selected, the influences of all the conditions are explored in that particular plant in the case study.

For instance, consider the selection of plants in the process sector (Table 7.5). In terms of the condition of *high variability in demand levels* plant 97 is selected because it is the only plant that perceived the condition as insignificant. All the other plants in that sector perceive *demand variability* as significant. The intention, therefore, is to explore the reasons why *demand variability* is insignificant as a driver in plant 97. Plants 115 and 76, which perceive *short product shelf life* as a driver of volume flexibility in the process sector as significant, are selected. The interesting thing here is that both plants 115 and 76 perceive *demand variability* as significant, and, therefore, provide an opposite view to plant 97 under the condition of *demand variability*. Also plant 97 perceives *short product shelf life* as insignificant and, therefore, provides opposing view to plants 115 and 76 under *short product shelf life*. So the plants selected in the process sector provide opposite cases to each other on each of the conditions.

The above selection procedure is used to select possible case study plants in all the other sectors for each driver of volume flexibility. For each condition therefore, there are cases that provide two extreme views. Thus, one is afforded the luxury of exploring why volume flexibility drivers are highly significant in some plants and insignificant in other plants.

Since it is impracticable to carry out studies in all the listed plants in Table 7.5, the most frequently occurring plants by sector are selected. Again, this selection is based on the analyses of RQ1 only. The plants selected here are compared with those selected from the analyses of RQ2 and a final selection is made.

Drivers	Process	Eng. consumer	Eng. capital kits	Electronics	Household/General Products	Food	Reasons for choice
Demand variability	97i		38s				Plant 97 is the only plant to score demva as insignificant
Short product shelf life	(115 & 76)s	(49, 86)s		(56, 103)s	46s	(26, 43, 57, 67, 69, 113, 121)s	Plants that score shelif as significant
Cust. influence on lead time	(28, 115)i	(9)i		(41, 74)i		(48)i	Plants that score leadtim as insignificant
Short product life cycle		(9, 12, 49, 104)s		(41, 56)s	(23, 45, 46)s	(26, 47, 113)s	Plants that score lifcycl as significant
Demand unpredictability		9i			(23, 75)i		Plants that score demunpr as insignificant
Material availability	31s	88s	38s				Variable identified by these plants. Note that all other plants did not think of this variable
Key customers					(22, 117)s	69s	As above
Competitors' action				62s		121s	As above
Growth ambition				62s			As above
Over capacity	76s						As above
Poor communication	97s	104s					As above
Acc. engineering		9s				100s	As above
Currency variation					102s		As above
Mass customisation					102s		As above
Stock holding	5s	36s			106s		As above
Max. throughput	5s			74s			As above
Process capability	3s						As above
Product mix	(58, 111)s	(61, 82, 104)s		55s	(45 & 102)s	(43 & 121)s	As above
Seasonality		110s			44s	69s	As above
Batch sizes					117s	(113 & 121)s	As above
Plants chosen	**76 and 115**	**9 & 104**	**38**	**56 & 62**	**45, 46 & 102**	**113 & 121**	**Total of 12 plants selected**

Table 7.5: Selection of case studies based on RQ1 analyses only

7.5 Chapter Summary

The results of the exploratory survey research relating to the first Research Question have been presented in this chapter.

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

Evidence from the analyses of the survey regarding the above question reveals that all the conditions identified from the literature and pilot study are drivers of volume flexibility requirements in manufacturing plants. These conditions are:

- High variability in demand levels
- Short product shelf life
- Customers' influence on lead time determination
- Short product life cycle
- High demand level unpredictability.

The condition of *short product shelf life* was found to be the only one that is significantly dependent on the sector to which the plants belong. This condition was thus classified as a *sector dependent driver* of volume flexibility. The condition of *high variability in demand levels* drives the highest proportion of plants in the sample to require high levels of volume flexibility. All the conditions (apart from *short product shelf life*) are classified as *sector independent drivers* of volume flexibility.

Additionally, responding plants identified other drivers of volume flexibility requirements. However, it was not possible to classify these as generic or sector specific as yet in the survey analyses because of insufficient data required for statistical analysis.

Implications for RQ1

In so far as the conditions under which a manufacturing plant require high levels of volume flexibility have been identified, the analyses have provided evidence to answer the first Research Question. The results also reveal that the requirements for high levels of volume flexibility between plants differ depending on the conditions in which the plants operate, highlighting the need for a correct assessment of flexibility requirements before implementation. This concurs with Jaikumar's (1986) study in which he posited that the reason for the failure of many flexibility implementation programmes in the companies studied in the USA is that many of them did not carry out sufficient assessment of flexibility needs prior to implementing Flexible Manufacturing Systems. Slack (1991) argues that clarifying why flexibility is needed (or identifying drivers) gives clues to which types of flexibility to develop.

All the drivers of volume flexibility identified have different effects on the responding plants. Except for the condition of *short product shelf life*, these differences cannot be explained by industrial classifications. The implication of this is that the differences may be due to other characteristics of the plants, which require further investigation. For instance, *'Are the conditions truly dependent on or independent of the sectors?' Are there other plant characteristics (other than sector) that can explain differences in the effects of the conditions on plants?'*

These questions are explored in the case studies. The next chapter will describe and present the analyses of the survey results in respect of the second Research Question.

Chapter 8 – Survey Analyses: Research Question Two

8.0 Introduction

This chapter describes and presents the analyses carried out in respect of the second Research Question.

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable and inhibit the achievement of volume flexibility in manufacturing plants?

From the results of the analyses, two other Research Questions (RQ3 and RQ4) are developed. Also, cases are selected for the case study research based on the survey analyses. The selected plants are then compared with plants selected based on the analyses of the first Research Question to arrive at a final list of case study plants.

For the purpose of the analyses, the second Research Question is broken down into two.

RQ2a: Identification of enablers
RQ2b: Identification of inhibitors

8.1 Analyses for RQ2a

The questions that address RQ2a are questions 10, 11, 12 and 13 in the questionnaire (see Appendix 2). Possible enablers of volume flexibility identified from the literature and pilot case studies were listed. Respondents were asked to rate (on a 5-point scale) these variables in terms of:

1. To what extent have they used them correctly to cope with demand fluctuations (1 = not used, 5 = Used extensively)
2. Their perception of the relative cost of usage (1 = not costly, 5 = very costly)
3. Their possible desirability in future (1 = not desirable, 5 = highly desirable)

The 5-point scale was collapsed into a 3-point scale for the analyses. Again, the 3-point scale helped to increase the number of cases in cells, needed for meaningful statistical analysis. A trial test was also performed to ensure that collapsing the scales does not significantly affect the outcome of the analysis.

8.1.1 *Steps for analyses*

1. Overall frequencies for all responding plants were obtained. This determines in general (in terms of proportion) how the responding plants rated these strategies.
2. Frequencies of responding plants by sectors were obtained. This shows the proportion of plants in each sector and how they rate the use of the strategies.
3. A chi-square test was performed. This determines whether respondents' ratings (or the use of the strategies) depend on the sectors in which they belong.
4. Other strategies identified by responding plants were obtained and classified by sectors.
5. Further analyses were done to determine which of the strategies are trade-offs or complements by correlating each strategy with one another.
6. Strategies considered as best by responding plants in achieving volume flexibility were analysed (Q12).

The above analyses were performed for each of the variables in question 10 (strategies used to achieve volume flexibility), question 11 (their perception of the relative cost of using the strategies in Q10) and question 13 (the possible desirability of the strategies in future).

It will be recalled that volume flexibility has been defined as *the ability to vary the level of aggregated output in a given period without any detrimental effects on the competitive criteria of the plant.*

To achieve true volume flexibility, it is required that a plant employs a strategy, for which its use does not have any detrimental effects on the competitive criteria (e.g. *cost*) of the plant. Thus, the likelihood of a strategy being a possible enabler of volume flexibility is enhanced if:

1. This strategy has been used to achieve volume flexibility in the plant (Q10 of the survey questionnaire)
2. The use of this strategy is not perceived by the plant to be costly (Q11 of the survey questionnaire).

3. It is suggested also that if a strategy is highly desirable in future for achieving volume flexibility, then this increases the likelihood of that strategy to be an enabler of volume flexibility (Q13 of the survey questionnaire).

In determining the likely enablers of volume flexibility, the three tests above were performed. Table 8.0 gives an overall frequency distribution of the extent of usage of different strategies to achieve volume flexibility in the plants surveyed.

Possible enablers	**Not used (%)**	**Used moderately (%)**	**Used extensively (%)**
Overtime by full time employees	5.0	20.0	75.0
Increased hours worked by part-time employees	72.5	13.3	14.2
Temporary Labour	30.8	25.0	44.2
Job sharing	95.0	4.2	0.8
Annual hours contract	87.5	3.3	9.2
Sub-contracting	47.5	38.3	14.2
Contract employees	71.7	14.2	14.2
Varying lead times	32.5	40.0	27.5
Rejecting orders	80.8	15.8	3.3

Table 8.0: Overall frequencies of responding plants (SPSS Output in Appendix 6).

Generally, the use of *overtime hours by full time employees* to achieve volume flexibility appears to be the most popular strategy used to achieve volume flexibility. *Rejecting orders* appears to be the least popular strategy used by the responding plants to achieve volume flexibility. Table 8.1 below shows the percentage of plants in each sector using these strategies extensively to achieve volume flexibility.

	Overtime	Part-time	Temporary labour	Job sharing	Annual hours	Sub-contracting	Contract employees	Varying lead times	Rejecting Orders
Process	62.5	4.2	37.5	0.0	16.7	8.3	16.7	16.7	4.2
Eng. consumer	96.2	11.5	50.0	0.0	0.0	23.1	19.2	38.5	0.0
Eng. Capital	83.3	16.7	50.0	0.0	8.3	25.0	25.0	50.0	0.0
Electronics	77.3	18.2	50.0	4.5	9.1	22.7	18.2	31.8	0.0
H/hold	61.9	23.8	33.3	0.0	9.5	0.0	0.0	19.0	9.5
Food	66.7	13.3	46.7	0.0	13.3	6.7	6.7	13.3	6.7

Table 8.1: Percentage of responding plants using the strategies extensively by sector.

From Table 8.1 above, it is interesting to note that a higher proportion of plants in the engineering consumer and engineering capital goods sectors use overtime, temporary labour and varying lead times extensively to achieve volume flexibility. The use of overtime hours in these sectors is linked to the traditional mechanism of balancing load and capacity through variation in quoted customer lead times. In the electronics sector, most of the plants use overtime, temporary labour, subcontracting and varying lead times. In the household goods sector, most of the plants use overtime, increased hours worked by part-time employees, temporary labour and varying lead times. In the food sector, most of the plants use overtime and temporary labour. More plants in the process and food sector use annualised hours contracts to achieve volume flexibility.

In an attempt to suggest reasons for the variation in the degree of usage of the strategies across all industrial sectors, a chi-square test was performed to determine whether the use of the strategies actually depends on the sectors to which the plants belong. The results of the test are summarised in Table 8.2 below. Further explanations of the trend observed in Table 8.1 above are sought from the subsequent case study research phase of the project.

Possible Enablers.	Overall Frequencies	Frequencies by sectors (Appendix 6)	*Chi-square test.	Comments
Overtime hours by full time employees	Used extensively- 75% Used moderately – 20% Not used – 5%	5% that did not use it belong to the Process, Household and Food sectors.	P = 0.056 Chi-square value = 17.89 Accept null hypothesis	The use of overtime hours is a likely enabler of volume flexibility. Plants (in different sectors) at least in the sample are equally likely to use this strategy to cope with actual demand level fluctuations. **(Sector independent)**
Increased hours worked by part-time staff	Used extensively– 14.2% Used moderately- 13.3% Not used – 72.5%	Similar pattern across the sectors, although Household sector plants appear to use it the most.	P = 0.57 Chi-square value = 8.52 Accept null hypothesis.	The use of increased hours worked by part-time employees is a likely enabler of volume flexibility. However, the use or lack of use of this strategy by the plants at least in the sample does not depend on the sector to which the plants belong. **(Sector independent)**
Temporary labour	Used extensively–44.2% Used moderately- 25% Not used – 30.8%	Similar pattern across the sectors.	P = 0.79 Chi-square value = 6.29 Accept null hypothesis	The use of temporary labour is a likely enabler of volume flexibility. Its use is **sector independent**.
Job sharing	Used extensively- 0.8% Used moderately- 4.2% Not used – 95%	The one plant that used jobsha0 extensively belongs to Electronics sector. Household & Food sectors' plants did not use it.	P = 0.5 Chi-square value = 9.27 Accept null hypothesis	The use of job sharing contract is a likely enabler even though only one plant used it. Also, plants (in different sectors) at least in the sample are equally likely to use or not to use this strategy to cope with actual demand fluctuations. **(Sector independent)**
Annual hours contracts	Used Extensively- 9.2% Moderately used- 3.3% Not used – 87.5%	Pattern appears to be similar across the sectors.	P = 0.32 Chi-square value = 11.49 Accept null hypothesis	The use of annualised labour hour contract is a likely enabler of volume flexibility. However, plants (in different sectors) at least in the sample are equally likely to use this strategy to cope with fluctuations in demand levels. **(Sector independent)**
Subcontracting	Used extensively- 14.2% Used moderately- 38.3% Not used – 47.5%	Relatively higher proportions of responding plants in the Process, Household and Food sectors did not use subcon0.	P = 0.00055 Chi-square value = 31.16 Reject null hypothesis.	The use of sub-contracting is a likely enabler of volume flexibility. The use of this strategy by the plants in the sample *actually* depends on the sector to which the plants belong. **(Sector dependent)**
Contract labour	Used extensively- 14.2% Used moderately- 14.2% Not used – 71.7%	Pattern appears to be similar across sectors, but proportion of plants that used it is higher in the Engineering capital kits sector.	P = 0.34 Chi-square value = 11.26 Accept null hypothesis	The use of contract employees is a likely enabler of volume flexibility. Its use is **sector independent**.
Varying lead times	Used extensively- 27.5% Used moderately- 40% Not used – 32.5%	Pattern appears similar, but proportion of plants that did not use it is higher in the Food sector.	P = 0.16 Chi-square value = 14.27 Accept null hypothesis	Varying lead times is a likely enabler of volume flexibility. Its use is **sector independent**.
Rejecting orders	Used extensively- 3.3% Used moderately- 15.8% Not used – 80.8%	Interesting that 4 plants in Process, Household & Food used it extensively.	P = 0.3 Chi-square value = 11.76 Accept null hypothesis	Rejecting orders is a likely enabler of volume flexibility. The use of rejecting orders is **sector independent**.

Table 8.2: Summary of results: Strategies employed by responding plants to cope with fluctuations in actual demand levels.

**Null Hypothesis: Plants (in different sectors) at least in the sample are equally likely to employ the strategy to cope with fluctuations in actual demand levels*
Alternative Hypothesis: The use of the strategy by plants at least in the sample depends on the sector to which the plants belong ***(Reject Null hypo. if $P \leq 0.05$; Chi-square value > 18.307 at 5% significance level).***

8.1.2 Other Strategies (enablers) Identified by Respondents

Respondents were given the opportunity to identify other strategies that they employed to achieve volume flexibility in their plants. These strategies are tabulated in Table 8.3. Each of these strategies qualifies as a likely enabler of volume flexibility as each has been identified by at least one responding plant.

Other strategies employed to cope with fluctuations in actual demand levels (identified by respondents).	Frequency (No. of respondents)	Sectors of identifying plants.
Multi skilling (multiski)	1	Process
Schedule/Priority negotiation (schprior)	1	Electronics
Upgrading equipment/Increasing automation (equpgrad)	1	Electronics
Using stock built in slack period (stockbld)	5	Process, Engineering Consumer, Engineering capital & Household (2).
Hiring new employees (hiring0)	3	Process and Electronics (2)
Change in shift pattern/extra shift (shiftpat)	4	Process (2), Household & Food.
Process/Method improvements (improces)	1	Electronics
Introduction of team working (teamwork)	1	Household
Improved training (training)	1	Household
Shift orders to or buy in from sister plants (sisplan0)	2	Process, Food
Stop making to stock (stopmts0)	1	Food

Table 8.3: Other strategies employed to cope with fluctuations in actual demand levels as identified by some of the respondents.

The responses to Q11 are then analysed (respondents' perceptions of the relative cost of using the strategies to cope with fluctuations in actual demand levels). As argued previously, the likelihood of a strategy (having identified it as a likely enabler in the previous analyses) to be an enabler of volume flexibility, is enhanced if a relatively higher proportion of responding plants perceive the use of the strategy not to be costly.

Table 8.4 gives the overall frequency distribution of responding plants' perceptions of the relative cost of using the strategies.

Enablers	Not costly (%)	Moderately costly (%)	Very costly (%)
Overtime by full-time employees (overti1)	2.5	40.8	56.7
Increased hours by part-time employees (partim1)	22.5	60.0	17.5
Temporary labour (temp1)	13.3	59.2	27.5
Job sharing (jobsha1)	23.3	62.5	14.2
Annual hours contract (anualh1)	45.0	45.0	10.0
Sub-contracting (subcon1)	10.8	36.7	52.5
Contract employees (contra1)	10.0	39.2	50.8
Varying lead times (leadti1)	15.0	54.2	30.8
Rejecting orders (rejec1)	7.5	3.3	89.2

Table 8.4: Overall frequencies of responding plants (SPSS Output in Appendix 7)

It is interesting to note from the above Table 8.4 that a higher proportion of plants perceives the use of overtime to be very costly in achieving volume flexibility. This perception reduces the strength of overtime as a likely enabler of volume flexibility. It will be recalled that the use of overtime appears to be the strongest possible enabler from the previous analyses. In contrast, the strength of an annualised hours contract as a likely enabler of volume flexibility is seen to increase as more plants perceive its use not to be costly. In the previous analyses, an annualised hours contract was seen to be a relatively weak enabler in that a lower proportion of plants use this strategy to achieve volume flexibility.

Again, the analyses seek to explain the differences observed in the perception of responding plants regarding the relative cost of using the strategies. Table 8.5 below has been used to summarise the results of the chi-square test carried out to determine whether management perceptions regarding the relative cost of using the strategies has been influenced by the sector to which their plants belong.

Perceptions on costs	Overall frequencies	Frequencies by sectors (Appendix 7)	[†]Chi-square test	Comments
Overtime hours	Very costly – 56.7% Moderately costly- 40.8% Not costly – 2.5%	Only 3 plants (Electronics and Food) felt overti1 was not costly to use. Other perceptions are skewed towards costly.	P = 0.36 Chi-square value = 10.92 Accept null hypothesis	The use of overtime hours by full time employees is perceived by most of the plants to be costly. Plants in the sample (in different sectors) are equally likely to rate overtime as being costly. **Sector independent**
Part time employees	Very costly – 17.5% Moderately costly – 60% Not costly – 22.5%	In all the sectors, a higher proportion of respondents felt that partim1 is moderately costly.	P = 0.25 Chi-square value = 12.42 Accept null hypothesis	The use of increased hours by part-time employees is perceived by more plants to be generally costly. Perception on cost is **sector independent.**
Temporary labour	Very costly – 27.5% Moderately costly – 59.2% Not costly – 13.3%	A higher proportion of respondents felt that temp1 is moderately costly.	P = 0.65 Chi-square value = 7.71 Accept null hypothesis	The use of temporary labour to cope with demand fluctuations is perceived by more plants to be generally costly. Perceptions are not influenced by sector identity. **Sector independent.**
Job sharing	Very costly – 14.2% Moderately costly – 62.5% Not costly – 23.3%	A higher proportion of plants in other sectors (except Capital kits) felt that jobsha1 is moderately costly.	P = 0.059 Chi-square value = 17.76 Accept null hypothesis	The use of job sharing contract to cope with demand fluctuations is considered by most of the respondents to be moderately costly. Perceptions on cost are **sector independent.**
Annual hours contract	Very costly – 10% Moderately costly – 45% Not costly – 45%	High proportion of plants in Food felt that Anualh1 is not costly. A balance between not/moderately costly is seen for other sectors.	P = 0.79 Chi-square value = 6.3 Accept null hypothesis	The use of annualised labour hours contract to be very costly by a smaller proportion of plants. The perceptions are not influenced by sector identity at least in the sample. **Sector independent.**
Subcontracting	Very costly – 52.5% Moderately costly – 36.7% Not costly – 10.8%	Higher proportion of plants in Engineering consumer/capital sectors felt subcon1 is moderately costly.	P = 0.045 Chi-square value = 18.62 Reject null hypothesis	Sub-contracting as a way of coping with demand fluctuations is perceived by most plants to be very costly. The perceptions are actually influenced by the sector identity. **Sector dependent.**
Contract employees	Very costly – 50.8% Moderately costly – 39.2% Not costly – 10%	Higher proportion of plants in Electronics & Household felt contra1 is moderately costly.	P = 0.068 Chi-square value = 17.27 Accept null hypothesis	The use of contract employees to cope with demand fluctuations is perceived by most plants to be very costly. These perceptions are not influenced by sector identity. **Sector independent.**
Varying lead times	Very costly 30.8% Moderately costly – 54.2% Not costly – 15%	The general pattern is similar across all sectors.	P = 0.94 Chi-square value = 4.12 Accept null hypothesis	Varying lead times as a way of coping with demand fluctuations is perceived by more plants to be moderately costly. The perceptions are not influenced by sector identity. **Sector independent.**
Rejecting orders	Very costly – 89.2% Moderately costly – 3.3% Not costly – 7.5%	9 plants (Engineering consumer/capital, Electronics & Household) felt rejec1 is not costly.	P = 0.27 Chi-square value = 12.16 Accept null hypothesis	Rejecting orders as a way of coping with demand fluctuations is perceived by most to be very costly. The perceptions are not influenced by sector identity. **Sector independent.**

Table 8.5: Summary of results: perceptions of responding plants in terms of relative cost of the use of coping strategies.

[†] *Null Hypothesis: Plants (in different sectors) at least in the sample are equally likely to perceive the strategy as very costly or not costly.*
Alternative Hypothesis: The perceptions of the respondents depend on the sector to which the plants belong. ***Reject null hypo. If $P \leq 0.05$ & Chi-square > 18.307 (at 5% significance level).***

8.1.3 Relative cost of other strategies identified by respondents.

Relative cost of using other strategies identified by respondents	Frequency (no. of respondents)	Sector of identifying plants
Multiskilling (multisk1)	1nc	Process
Schedule/Priority Negotiation (schprio1)	1mc	Electronics
Shut down (shut)	1vc	Household/General products
Change from core product (prochang)	1vc	Household/General products
Using stock built during slack period (stockbd1)	4mc	Process(1), Engineering consumer (1), Household/Gen. (2)
Change in shift pattern/Extra shift (shiftpa1)	1nc, 2mc, 1vc	Process (2), Household (1), Food (1)
Process/Method improvements (improce1)	1nc	Electronics
Productivity bonus/incentive (incentiv)	1vc	Food
Hiring new staff (hirin1)	2vc	Electronics
Introduction of team working (teamwor1)	1mc	Household/General products
Improved training (trainin1)	1mc	Household/General products
Slow new product releases (newprod1)	1vc	Food
Stop making to stock (stopmts1)	1mc	Food
Shift orders/Buy-in from sister plants (sisplan1)	3vc	Process (2), Food (1).

nc – not costly; mc – moderately costly, vc – very costly.

Table 8.6: Other strategies identified and respondents' perceptions in terms of their relative costs.

The use and the relative cost of the strategies identified in Table 8.6 are explored in the case study research. Unless otherwise revealed in the subsequent case study research, strategies that are perceived not to be costly in the above table are classified as likely enablers of volume flexibility (provided that these strategies give the plants the required volume flexibility).

The third test in the determination of likely enablers of volume flexibility consists of the analysis of the responses given to Q13, that is, the desirability of each of the listed strategies to achieve volume flexibility in future. As argued previously, the likelihood of a strategy to be an enabler of volume flexibility is enhanced if that particular strategy is felt to be highly desirable in future by responding plants. The summary of overall frequency is shown in Table 8.7.

Enablers	Not desirable (%)	Moderately desirable (%)	Highly desirable (%)
Overtime by full-time employees (overti3)	10.8	49.2	40.0
Increased hours worked by part-time employees (partim3)	54.2	24.2	21.7
Temporary labour (temp3)	30.8	31.7	37.5
Job sharing (jobsha3)	57.5	31.7	10.8
Annual hours contract (anualh3)	26.7	37.5	35.8
Sub-contracting (subcon3)	39.2	41.7	19.2
Contract employees (contrac3)	48.3	37.5	14.2
Varying lead times (leadti3)	40.8	42.5	16.7
Rejecting orders (rejec3)	97.5	2.5	0.0

Table 8.7: Overall frequencies of responding plants (SPSS Output in Appendix 8).

The Table 8.7 above shows that using annual hours contracts and overtime hours to achieve volume flexibility are felt to be desirable in future by a higher proportion of responding plants. A comparative analysis of the results of this Table 8.7, with the results of Table 8.0 reveals the differences between current strategies for delivering volume flexibility and planned future strategies. This is shown in Figure 8.0 below.

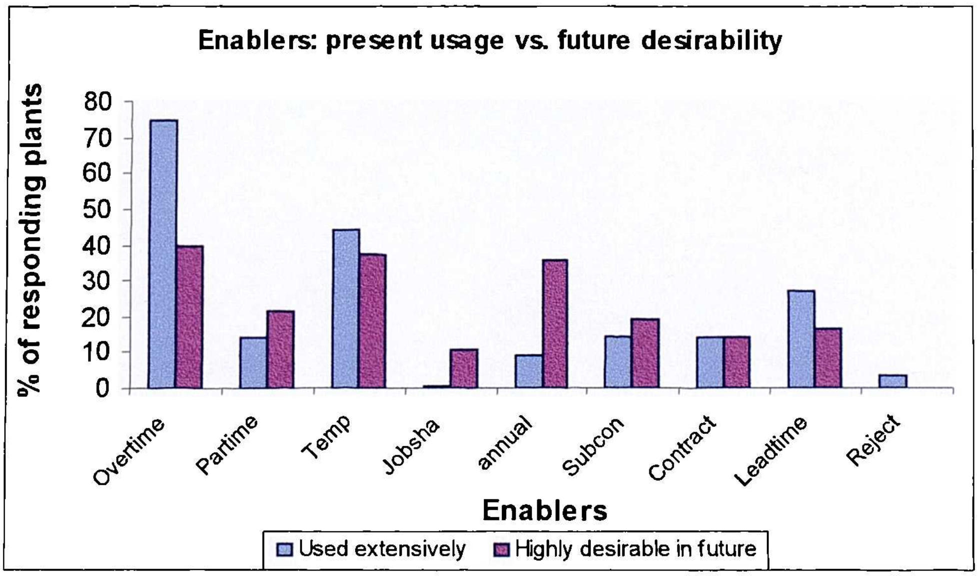

Figure 8.0: Likely enablers of volume flexibility: present usage versus future desirability.

It is interesting to note the trends observed in Figure 8.0 above. For instance, 75% of responding plants presently use overtime hours extensively to achieve volume flexibility. However, only 40% of responding plants desire its use in the future. On the other hand, the figure reveals that only 9.2% of responding plants presently use an annualised hours contract extensively to achieve volume flexibility. However, 35.8% of the responding plants desire its use in the future.

The breakdown of management perceptions for future desirability of solutions to achieve volume flexibility by sector further sheds light on the above differences, as shown in Table 8.8 below.

	Overtime	Part-time	Temporary labour	Job sharing	Annual hours	Sub-contracting	Contract employees	Varying lead times	Rejecting Orders
Process	* 62.5 » (25) ↓	4.2 (8.3)	37.5 (25.0) ↓	0.0 (12.5) ↑	16.7 (41.7) ↑	8.3 (8.3)	16.7 (8.3)	16.7 (25.0) ↑	4.2 (0.0) ↓
Eng. consumer	96.2 (57.7) ↓	11.5 (26.9) ↑	50.0 (46.2)	0.0 (11.5) ↑	0.0 (38.5) ↑	23.1 (23.1)	19.2 (15.4)	38.5 (19.2)	0.0 (0.0)
Eng. Capital	83.3 (50.0) ↓	16.7 (0.0) ↓	50.0 (41.7)	0.0 (8.3)	8.3 (8.3)	25.0 (50.0) ↑	25.0 (16.7) ↓	50.0 (25.0) ↓	0.0 (0.0)
Electronics	77.3 (36.4) ↓	18.2 (27.3)	50.0 (40.9)	4.5 (9.1)	9.1 (27.3) ↑	22.7 (22.7)	18.2 18.2)	31.8 (9.1) ↓	0.0 (0.0)
H/hold	61.9 (47.6) ↓	23.8 (38.1)	33.3 (38.1)	0.0 (0.0)	9.5 (42.9) ↑	0.0 (14.3) ↑	0.0 (14.3) ↑	19.0 (19.0)	9.5 (0.0) ↓
Food	66.7 (20.0) ↓	13.3 (20.0)	46.7 (33.3)	0.0 (26.7) ↑	13.3 (46.7) ↑	6.7 (6.7)	6.7 (13.3)	13.3 (0.0) ↓	6.7 (0.0) ↓

* % of plants using this strategy extensively
» % of plants rating the use of this strategy as highly desirable to them in future
↑ Increase ↓ Decrease

Table 8.8: Existing and planned future use of possible enablers of volume flexibility

In the process sector the use of annualised hours contracts, job sharing and varying lead times are preferred to using overtime and temporary labour in future. In the engineering consumer sector, the use of overtime is to be replaced by annualised hours, increased hours worked by part-time employees and job sharing in the future. In the engineering capital sector, there is a switch from the use of overtime and an apparent increase in the use of subcontracting in the future. Plants in the electronics sector favour a switch from overtime and varying lead times into annualised hours and an increased use of additional hours by part-time employees. Plants in the household products sector will seek future volume flexibility through annualised hours contracts, increased hours by part-time employees, subcontracting, temporary and contract employees. Plants in the food sector are seeking to replace the use of overtime and temporary labour by annualised hours, job sharing and contract employees.

Generally there are reductions in the use of overtime, temporary labour and varying lead times to achieve volume flexibility. There are increases in the use of annualised hours contracts, increased hours worked by part-time employees and job sharing to achieve volume flexibility.

The reasons for the trends observed in the above table can be partly explained by the perception of relative cost of using these strategies as shown in Figure 8.1.

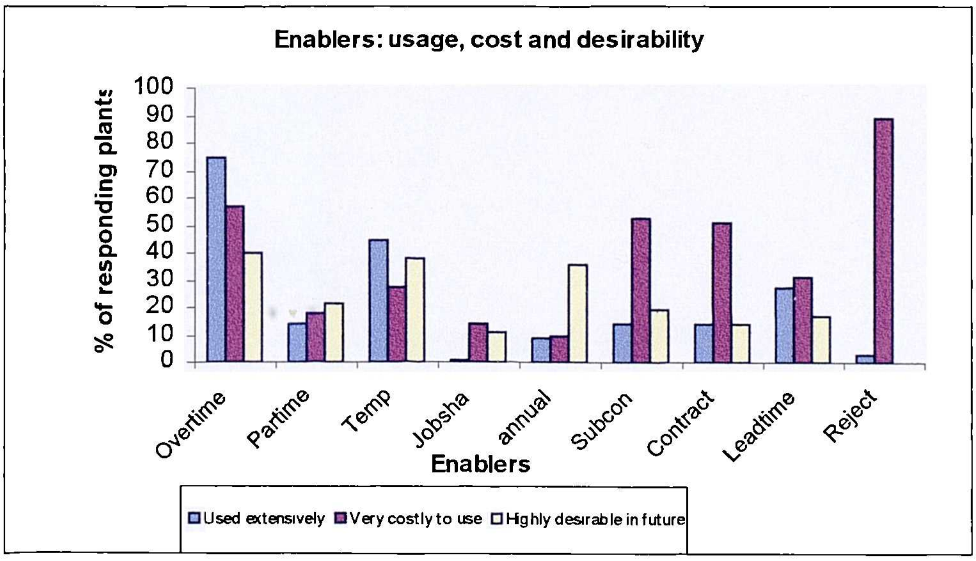

Figure 8.1: Possible enablers of volume flexibility: present usage vs. cost vs. future desirability

The general switch from the use of overtime towards annualised hours type contracts may be due to the perception which plants have of relative costs of using the strategies to achieve volume flexibility. For instance, 56.7% of the responding plants perceived the use of overtime hours to be very costly while only 10% perceived the use of annualised hours contracts to be very costly, hence the propensity towards the decreasing adoption of overtime hours and increasing use of annualised hours contracts to achieve volume flexibility. Rejecting orders is seen to be the most expensive, hence it is not felt to be desirable in future by any of the responding plants. Other reasons underpinning the decreasing or increasing adoption of each enabler relate to the market drivers of volume flexibility which were identified in answering the first Research Question. These are, however, investigated in depth, in the case study research.

Additionally, a chi-square test was performed to explore whether differences in the perceptions of responding plants relating to the future desirability of different policies are sector dependent. The results are presented in Table 8.8 below.

Likely enablers	Overall frequencies	Frequency by sectors (Appendix 8)	[1]Chi-square test	Comments
Overtime hours	Highly desirable – 40% Mod. desirable – 49.2% Not desirable – 10.8%	Higher proportions of plants in Engineering consumer & capital kits highly desire overti3. Pattern is similar in other sectors.	P = 0.12 Chi-square = 15.29 Accept null hypothesis	The future use of overtime hours to cope with demand fluctuations is generally desirable by most plants. Perception on future desirability is **sector independent.**
Increased hours worked by part time staff	Highly desirable – 21.7% Mod. desirable – 24.2% Not desirable – 54.2%	Across desirability levels, responses in Electronics & Household are more even.	P = 0.11 Chi-square = 15.48 Accept null hypothesis	The use of increased hours worked by part-time employees to cope with demand fluctuations in future is not desirable by more plants. Perception on future desirability is **sector independent.**
Temporary labour	Highly desirable – 37.5% Mod. Desirable – 31.7% Not desirable – 30.8%	Even and similar pattern across all sectors	P = 0.65 Chi-square = 7.74 Accept null hypothesis	Although more plants highly desire the use of temporary labour to cope with demand fluctuations in future, the distribution is somewhat even. Perception on future desirability is **sector independent.**
Job sharing	Highly desirable – 10.8% Mod. desirable – 31.7% Not desirable – 57.5%	Pattern is similar across all sectors. Less proportion of plants in Household do not desire job sharing.	P = 0.27 Chi-square = 12.13 Accept null hypothesis	The use of job sharing contract to cope with demand fluctuations is not desired by most responding plants. Perception on future desirability is **sector independent.**
Annual hours contracts	Highly desirable – 35.8% Mod. desirable – 37.5% Not desirable – 26.7%	Pattern similar across sectors. Only one plant in Eng. Capital would highly desire annual hours contracts.	P = 0.36 Chi-square = 10.91 Accept null hypothesis	Less proportion of plants would not desire the use of annual hours contract to cope with demand fluctuations. Perception on future desirability is **sector independent.**
Subcontracting	Highly desirable – 19.2% Mod. desirable – 41.7% Not desirable – 39.2%	Higher proportion of plants in both Eng. Consumer & capital sectors would desire subcontracting.	P = 0.019 Chi-square = 21.21 Reject null hypothesis	Most of the plants in Eng. Capital & Consumer sectors would highly and moderately desire using sub-contracting in future respectively. Perception on using subcontracting in future is **sector dependent.**
Contract staff	Highly desirable – 14.2% Mod. desirable – 37.5% Not desirable – 48.3%	Higher proportion of plants in both Eng. Consumer & Electronics sectors would desire contracting.	P = 0.29 Chi-square = 11.84 Accept null hypothesis	Higher proportion of plants would not desire using contract employees in future to cope with demand fluctuations. Perception on future desirability is **sector independent.**
Varying lead times	Highly desirable – 16.7% Mod. desirable – 42.5% Not desirable – 40.8%	Higher proportion of plants in the Food sector would not desire varying lead time.	P = 0.35 Chi-square = 11.07 Accept null hypothesis	Higher proportion of plants would only moderately desire varying lead times to cope with demand fluctuations in future. Perception on future desirability is **sector independent.**
Rejecting orders	Highly desirable – 0% Mod. desirable – 2.5% Not desirable – 97.5%	3 plants that moderately desire rejection of orders in future belong to the Electronics sector.	P = 0.06 Chi-square = 10.53 Accept null hypothesis	Most plants would not consider rejecting orders as a way to cope with fluctuations in demand levels in the future. Perception on future desirability of rejecting orders is **sector independent.**

Table 8.9: Summary of results: desirability of strategies for use in the future to cope with demand fluctuations.

[1] *Null Hypothesis: Plants in different sectors (at least in the sample) are equally likely to desire (or not desire) the strategy to cope with fluctuations in actual demand levels in the future.*
Alternative Hypothesis: The desirability of the strategies for future use by plants depends on the sectors they belong to. ***Reject null hypothesis if*** $P \leq 0.05$***, & if Chi-square > 18.307 (CV)***

8.1.4 Other strategies desired in future as identified by responding plants.

Strategies to cope with demand fluctuations in future	**Frequencies (no. of plants) & desirability levels**	**Sectors of identifying plants**
Multiskilling (multisk3)	5hd	Process (3), Eng. Capital (1), Household (1)
Efficiency importance/Reduction in cycle time (improce3)	5hd	Eng. Consumer (1), Eng. Capital (20, Electronics (2).
Upgrading equipment/increasing automation (equpgra3)	4hd	Eng. Capital, Household, Electronics & Food
Shut down (shut3)	1nd	Household
Change from core product (prochan3)	1nd	Household
Using stock built during slack period (stockbd3)	2md	Engineering capital & Household
Hiring new employees (hiring3)	2md, 1hd	Process (1) & Electronics (2)
Better demand forecasting /planning (forecast)	2hd	Electronics & Household
Change in shift pattern/extra shift (shiftpa3)	2hd	Process & Food
Demand flow technology (demflow)	1hd	Engineering capital
Cellular manufacture/change factory layout (cellmanu)	1hd	Engineering capital
Having spare capacity (sparecap)	1hd	Food
Extend team working to 90% (teamwor3)	1hd	Household
Improve training (trainin3)	1hd	Household
Synchronisation of supply chain (supplych)	1hd	Food
Shift orders/buy in from sister plants (sisplan3)	1md	Process

hd = highly desirable, md = moderately desirable, nd = not desirable.

Table 8.10: Other strategies that can be used for coping with demand fluctuations and their desirability in future.

8.1.5 Further Analyses

Further analysis was carried out to identify other classes of volume flexibility strategies classified as *substitutes* and *complements*. *Substitute* enablers are defined as those strategies, which can replace or can be replaced by other strategies in achieving volume flexibility. Generally, these types of enabler are not normally used simultaneously. *Complement* enablers are those strategies which, when used by a plant, are likely to encourage the use of other specific strategies.

Substitute and complementary enablers of volume flexibility are determined from the analyses by correlating the strategies employed to achieve volume flexibility with each other. A significant negative correlation (i.e. either one or the other is used to achieve volume flexibility) provides likely candidates for *substitutes*. A significant positive correlation provides likely candidates for *complementary* enablers.

Table 8.11 summarises the result of the analyses. Only the results of the variables that qualify as likely *substitutes* and *complements* are displayed.

Strategies used to cope with demand fluctuations	**Significant Cross-tabs & correlation results by sectors.**	**Comments (are the strategies substitutes or complements when used in coping with fluctuations in demand levels?)**
Overtime vs. Temporary labour	**Food**: most of the plants that used temporary labour also used overtime hours. (r = 0.52, P = 0.048).	The use of overtime hours and temporary labour appear to be complementary in the Food sector.
Overtime vs. annual hours contracts	**Process**: Most of the plants that used annual hours did not use overtime hours and vice-versa (r = -0.74, P = 0.00003) **Household**: as in process (r = -0.5, P = 0.02)	The use of overtime hours appears to be a substitute enabler to the use of annual hours contracts in the process & household sectors.
Overtime vs. contract staff	**Process**: Most of the plants that used overtime did not use contract labour. (r = -0.50, P = 0.01)	The use of overtime hours appears to be a substitute enabler to the use of contract employees in the process sector.
Overtime vs. varying lead times	**Eng. Capital**: Most of the plants that used overtime also used variation in lead time (r = 0.67, P = 0.016)	The use of overtime hours appears to complement the use of variation in lead times in the Eng. Capital kits sector.
Overtime vs. rejecting orders	**Food**: Most of the plants that used overtime hours did not reject orders. (r = -0.56, P = 0.028)	In the food sector, rather than reject orders, overtime hours are used. These are substitutes.
Job sharing vs. part time employees	**Eng. Consumer**: Most plants that did not use part time staff also did not use job sharing. (r = 0.47, P = 0.014)	The use of increased hours by part-time staff and job sharing contracts are complementary in the Engineering consumer products sector.
Subcontracting vs. contract staff	**Electronics**: Most of the plants that used subcontracting also used contract staff and most of those that did not use subcontracting also did not use contract staff (r = 0.52, P = 0.014).	The use of subcontracting and contract employees appears to be complementary in the Electronics sector at least in the sample.
Subcontracting vs. varying lead times	**Eng. Consumer**: Most of the plants that used subcontracting also used varying lead times and vice versa in this sector (r = 0.53, P = 0.005).	The use of sub-contracting and variation in lead-time appears to be complementary in the Engineering consumer sector at least in the sample.

Table 8.11: Identifying likely enablers that are substitutes and complements in achieving volume flexibility. SPSS Output in Appendix 10.

Further analyses were carried out to determine the strategies regarded by responding plants as the best in achieving volume flexibility (Q12 on the questionnaire). These are tabulated in Table 8.11.

Best coping mechanism used (beststra)	Frequency	Percent	Sector
None, but considering annual hour labour contract	3	2.4	Food
Team working	2	1.7	Electronics & Household
Overtime hours worked by full timers	51	42.5	Process (10), Engineering consumer (15), Eng. Capital (6), Electronics (7), Household (9), Food (2)
Increased hours worked by part-time staff.	3	2.5	Household (2), Food (1)
Temporary labour	24	20.0	Process (5), Eng. Consumer (3), Eng. Capital (3), Electronics (6), Household (4), Food (3).
Job sharing	1	0.8	Electronics
Annual hours contract	8	6.7	Process (3), Eng. Consumer (1), Engineering capital (1), Household (2), Food (1).
Sub-contracting	4	3.3	Engineering consumer (1), Electronics (2), Household (1)
Contract employees	4	3.3	Process (1), Eng. Consumer (2), Eng. Capital (1)
Varying lead times	1	0.8	Process
Multiskilling	1	0.8	Process
Upgrading equipment/increasing automation	1	0.8	Electronics
Combining overtime and increased hours worked by part-timers	3	2.5	Process, Electronics & Household
Overtime and temporary labour	5	4.2	Process (1), Eng. Consumer (2) & Electronics (2)
Overtime and sub-contracting	1	0.8	Eng. Capital
Temporary labour and stock building	1	0.8	Eng. Consumer
Temporary labour and annual hours labour contract	2	1.7	Process & Food
Flexible working (variants of annual hours contract)	2	1.7	Eng. Consumer & Food
Multi-shift	1	0.8	Food
Overtime and flexible working	1	0.8	Household
Overtime and Sub-contracting	1	0.8	Electronics

Table 8.12: Strategies considered by responding plants, as the best in coping with fluctuations in actual demand levels.

8.1.6 Summary of Results: Identification of enablers of Volume Flexibility in manufacturing plants.

Three tests have been performed to identify the likely enablers of volume flexibility from the survey.

1. If responding plants used the strategy extensively (the proportion of plants that used it extensively determines the relative strength). See Figure 8.3.
2. If the strategy is not costly to use by responding plants (relative strength is determined by the proportion of plants that perceived it not to be costly to use). See Figure 8.4.

3. If the strategy is highly desired in future by responding plants (relative strength determined by the proportion of plants that highly desire to use it in future). See Figure 8.5.

The Figure below displays the tests carried out to determine the likely enablers of volume flexibility based on the proportion of respondents rating each item on three scales (Q10, Q11 and Q13 of the survey questionnaire).

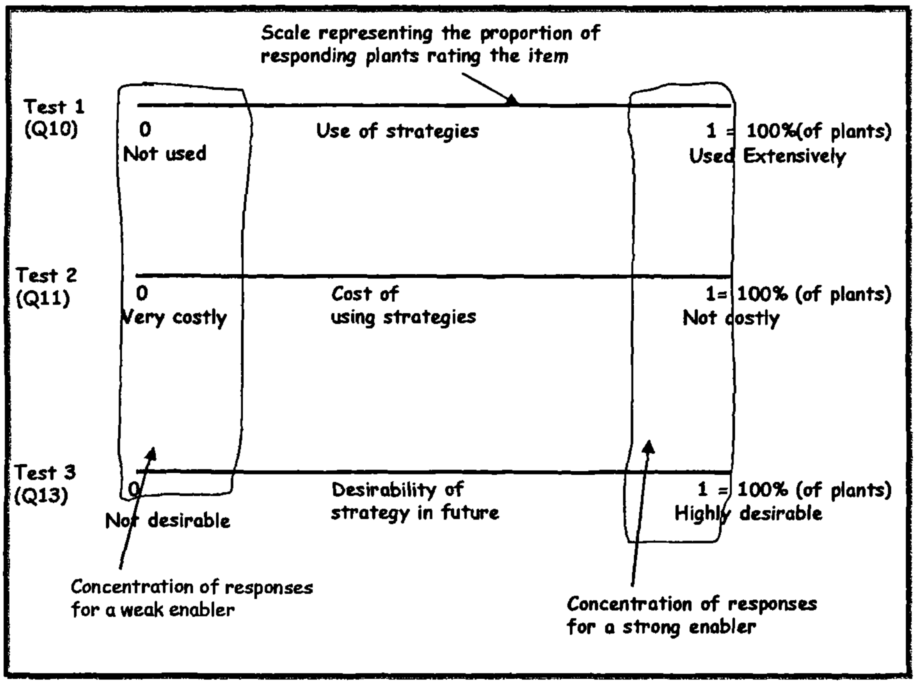

Figure 8.2: Identifying likely enablers of volume flexibility.

As the figure above shows, likely enablers of volume flexibility can be determined by comparing the proportion of plants rating the variable on the three scales by considering two approaches.

1. Determine the likely enablers and their strengths by looking at the three tests separately. The implication is that, we have three possible different classifications. These are based on the proportion of plants that used the strategy extensively, perceive its use not to be costly and desire its use in future (Figures 8.3, 8.4 and 8.5).
2. Develop a model (additive or multiplicative) which combines the three scales in Figure 8.2 above to identify enablers and their relative strength.

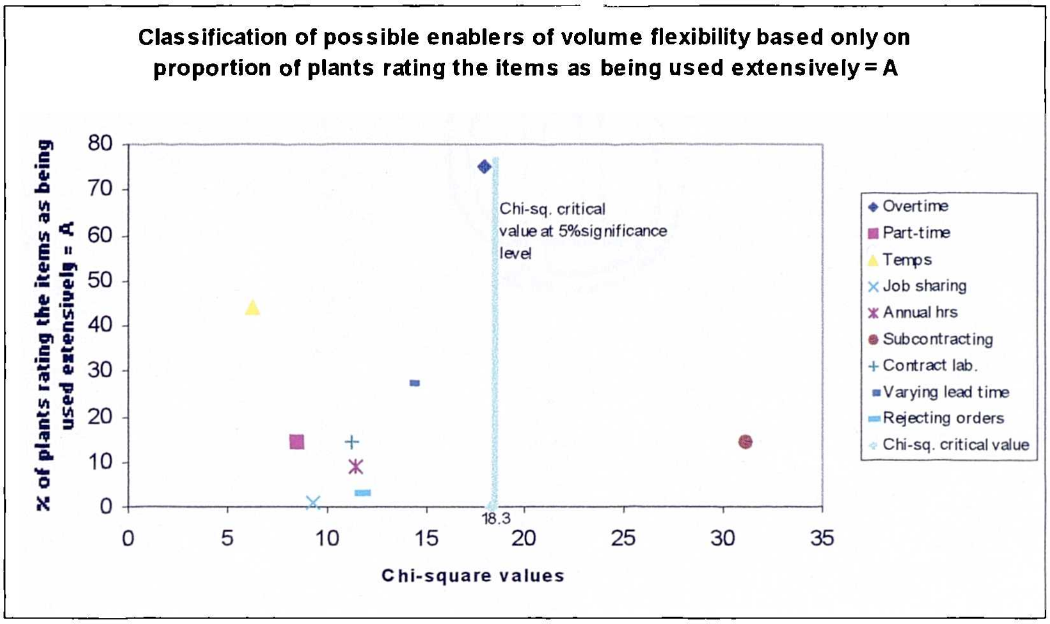

Figure 8.3: Proportion of plants that used the strategies extensively to achieve volume flexibility.

The positioning of the strategies after test 1, is represented in Figure 8.3. The y-axis in Figure 8.3 represents the proportion of plants that used the strategies extensively to achieve volume flexibility. In so far as this classification is concerned, the use of *overtime hours by full time employees* appears to be the strongest likely enabler of volume flexibility.

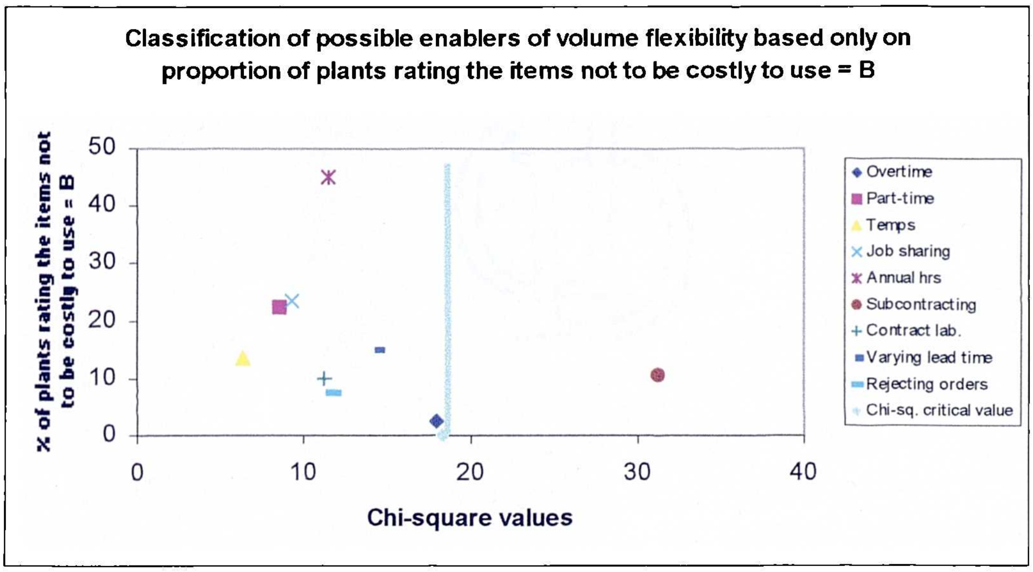

Figure 8.4: Representation of enablers of volume flexibility after test 2 (i.e. after applying cost penalty).

The positioning of the strategies after test 2, is represented in Figure 8.4. The y-axis in Figure 8.4 represents the proportion of plants that felt that the strategy is not costly to use in achieving volume flexibility. It is interesting to note that, when the costs of usage are considered, the *use of overtime hours* appears to be a weak enabler of volume flexibility as the smallest proportion of plants perceive its use not to be costly. On the other hand, *annualised hours contracts* appear to be the strongest enabler when the perceptions of relative costs of using the different policies are considered.

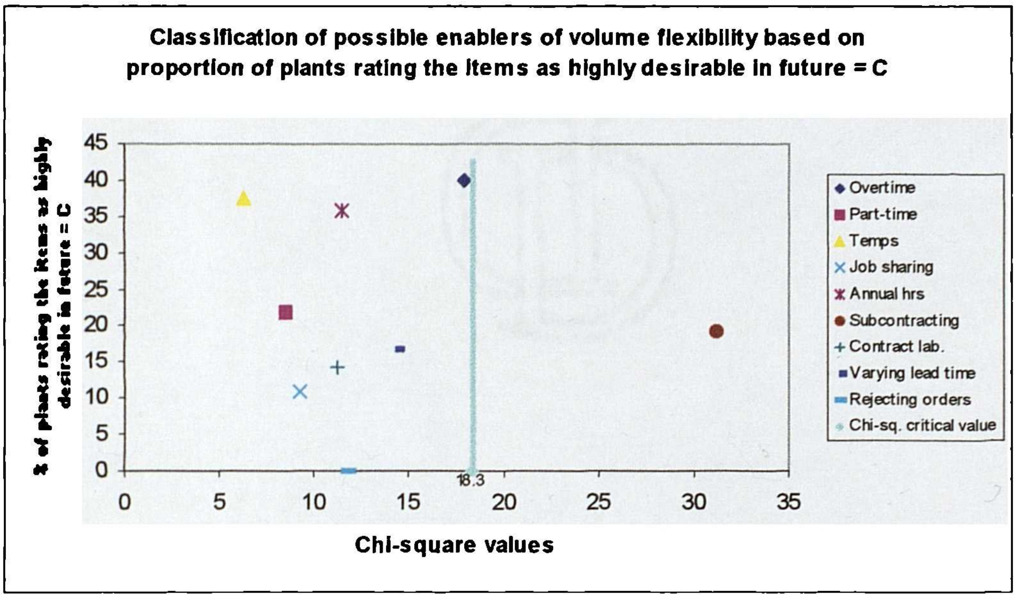

Figure 8.5: Representation of enablers of volume flexibility after test 3 (i.e. after applying level of desirability of each strategy in future).

The positioning of the strategies after test 3, is represented in Figure 8.5. The y-axis in Figure 8.5 represents the proportion of plants that desire the use of the strategies in future to achieve volume flexibility. Again, the use of *overtime hours* comes top, but only slightly stronger than both *temporary labour* and *annualised hours contracts*. On the other hand, as one might expect, *rejection of orders* appears to be the weakest enabler as not a single plant rated this strategy as desirable in future to achieve volume flexibility.

The x-axes in the figures above represent the chi-square test values for each of the factors. They show the likelihood of the strategies to be either sector independent or sector dependent. If the observed significance level of a strategy is less than 0.05 (or chi-square value is more than the critical value of chi-square), then that strategy is classified as *sector dependent*. Thus, the use of *subcontracting* is *sector dependent* as its chi-square value of 31.16 is greater than the critical value of 18.3 at 5% level of significance. On the other hand, the use of *annualised hours contracts* is *sector independent* as its chi-square value of 11.49 is less than the critical value of 18.3 at 5% significance level. The use of the other strategies was also found to be *sector independent*.

Developing a Combination Model

A combination model can be developed to combine the results of the three tests explained above in Figures 8.3, 8.4 and 8.5 such that one is able to arrive at a single classification of likely enablers based on their relative strengths. Two types are applicable.

a. Multiplicative Model – multiplicative models are well suited to situations in which percentage changes best represent the entities that are being analysed. These models are widely used to analyse economic series where there are inter-dependencies between variables (Hanke and Reitsch, 1992). For example, the consumption of a particular commodity Y might depend on consumption of commodities X and Z. Multiplicative models are better suited to analysing such data. The models could either be weighted or unweighted multiplicative models.

The weighted multiplicative model, $I_w = xI_A \text{ x } yI_B \text{ x } zI_C$
I = Final index factor which determines the relative strength of the enabler
x, y and z are the assigned weights
I_A, I_B and I_C represent the index factors for the proportion of plants that used the strategy extensively, proportion of plants that did not perceive the use to be costly and proportion of plants that felt the strategy is highly desired in future, respectively.

The unweighted multiplicative model, $I_u = I_A \text{ x } I_B \text{ x } I_C$

The main drawback of the multiplicative model can be illustrated with a simple example. Suppose the proportion of plants that use overtime hours extensively is 100% (factor I_A = 1) and the proportion of plants that desire its use in future is also 100% (I_C = 1). However, all the plants perceive its use to be very costly. In other words, I_B = 0. The implication of this is that, I_u = 0, hence, overtime hours will be totally disqualified as an enabler of volume flexibility. This is not likely to be true in reality. Additionally, there are no inter-dependencies between the variables (A, B and C) under consideration. The multiplicative model is, therefore, not the preferred choice for a combination model in this research.

b. Additive models – are used when components of a given quantity can well be assumed to interact in an additive fashion (Hanke and Reitsch, 1992). For example, we may well assume that disposable income is an addition of income and savings. Therefore, absolute quantities of income and savings will add up to disposable income. In the same vein, we can assume that absolute quantities of variables A, B and C will produce an enabler of volume flexibility. We could have either a weighted or an unweighted additive model. Weighting is used to account for some "unbalance" between variables, to come to a combined one.

The weighted additive model, $I_w = \frac{xI_A + yI_B + zI_C}{3}$

The unweighted additive model, $I_u = \frac{I_A + I_B + I_C}{3}$

The additive model does not suffer from the drawback of the multiplicative model illustrated above. However, assignment of suitable weighting factors to a weighted model (additive or multiplicative) is very problematic. This is because it may be highly subjective. As such, the unweighted additive model is adopted to provide an indication of the classification of enablers according to their relative strength. Figure 8.6 below shows a classification of volume flexibility enablers using an unweighted additive model.

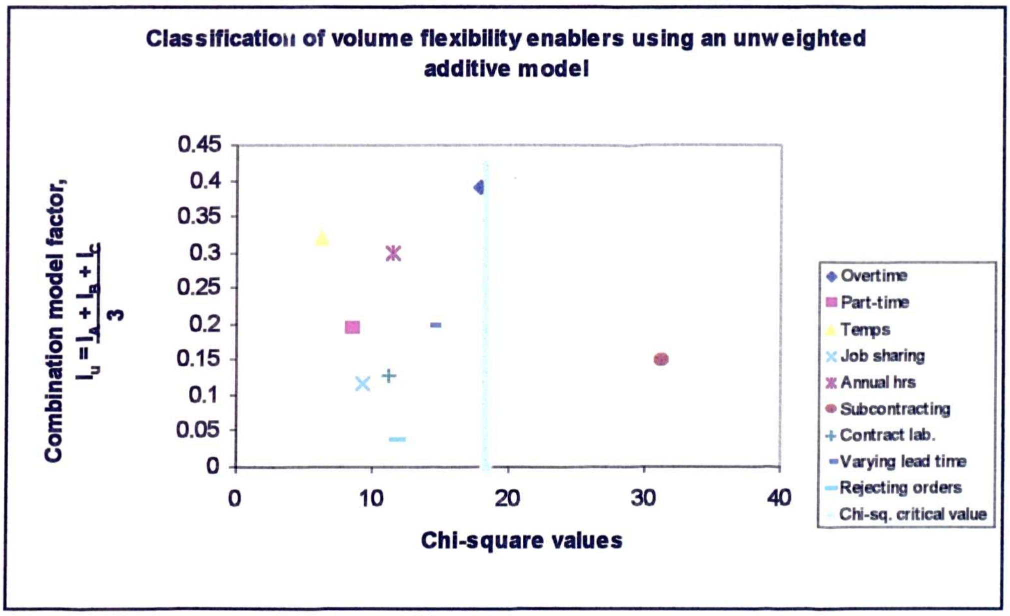

Figure 8.6: Classification of enablers based on the combined analysis of all the three tests. Detail calculations outlined in Appendix 9.

The Figure 8.6 above reveals that all the identified factors are indeed enablers of volume flexibility. The use of *overtime hours by full time employees* appears to be the strongest enabler, closely followed by the use of *temporary labour* and *annualised hours* contracts to achieve volume flexibility. As one might expect, *rejection of orders* appears to be the weakest enabler of volume flexibility.

The analyses also identify which enablers are possible *substitutes* and which are possible *complements* in achieving volume flexibility (see Table 8.10). For instance, it is interesting to observe that *annualised hours contracts* can be used to replace *overtime hours by full time employees* in achieving volume flexibility. This is what one would expect since one of the objectives of *annualised hours contracts* is to eliminate the need for overtime in manufacturing plants. Employees on *annualised hours contracts* are required to work a varying number of hours within a given period in the year as long as the hours worked do not exceed the annually contracted hours.

The analyses also reveal other enablers identified by the responding plants. These have been defined only as likely enablers of volume flexibility. Their classification and positioning on the plot could not be determined at the survey research analysis stage because of insufficient data. It is pertinent to note that the analyses of the first part of Research Question Two have raised some interesting issues that require further investigation. For instance,

Why do plants prefer certain enablers to others?
Are the sector independent enablers identified here truly independent of sectors?
Why would plants adopt certain enablers and discontinue the use of others in future?
How do plants actually use the enablers to achieve high levels of volume flexibility?

These questions seek to explain the trends observed in the survey analysis. Yin (1994) argues that the use of the case study method is most suitable for investigating the 'why' and the 'how' questions. Further investigations are thus carried out through the use of interviews within case study contexts to seek answers to the above questions.

Previously, some cases were identified for investigating further questions arising from the analyses of the first Research Question in Chapter 7. The following section identifies plants that are useful for further investigation of the questions arising from the analyses of the second Research Question. The two sets of selected plants are then compared and combined to select the final cases where further empirical research is carried out.

8.1.7 Case Study Selection

The strategy used to select cases for further investigation of issues resulting from RQ1 (Chapter 7) is also used here. Possible cases (with regard to RQ2 only) are selected as shown in Table 8.13. The focus is on plants that use the enablers extensively to achieve high levels of volume flexibility and plants that have found the use of some enablers relatively inexpensive. However, where most of the responding plants within a particular sector use a particular enabler extensively, the outliers in that sector are selected. Thus, one is afforded the luxury of exploring why a certain enabler is used and not used in selected plants. It is of course the case that once a plant is selected, all the enablers being used by that plant will be explored. The most frequently occurring cases in each sector are selected in the last row of the table. Plants' identity numbers have been used.

Since it is impracticable to carry out studies in all the listed plants in Table 8.13, the most frequently occurring plants by sector are selected. Again the selection is based on the analyses of RQ2 only.

Strategies	Process	Engineering consumer	Engineering Capital kits	Electronics	Household/ Gen. Products	Food	Reasons for choice
Overtime hours	(50, 60, 76)nu				(23 & 102)nu	121nu	These plants provide the exceptions to the general pattern of responses.
Part -time	51ue	71ue	(38, 78)ue	(15, 18)ue	98ue	26ue	As above
Temps.	28ue	(7, 9)ue	38ue	15ue	(21, 24)ue	(25, 43)ue	General pattern even. So chose ue cases.
Job sharing				90ue			Only plant that used it extensively
Annual hours contracts	(50, 60, 76)ue	106ue	78ue	(56, 62 & 63)ue	(45 & 102)ue	(43, 121)ue	Chose exceptions to general pattern
Sub-contracting	3ue	104ue	38ue	(42, 56, 64)ue	45ue	105ue	As above.
Contract labour	(76, 81)ue	(10, 32)ue	(38, 120)ue	64ue		77ue	As above
Varying lead times	28ue	(10, 12)ue		17ue		26ue	General pattern even, so chose ue cases
Rejecting orders	1ue				(22, 93 & 102)ue		Chose exceptions to general pattern.
Overtime cost				(17, 74)nc		113nc	As above.
Annual hours cont. cost	109c	(39, 52)c	11c	16c	68c		As above
Cost of Subcontracting		(33, 94, 112, 118)nc	(11, 95)nc	63nc	(20, 22, 45 & 66)nc	(105 & 119)nc	Chose exceptions to the general pattern.
Contract labour cost		(94, 104)nc	(53, 95)nc	63nc	102nc	119nc	As above
Rejecting orders cost		(39, 104, 118)nc	53nc	(63, 89, 99)nc	20nc		As above
Cases chosen (on RQ2 only)	**76 & 28**	**9 & 104**	**38 & 95**	**56, 62 & 63**	**45 & 102**	**43 and 121**	**A total of 14 plants have been selected.**

Table 8.13: Selection of case study plants from the analysis of RQ2 results only. nu = not used, ue = used extensively, nc = not costly, c = very costly.

8.2 Analysis for RQ2b: Identification of volume flexibility inhibitors.

The questions that address RQ2b are questions 14 & 15 in the questionnaire (Appendix 2).

In his study of the investigation of enablers and inhibitors to the flow of materials in different operations contexts Harrison (1997) defines inhibitors as features of an Operations Management system, which slow down flow. Adapting the definition to this research, inhibitors of volume flexibility are defined as those actions that impede or slow down the achievement of volume flexibility in manufacturing plants.

Harrison (1997) argues that inhibitors to material flow tend to be the opposites of enablers. Thus, inhibitors to the achievement of volume flexibility are defined as opposites of the identified enablers, and respondents were asked to rate these variables in terms of:

1. How problematic the factors have been in terms of their ability to cope with fluctuations in demand levels (Q14).
2. How problematic they perceive these factors would be in future (Q15).

8.2.1 Steps for Analysis

1. Overall frequencies for all responding plants were obtained. This determines in general how the responding plants rated these factors.
2. The chi-square test was performed. This explores whether the differences observed in the way inhibitors impede the achievement of volume flexibility are sector dependent.
3. Other factors identified as inhibitors by respondents are classified.

From the analysis, a factor qualifies as a likely inhibitor of volume flexibility if that factor is perceived to be very problematic (or highly inhibiting) by responding plants to the achievement of volume flexibility.

The proportion of responding plants and the way they rated the inhibitors are displayed in Table 8.14 below.

Inhibitors	**Not Used (%)**	**Very problematic (%)**	**Moderately problematic (%)**	**Not problematic (%)**
Hiring of full-time employees	7.5	40.0	35.8	16.7
Getting full-time employees to work overtime hours	0.8	11.7	50.0	37.5
Getting part-time employees to work increased hours	42.5	10.0	23.3	24.2
Securing temporary labour	17.5	24.2	35.0	23.3
Implementing job sharing	60.8	16.7	9.2	13.3
Implementing annual hours contract	55.8	21.7	11.7	10.8
Sub-contracting	30.0	20.8	37.5	11.7
Securing contract employees	43.3	15.8	25.8	15.0
Getting customers to agree to variation in lead time	12.5	55.0	30.8	1.7

Table 8.14: Overall frequency distribution of plants that responded to Q14. SPSS Output in Appendix 11.

Generally, a relatively higher proportion of plants felt that *getting full time staff to work overtime hours* is not problematic when compared to the other inhibitors. This is not surprising because of the premium which overtime working attracts for the workers. It may also be that because it is used frequently, it tends to become part of the 'status quo'. It is pertinent to note, however, that the problem of *getting full-time staff to work overtime hours* and *getting part-time workers to work increased hours*, tends to be more related to short-term availability or willingness issues. Other inhibitors such as, *implementing annualised hours contracts* would require a major structural change to get it implemented. So, problems in implementation would be experienced in the short-term rather than in the long-term when the contracts are already in place.

Chi-square tests were performed to explore whether the differences observed in the responses of responding plants regarding inhibitors to volume flexibility depend on the sector to which the plants belong. The tests reveal that *securing temporary labour* and *subcontracting* are *sector dependent* inhibitors of volume flexibility. The other inhibitors are *sector independent.*

8.2.2 Other Inhibitors identified by respondents

Respondents were given the opportunity to identify other likely inhibitors to the achievement of volume flexibility. The classification is shown in Table 8.15 below.

Other identified inhibitors	Frequency (no. of identifying plants)	Sector
Implementing multiskilling	1np, 1vp	Process & Household
Implementing process improvement	1mp	Electronics
Implementing teamworking	1vp	Household
Training employees	1vp	Household
Implementing multi shift system	2vp	Household and Food
Dealing with oversold capacity	1vp	Process

np = not problematic; mp = moderately problematic; vp = very problematic
Table 8.15: Other likely inhibitors identified by responding plants·

8.2.3 Summary of Results: Inhibitors of volume flexibility

All the factors identified and listed for the respondents to rate appear to be inhibitors to the achievement of volume flexibility for at least some of the plants in the sample. Figure 8.7 has been drawn to represent the relative positions of the inhibitors.

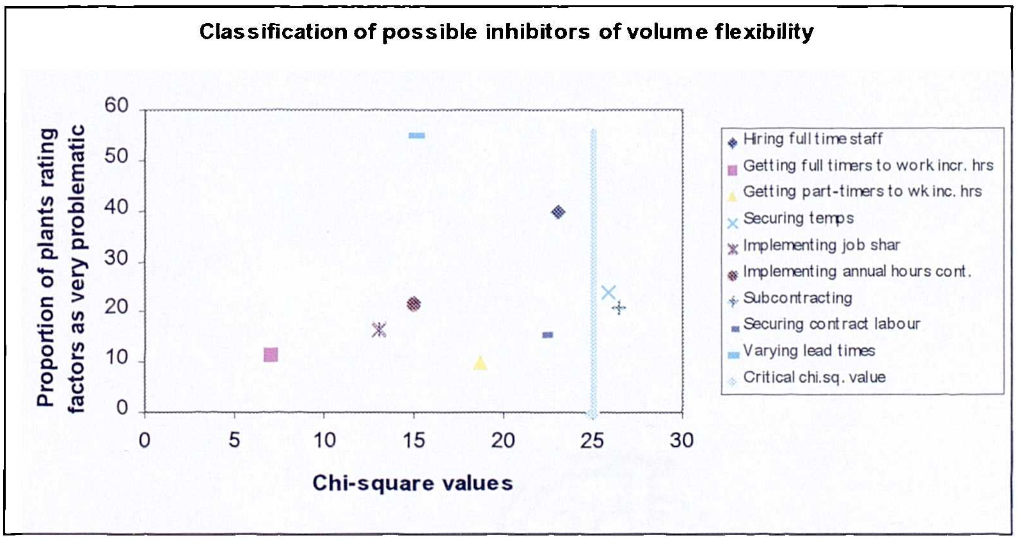

Figure 8.7:Representation of inhibitors of volume flexibility. SPSS Output in Appendix 11.

The y-axis in Figure 8.7 represents the proportion of plants that perceived the variables as inhibiting to their ability to achieve volume flexibility. Thus *getting customers to agree to lead time variations* appears to be problematic for most of the responding plants, hence it is the strongest inhibitor. This is not surprising because of the increasingly competitive nature of today's markets – customers simply will not wait.

The x-axis in Figure 8.7 represents the chi-square test values for each of the inhibitors. The critical chi-square value is 24.99 at 5% level of significance. Factors with chi-square values of less than the critical value are classified as *sector independent inhibitors* and factors with chi-square values of more than 24.99 are classified as *sector dependent inhibitors*. Thus, the analyses reveal that *securing temporary labour* and *subcontracting* are *sector dependent*.

Arising from these analyses are some interesting questions that require further investigation:

Why do differences exist in the way some of these factors inhibit the achievement of volume flexibility in the responding plants?
Are there other plant characteristics that can explain these differences?
How do plants overcome inhibitors to achieve high levels of volume flexibility?

The above questions are investigated in the case study phase of the research in the selected plants using in-depth interviews and collection of relevant data.

8.3 Chapter Summary

The chapter has described the analyses and results for the second Research Question. The analyses are separated into two parts: identification of enablers and identification of inhibitors to the achievement of volume flexibility.

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable and inhibit the achievement of volume flexibility in manufacturing plants?

Evidence from the analyses of the survey regarding the above question reveals that all the strategies identified from the literature and pilot study are indeed enablers of volume flexibility at least for the plants in the sample. These are:

- Overtime by full-time employees
- Increased hours worked by part-time employees
- Temporary labour
- Job sharing
- Annual hours labour contract
- Sub-contracting
- Contract employees
- Varying lead time
- Rejection of orders

Using an unweighted additive model, the use of *overtime hours by full time employees* was found to be the strongest enabler of volume flexibility. It is, however, closely followed by *temporary labour* and *annualised hours contracts*. *Rejection of orders* was found to be the weakest enabler of volume flexibility. In an attempt to explain variations in the usage of different strategies by responding plants to achieve volume flexibility, chi-square tests were performed. *Sub-contracting* was found to be the only strategy for which the use is significantly dependent on sector. It is thus classified as a *sector dependent* enabler of volume flexibility. Although there are differences in the use of the other strategies across the sectors, these are not significant enough to make any of them a sector dependent enabler. They are classified as *sector independent enablers* of volume flexibility.

Responding plants identified other strategies that are being used in their plants to achieve volume flexibility. These could not be classified as either sector dependent or sector independent because of insufficient data for statistical analysis. The strategies are explored in the second phase of the empirical study to determine whether there are differences in their use and the reasons for these differences.

The analyses also reveal that the use of certain strategies either conflict with or complement the use of other strategies. These are classified as *substitute enablers* and *complementary enablers* respectively. For instance, *annualised hours contracts* can be used to replace *overtime hours by full time employees* to achieve volume flexibility.

Further analyses relating to the second Research Question reveal that all the strategies, which are defined as inhibiting to the achievement of volume flexibility in manufacturing plants, are indeed inhibitors, at least for plants in the sample. These are:

- Hiring of full-time employees
- Getting full-time employees to work overtime hours
- Securing temporary labour
- Implementing job sharing
- Implementing annual hours contracts
- Sub-contracting
- Securing contract employees
- Getting customers to agree to a variation in lead-time

Securing temporary labour and *subcontracting* are classified as *sector dependent* inhibitors. Other inhibitors identified are all *sector independent*. The analyses reveal that most of the responding plants perceived, *getting customers to agree to variation in lead-time,* as very problematic. Also, *getting full-time employees to work overtime hours* was perceived as not problematic by many of the plants, hence it is the weakest inhibitor. Responding plants also identified other inhibitors that are explored in the case study phase of the empirical research.

Implications for RQ2

In so far as the enablers and inhibitors of volume flexibility have been identified, the analyses have provided evidence to answer the second Research Question. The results show that there are some small differences in the use of the enabling strategies across sectors. It was observed that although responding plants used some strategies extensively to cope with demand fluctuations, these solutions are not desirable for use in future. In the case of *subcontracting*, some of the differences observed in its use can be explained by sectoral differences. Other differences and trends observed in the analyses relate to the perception which plants have of the relative costs of the different strategies in achieving volume flexibility, specific market conditions, product and other plant characteristics. These are further investigated in the case study research, thereby providing a useful contribution to knowledge and practice with respect to the adoption of labour strategies in manufacturing plants to achieve volume flexibility. The following questions require further investigation in the second phase of the empirical research:

Why do plants prefer certain enablers to others?
Are the sector independent enablers identified here truly independent of sector? Or are there other plant characteristics that can explain the differences in the use or non-use of certain enablers?
How do plants actually use the enablers to achieve high levels of volume flexibility?
Why are some inhibiting factors very problematic to some plants and not problematic to others?
Are the inhibitors identified as sector independent truly independent of sector?
How do manufacturing plants overcome inhibitors to achieve high levels of volume flexibility?

The analyses and the trends and questions arising from them resulted in the development of two more Research Questions for the project.

RQ3: Why do some plants choose some solutions (or enablers) and other plants choose other solutions to achieve high levels of volume flexibility?

RQ4: How do plants actually use or implement the enablers and overcome the inhibitors to achieve high levels of volume flexibility?

8.4 Final Case Study Selection

	Process	**Engineering consumer**	**Engineering Capital**	**Electronics**	**Household/ Gen. Prod.**	**Food**	**Total**
Plants chosen based on RQ1 analyses	76 & 115	9 & 104	38	56 & 62	45, 46 & 102	113 & 121	12 plants
Plants chosen based on RQ2 analyses	76 & 28	9 & 104	38 & 95	56, 62 & 63	45 & 102	43 & 121	14 plants
Final selection	**76**	**104**	**38**	**56 & 62**	**45 & 102**	**121**	**8 plants**

Table 8.16: Selection of cases based on analyses of RQ1 and RQ2.

By combining the selected plants based on the analyses of the two Research Questions, eight plants have been selected. All of these plants, when contacted, agreed to participate in the case study research activity. There is at least one plant chosen from each sector. In the Electronics and Household goods sector, two plants each have been selected. This is because these plants (e.g. 56 and 45) provide further enrichment on some issues of flexibility that are peculiar to them. For instance, plant 56 uses subcontracting extensively more than any other plant in the sample and it included a comprehensive submission on the use of this enabler in its survey questionnaire.

Plant Identity Numbers	**Names***	**Sector**
76	Proceco	Process
104	Lachstone	Engineering Consumer
38	Engico	Engineering Capital
56	Electco	Electronics
62	Teleco	Electronics
45	FonGoods	Household goods & General products
102	Plastico	Household goods & General products
121	Foodco	Food

Table 8.17: Case Study plants

* These names have been used to disguise the identity of the plants involved in the study.

The names of the plants have been disguised for confidentiality purposes. The disguised names are used for the remaining part of the thesis.

The next three chapters (9, 10 and 11) will describe the final phase of the empirical research (i.e. description of the cases and analyses).

Chapter 9 - Research at Engico, Teleco, Proceco and FonGoods.

9.0 Introduction

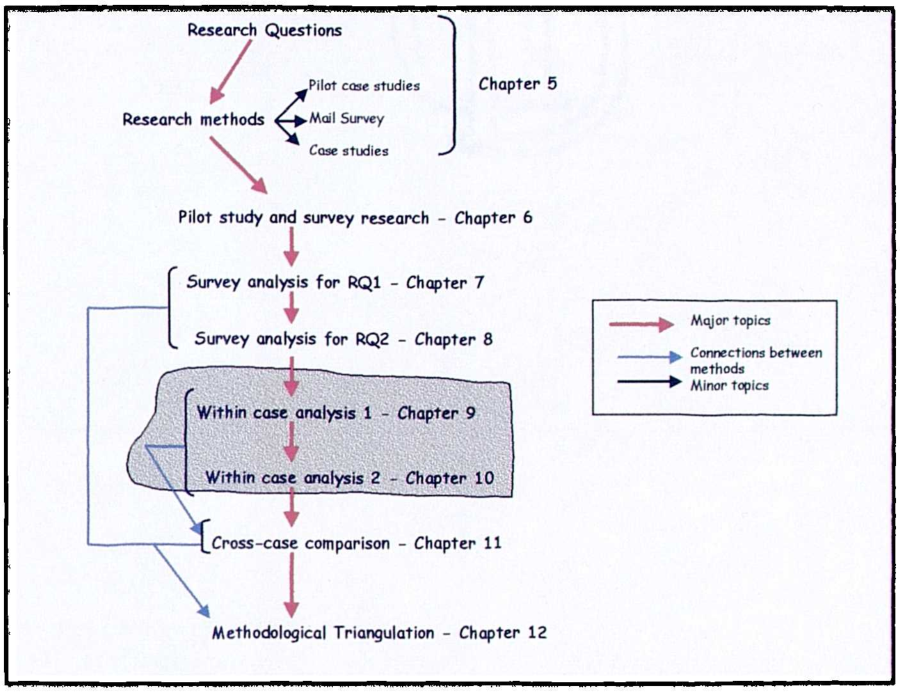

Figure 9.0: Empirical Research Road map. Chapter coverage for the within case analyses chapters shaded

The objectives of the case studies are:

1. To identify the drivers of volume flexibility in manufacturing plants
2. To identify the enablers and inhibitors of volume flexibility in manufacturing plants
3. To explain why certain enablers of volume flexibility are preferred to others
4. To explain how plants actually use the enablers and overcome the inhibitors to achieve high levels of volume flexibility in manufacturing plants

The first two objectives above are required to provide insights into the first and the second Research Questions for the project and hence provide triangulation for the results of the survey research. It will be recalled that the Research Questions are:

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

Objectives three and four are required to provide insights into the third and fourth Research Questions for the research project.

RQ3: Why do some plants choose some enablers and other plants choose other enablers to achieve high levels of volume flexibility?
RQ4: How do plants actually use the enablers and overcome the inhibitors to achieve high levels of volume flexibility in manufacturing plants?

Figure 9.01 below shows a theoretical map that relates the Research Questions to the concepts used in answering the questions in a logical manner as followed in the case study analyses.

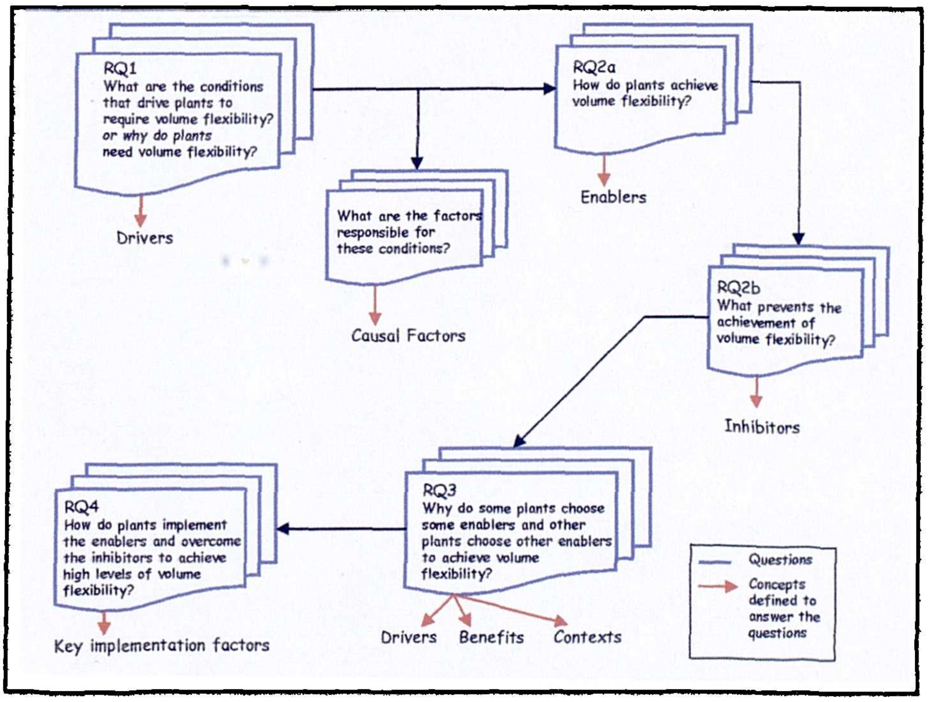

Figure 9.01: Theoretical map for case study research.

The above Research Questions are explored in each of the selected plants. The methods described by Miles and Huberman (1994) were used for the case study research.

Sampling - Many of the issues under investigation as highlighted in the theoretical map (Figure 9.01) are strategic. These issues concern mainly manufacturing management and analysis is required at the factory or the manufacturing plant level. Thus, in each of the cases, the manufacturing or the production manager or whoever was in charge of the production operations was interviewed and some quantitative data were collected to provide within-method triangulation.

Interview questions – The questions are based on the concepts identified from the preceding pilot study and survey research study (Figure 9.01). The format of the interview is semi-structured or focused (Yin, 1994) and it lasted between one and two hours. Interviews were audio taped to provide verbatim transcripts for subsequent analysis. Questions asked include:

What factors drive your plants to require high levels of volume flexibility? And how?
What are the strategies that you employ to cope with demand level fluctuations in your plant?
Why did you adopt these strategies?
What are the ingredients for the successful use of these strategies?
How did you implement these strategies? And what implementation problems did you encounter?
How did you overcome these problems?

Data analysis – Chapters 9 and 10 describe the within-case analyses carried out for the research project. Within-case analysis helps the researcher to start the process of progressively making sense out of the large amount of data collected (Eisenhardt, 1989). Emerging themes for exploration and explanation are identified from interview and data analyses and the relationships between the identified variables are explored and defined in subsequent interviews (Miles and Huberman, 1994). There were eight interview transcripts from which conclusions were to be drawn. Analysis was carried out by manipulating interview files using Word 7. The categories and the coding list used for the analysis had been prepared based on the survey research as the case study research was used to complement the survey research. However, some modifications were made to these as the analysis progressed. An example of the coding list for Engico is shown in Table 9.0.

Category	Code	Description
Contexts	Sector: Sector, 1.1 Business: Contr, 1.2 Suppliers: High, 1.3	Engineering capital sector Business type, i.e. contract manufacturing Number of suppliers is more than 100
Drivers of volume flexibility	Demand level uncertainty: DR - demunpr, 2.1 Supply chain complexity: DR - scomplex, 2.2 Component obsolescence: DR - lifecycle, 2.3 Demand level variability: DR - demvar, 2.4	Drivers of volume flexibility refer to the reasons why the plant requires high levels of volume flexibility
Causal Factors	Political changes: CF - polchange, 2.1.1 Forecast error: CF - fcast, 2.1.2 War: CF - war, 2.1.3 Long procurement lead time: CF - mateava, 2.2.1 Market factors: CF - market, 2.3.1 Reduced order books: CF - reductn, 2.4.1 Stop to multi-year order: CF – discont, 2.4.2	Causal factors are related to each driver of volume flexibility. They refer to the reasons why the drivers influence the plant
Enablers of volume flexibility	Overtime hours: EN – overtim, 3.1 Multiskilling: EN – multiski, 3.2 Sister plants: EN – sisplan, 3.3	Enablers of volume flexibility are factors or strategies that aid the achievement of volume flexibility in the plant.
Benefits	Provides volume flexibility: BN – volflex, 3.1.1 Provides volume flexibility: BN – volflex, 3.2.1 Motivates workforce: BN – motivate, 3.2.2 Provides volume flexibility: BN – volflex, 3.3.1	The benefits obtained from the implementation of enablers explain why some enablers are preferred to others and why a plant will continue to use some enablers to achieve volume flexibility.
Inhibitors	None: IH – none, 3.1.a Enlisting workers: IH – enlist, 3.2.a Transferability: IH – transfer, 3.3.a	Each inhibitor is related to a particular enabler. The inhibitors refer to factors that prevent the achievement of volume flexibility.
Key Implementation factors	Financial incentive: KIF – incent, 3.1.a1 Good training programme: KIF – training, 3.2.a1 Financial incentive: KIF – incent, 3.2.a2 Voluntary: KIF – voluntary, 3.2.a3 Integration across plants: KIF – integr, 3.3.a1 Cross-site project teams: KIF – crosite, 3.3.a2	Each enabler requires some factors to get it implemented successfully. These are the key implementation factors. They are also required to overcome the inhibitors.

Table 9.0: List of codes used to analyse Engico interviews

Data display – the evidence obtained from the analysis is voluminous. Therefore, it was preferred to present the evidence of the within-case analysis in a report format rather than presenting it in a tabular format or cell displays. This is based on the categories identified in Table 9.0 and involves detailed case study write-ups for each manufacturing plant in respect of the phenomena being investigated. For each case, however, the results of the analysis are summarised in a tabular format.

The two within-case analysis chapters (9 and 10) are divided into four main sections. Each section discusses and analyses the research carried out in each of the manufacturing plants listed above. The cases have been described and analysed in the following sequence or sub-sections:

1. Contextual considerations/Description of operations/Market characteristics – to provide insights into why some factors (e.g. drivers and enablers of volume flexibility) are more important or more used in some plants than in others.
2. Drivers of volume flexibility – to identify the drivers of volume flexibility in the plants and the causal factors for the drivers (RQ1)
3. Enablers of volume flexibility – to identify the enablers and the inhibitors of volume flexibility and to explain how the plants implement the enablers to achieve volume flexibility (key implementation factors)
4. Summary of analyses

9.1 Case Analyses - Engico

The manufacturing manager was interviewed (the source of all the quotes cited in the case study). Data on the production plan for the plant and the contract agreement of the flexible working scheme that was previously introduced into the plant were collected. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out as to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1. *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2. The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3. The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4. The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

9.1.1 Contextual Considerations

The company designs and manufactures a range of mechanical components for military and commercial applications in the UK and overseas. It belongs to the Engineering capital sector. With a turnover of over £33 million, it employs about 440 people. 290 are directly involved in production operations and 100 are involved in design operations. The plant has complete in-house capability in all aspects of design and manufacture. Most of the company's products have established standard designs, which are archived. So, if there is an order for such a product, the design is pulled out and modified to meet any specific customer requirements.

The plant has about 160 suppliers of different components. The average purchasing lead-time is 45 days, the average manufacturing lead-time is 15 days and the average customer lead-time is 50 days. About 50% of the plants' products are supplied as intermediate goods and the remaining 50% as consumer goods. The export market accounts for about 35% of annual turnover.

9.1.2 Market Characteristics

The company's customers include government defence agencies, other government bodies and defence contractors. Because the plant engages in contract manufacture, orders are secured through bidding. Orders could involve both the design and production of new equipment with lead times of up to 9 months and also contract repairs with relatively shorter lead times executed on a call-off contract basis over a period of time.

Due to the contract nature of its business, the plant has knowledge of firm orders ahead of time. It also carries out forecasts, which are built on top of the firm orders for planning purposes. The figure below gives a picture of the firm orders, firm orders + forecasts and available hours for the assembly operations of Engico.

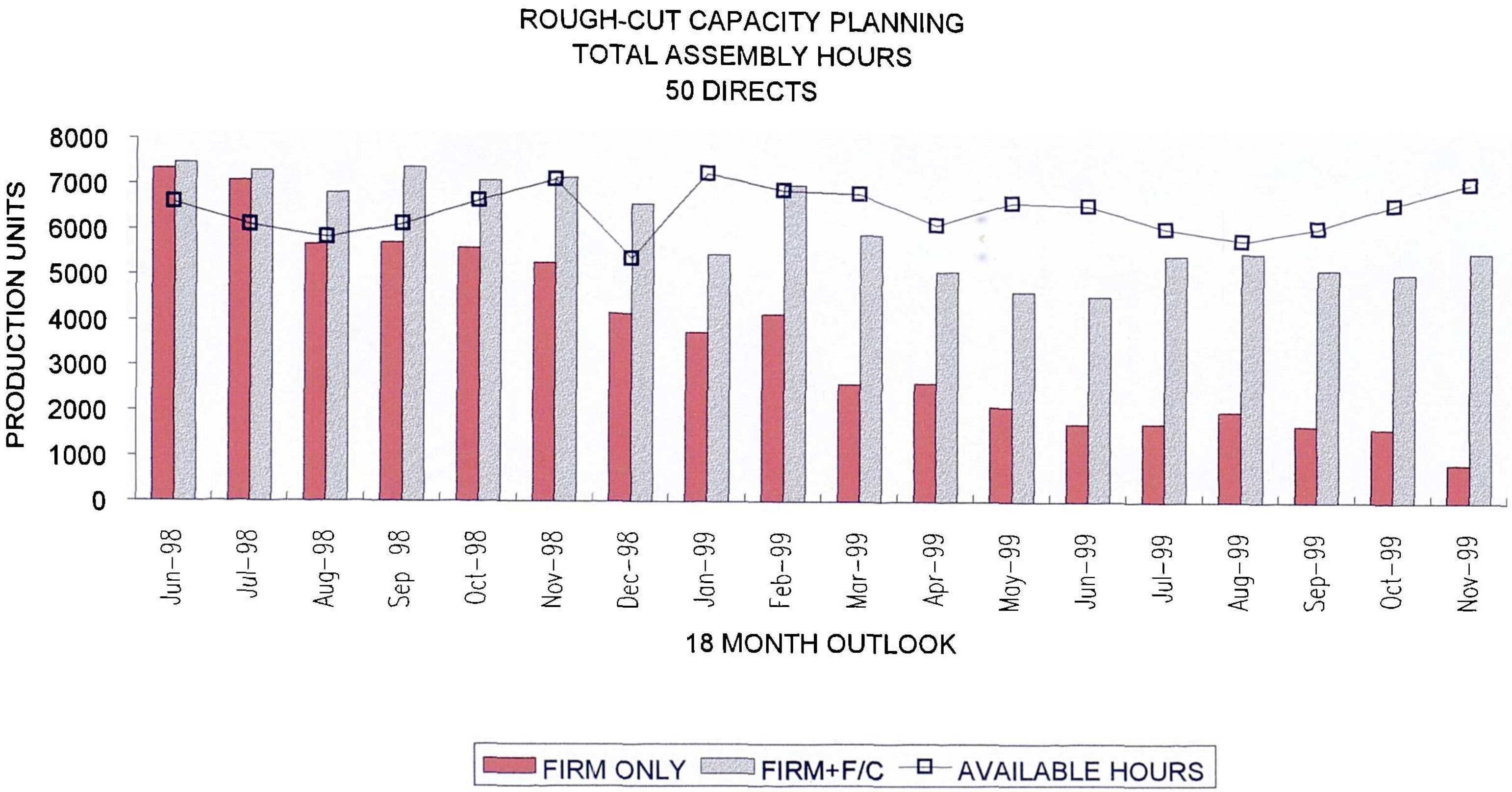

Figure 9.1a: Engico's demand profile for assembly operations

Figure 9.1a gives a picture of the variability and uncertainty in demand levels for Engico. This was the snapshot view in April 1999. As can be expected, the further one moves into the future, the fewer the number of firm orders and the more the reliance on forecasts to carry out planning and scheduling.

9.1.3 Drivers of Volume Flexibility at Engico

The figure below summarises the drivers of volume flexibility (conditions that make the plant require high levels of volume flexibility) and the causal factors of the drivers as identified from the interview analyses.

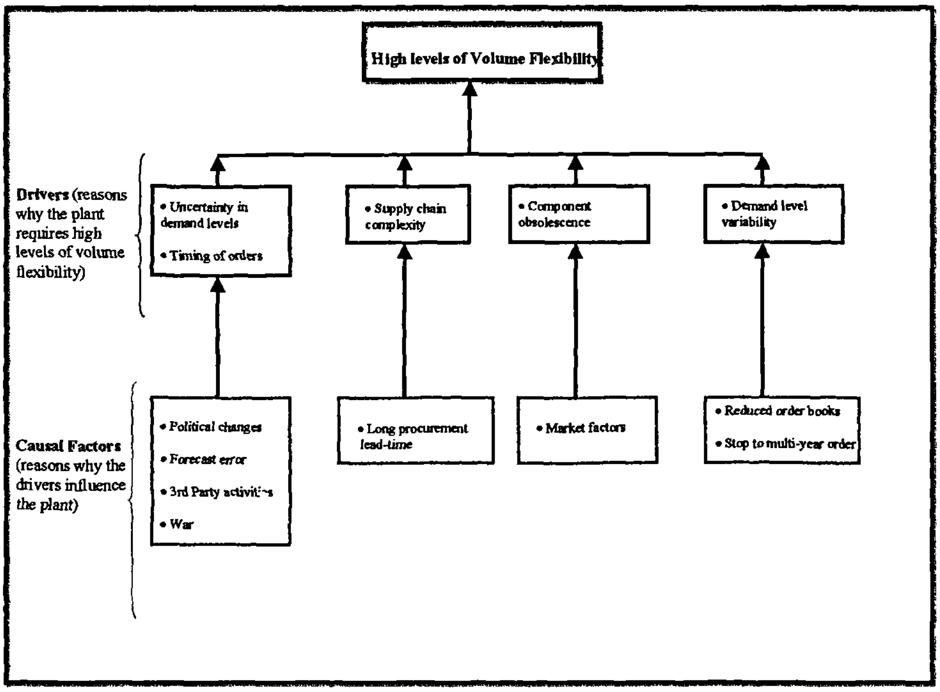

Figure 9.1b: Drivers of volume flexibility at Engico

Uncertainty in Customer Demand Levels and Timing of Orders*

Being in the defence industry, Engico's main customers are government agencies either directly or through other defence contractors. The implication of this is that order books may be subject to factors such as political changes and changes in budgets or government policies. Unforeseen events such as the Kosovo ethnic cleansing crisis also lead to demand uncertainty.

* The terms demand unpredictability and demand uncertainty have been used interchangeably in this project. The former was used mainly in the survey research. However, the latter was adopted for the case study research as it has been used more frequently in the literature. The case studies also provided the opportunity to define demand uncertainty in terms of time scales.

"Our orders are very unpredictable" "...the main changes we experience is the timing...".

Planning is based on firm orders (contracts already won) and forecasts (a combination of the probability of the customer placing a bid and the probability of the company winning the bid). Thus, errors in forecasts will be translated into planning and scheduling (see Figure 9.1a). The period between June 1998 and January 1999 shows an indication of the uncertainty in demand levels for the assembly operations in the plant. The difference between firm orders and 'firm plus forecast' increases over this period indicating an increase in the level of demand uncertainty.

A proportion of the plant's business is done with other defence contractors, therefore Engico can sometimes be far removed from the end user and hence may have little influence over what the ultimate customers require. These factors result in a certain level of short-term demand uncertainty and most importantly the timing of orders, which drive the need for the company to require high levels of volume flexibility.

Supply Chain Complexity

The typical customer lead time of the plant ranges from about 12 weeks to 9 months for new equipment. For repair items and contracts it is usually less. Because Engico buys components to order, the manufacturing lead-time is sometime determined by the availability of the components. Components for production are not readily available and are mostly sourced from overseas. Hence, the bulk of the lead-time is often due to procurement delays. This, coupled with having to deal with many suppliers, leads to complexity in the supply chain. The implication is that the plant must have the capability of streamlining its supply chain in order to obtain any required volume of material when needed to meet delivery schedules. That is, it must have a flexible supply chain to provide the required high levels of volume flexibility (Slack, 1991).

Component Obsolescence

Some of the company's products consist of printed circuit boards, which use high technology electronic components. There is usually a long lead-time that elapses between the time of bidding for a particular contract and contract award. In some cases, by the time the customer awards the contract for manufacture, some of the electronic components required in the original design will have become obsolete due to the short product life cycle of the components. This requires the plant not only to have the design flexibility required to introduce new components for production, but also to have volume flexibility especially in a situation where these changes have volume implications.

High Variability in Demand Levels

Over the years, the total sales values of orders for the company have been decreasing. Also, the sizes and therefore values of individual orders have been falling.

"Five years ago, the value of business going through the shop floor was in the region of between £35 and £40 million. It is now in the region of between £20 and £25 million".

Values of orders have ranged in 1999 from a minimum of about £300 to a maximum of about £3 million. This high variability in levels of demand is due to various political changes and government policies on defence budget cuts. Figure 9.1a illustrates the typical variability in demand levels (firm orders, forecasts and available hours) for the assembly operations of the plant between June 1998 and November 1999. The 'firm + forecast' bar gives an indication of the demand variability that Engico experiences. It ranges from about 7500 units in June 1998 to about 4500 units in June 1999. The available capacity hours over this period are in excess of the forecast production units, especially between January and June 1999. The expected fall in production between January and June 1999 requires Engico to have flexible strategies that would enable it to match available capacity hours with production requirements.

9.1.4 Enablers and Inhibitors of Volume Flexibility

The figure below summarises the enablers of volume flexibility (strategies that the plant employs to achieve volume flexibility), the inhibitors (factors that prevent the achievement of volume flexibility). It identifies the key factors for the implementation of the enablers (how the plant has gone about implementing the enablers and overcoming the inhibitors to achieve volume flexibility).

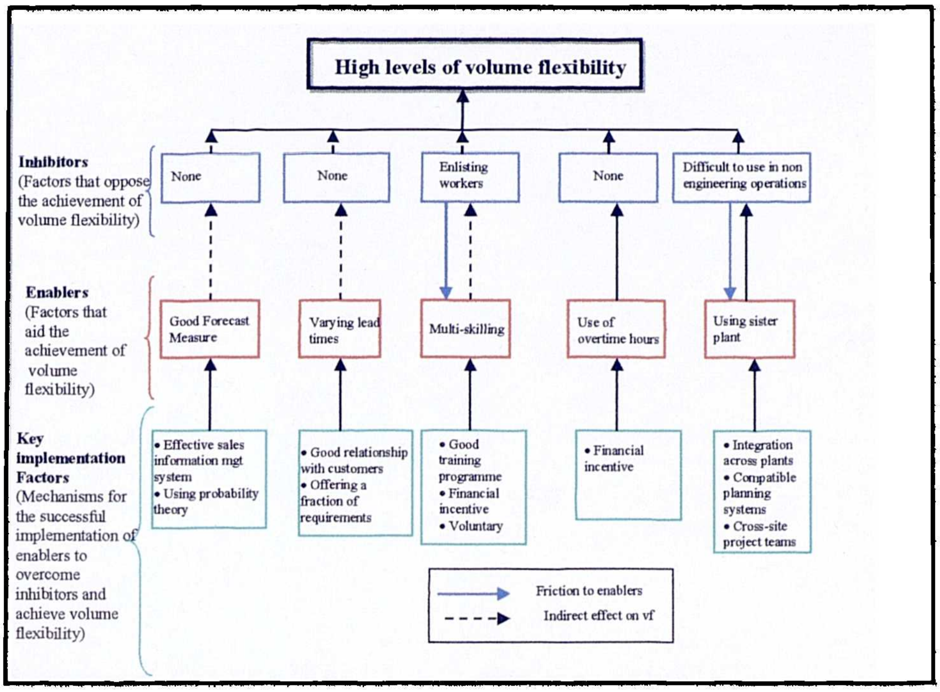

Figure 9.1c: Enablers and Inhibitors of volume flexibility at Engico

Forecast Measure

Engico experiences long-term demand uncertainty. One of the strategies that the plant employs to cope with this is to have a good forecast measure, which utilises probability theory. This has helped the plant to reduce the level of uncertainty and the need for internal volume flexibility.

Implementation

Engico has an effective sales information system, which monitors enquiries, bids and lost bids. The accuracy of the measure depends on the accuracy of the information provided by the sales information system. Generally, the company puts into planning everything that has a 70% or more probability of their winning it. This probability is referred to as P_3 and it is a product of two other probabilities P_1 and P_2 ($P_3 = P_1 \times P_2$). P_1 is the probability that a direct customer will have a requirement for the product. This is determined by knowledgeable and educated guesswork. P_2 is the probability of the customer placing the order with Engico as opposed to with a competitor. The sales force also determine this. P_2 is more influenced by the competition that exists for the order. If, for example, Engico is the sole supplier of the product required by the customer, then the probability P_2 is likely to be 100%. If in this example the probability (P_1) that the customer has a requirement for the product is at least 70%, then $P_3 = 0.7 \times 1 = 0.7$ (or 70%). Therefore, the production of the product can be put into planning.

Benefits

The use of this probability measure has drastically reduced forecast errors and has helped to manage demand uncertainty in the plant.

"Because of the measure that we use, we don't often lose orders that we put forward for planning".

Varying lead times

Negotiating delivery dates or customer lead-time is one strategy that is employed by the plant to manage fluctuations in demand levels. The use of this strategy reduces the need for volume flexibility. As such it can be regarded as an indirect enabler of volume flexibility.

As observed earlier, one of the drivers of volume flexibility in the plant is the change in timing of orders. Orders may be subject to political changes. The plant usually is able to re-negotiate the deliveries of orders affected by such changes.

Implementation

In cases where the plant is not able to meet its contractual delivery dates due to internal constraints or problems, it is often able to negotiate extensions with the customer. In the worst scenario, it tries to deliver a fraction of the requirements. This is possible because of the good relationship that the plant has with its customers.

Multi-skilling

The larger the range of skills of a worker, the more flexible the worker is either in terms of product mix changes or inter-changeability of workers between work stations (Adler, 1987 and Kohler, 1989). Multi-skilling is seen as an indirect enabler of volume flexibility in the plant as it provides the opportunity for labour to be transferred from one department (e.g. machine shop) to another department (assembly) depending on the demand placed on various departments. The use of a multiskilling strategy in the plant is driven by high variability in demand levels and the requirement for high levels of skills for workers due to the nature of the operations in the plant.

Inhibitor

It is sometimes difficult to implement multiskilling due to workers' reluctance to enlist for training.

Implementation

Due to the highly technical nature of the skills required to work in the plant, college training is usually required for workers for them to acquire the necessary skills. When the plant requires more skills in a particular department or work area, it places an internal advert for anyone who wants to go there. Volunteers are then sent to a college for a month's training. By financially rewarding people with more skills (i.e. salary increases with skill levels), the plant is able to encourage more participation in the training scheme and overcome the problem of getting people to enlist for the college training.

Overtime

The company uses cvertime hours by its full time employees to provide additional capacity when required. The main driver for the use of this strategy is high variability in demand levels and short-term uncertainty in demand.

Implementation

There are two standard shifts (morning and afternoon) being run from Mondays to Fridays. There is only one department that runs a night shift from Mondays to Thursdays. Any work outside these shift patterns is regarded as overtime hours and is paid as such.

It is relatively easy to get people to work overtime hours at premium pay. The decision to run overtime is based on demand requirements versus schedule and most importantly the actual output required within a given period. More often than not, actual output is less than schedule, requiring the constant use of overtime hours. The actual output within a given period (say, one week) determines the schedule for the following week. This inadvertently rubber stamps low productivity for any given week and encourages more overtime hours depending on the demand requirements. Thus, the use of overtime hours becomes institutionalised. People tend to regard overtime as part of their basic income and use it to pay mortgages and so on. When demand dries up it becomes difficult for the plant to disengage the workers from working overtime hours.

In view of the problems stated above, the plant has found it difficult in the past to put a total stop to overtime work during demand slump although it was able to reduce the overtime hours worked. Rather than cancel overtime work outright, Engico had to make some people redundant in order to reduce capacity in line with slumping demand. However, workers were given the option to volunteer for this redundancy scheme and the settlement was very generous and attractive. Because of the good parting relationship between the plant and those made redundant, Engico was able to call up these people for part time work when demand picked up.

Although the use of overtime hours has become institutionalised in the plant, it is the main source of labour capacity flexibility in Engico. This is because the plant has unsuccessfully implemented flexible working strategies in the past such as an annualised hours system. The key factor for the implementation of overtime hours is the provision of financial incentives or premiums for the hours worked.

Sister plant

The plant has a sister plant to which it can download work when it is overloaded and vice versa. This is a tactical solution, which gives Engico direct short-medium term volume flexibility. In the past, the sharing of loads has occurred mainly in engineering where design work has been downloaded across the two sites. Allocation is based on the area of expertise, excellence and experience.

Implementation

Planning and allocation of resources are based on the combined resources at the two sites. This is facilitated by the use of MRPII systems, which are compatible across the two sites. Frequent transfer of engineers between the two sites on short assignments also improves integration and the ability to transfer work successfully.

Inhibitor

There has not been transfer of major activities or production work across the two sites. This is because the plants are different in terms of capital equipment. In so far as design and engineering work sometimes form the main activity of the plant, and since this is transferable across the plants, it is sufficient to conclude that transfer of work across sister plants is an enabler of volume flexibility in Engico.

Annualised Hours Contracts

The use of an annualised hours contract has not been regarded as an enabler of volume flexibility in the plant because its use had not been successful there in the past. It was introduced about 12 years ago to curb the big overtime bill being incurred by the plant.

"Working practices were a bit different, people were a bit relaxed about working, they popped in on a Saturday morning to do some paper work just to claim overtime".

Annualised hours was one of the many changes that the plant introduced at the time (see Appendix 12 for contract agreement). The purpose was to permit variation of weekday working hours to meet operational and business needs (i.e. volume flexibility).

Implementation

In order to implement it and other changes going on at the time, people were given a 15% pay rise.

"In fact all the people that had never been asked to do overtime voted for it".

Workers were contracted and paid to work 1744 hours per annum, which is equivalent to 38.25 hours per week on average. The nominal working hours were between 08:00 - 16:00 (with half-hour unpaid lunch break). The individual was normally committed to working 45 weeks of 37.5 hours per week except when 'short weeks'[†] were worked. This gives 225 working days per annum of 7.5 hours per day or 1687.5 annual hours.

[†] Short week was worked during low activity period with early finish on Friday. 2.5. hours per week were added to reserve.

56.5 hours are held in reserve to be used to cope with demand uncertainty. The individual would not normally be asked to utilise more than 5 of the reserve hours in any week. Additional weekday reserve hours were created by the addition of the 'short week' hours. Notice for short weeks was given by the end of the previous week. Notice for working extended days (required during busy periods) was given by the end of the previous working day.

The above was implemented basically by a contract agreement. The plant could of course call for the extra hours (56.5 hours) when needed. If any individual worked beyond the required basic and extra hours at the end of a quarter, he was paid for the extra hours worked. Although it was required that anyone being under-loaded in a particular department be sent home, "*I don't think we ever did that*".

Problems

The plant found the system unmanageable. There was lack of trust between the two main parties (management and the operators). Management installed clocking machines to control the system, but generally the system was badly managed. With the realisation that management could not effectively manage the system, it was easy for the workers to exploit the gaps. People were exhausting their committed and reserved hours and still had a chance to work unauthorised overtime without much productivity to show for it. Rather than curb labour costs, the annualised hours contract led to an escalation of labour costs. The contract had to be cancelled. However, because people got days off at Christmas as part of the deal, when the system was stopped, they stopped taking these days, so management had to buy off the hours again when the system was discontinued. Thus, a big pay rise was given to the workers to implement the deal, and they were also paid when it was stopped.

Finally, it appears that the annualised hours system also failed because it was not suited to the conditions of long-term demand uncertainty which Engico experiences. The success of the system depends very much on the ability to predict reasonably the total demand within the period of the agreement (usually one year).

9.1.5 Summary of Analyses

Table 9.1.1 summarises the insights provided in respect of the first Research Question.

RQ1: Under what conditions does Engico require high levels of volume flexibility?
Concept used to answer the question: Drivers

Drivers	Uncertainty of demand levels and timing or orders	Supply chain complexity	Component obsolescence	High variability in demand levels
Causal Factors	• Political Changes • Forecasts error • Subcontractor to main contractor. • War	• Long procurement lead-time. • Many suppliers	• Market factors	• Reduced order book • Stop to multi-year order.

Table 9.1.1: Summary of volume flexibility drivers and their causal factors at Engico

Table 9.1.2 summarises the insights provided to answer the second, third and fourth Research Questions.

RQ2: What are the enablers and inhibitors of volume flexibility in Engico?
Concepts used to answer the question: Enablers and Inhibitors

RQ3: Why does Engico use these particular enablers to achieve high levels of volume flexibility?
Concepts used to answer the question: Benefits and Drivers

RQ4: How does Engico use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used to answer the question: Key implementation factors

Enablers	Good Forecast measure	Varying lead times	Multi-skilling	‡Overtime	Sister plant
Drivers	• Resource allocation • Demand uncertainty	• Changes in timing of orders • Political changes/demand uncertainty	• High variability in demand levels • High skill level requirement	• High variability in demand levels and short-term demand uncertainty.	• High variability in demand levels and short-term demand uncertainty
Benefits	• Little or no forecasts error • Losses on planned orders minimised	• Reduces the need for volume flexibility	• Provides mix and indirectly volume flexibility • Motivates workforce	• Provides volume flexibility (+) • Costly (-) • Becomes institutionalised (-)	• Provides volume flexibility
Inhibitors	• None	• None	• Enlisting workers	• None	• Difficult to use in non engineering operations
Key implementation Factors	• Effective sales information management system. • Use of probability theory	• Offer a fraction of requirements • Good relationship with customers	• College training • Voluntary basis • Financial incentive	• Financial incentive	• Integration • Cross-site project teams • Compatible MRPII system

Table 9.1.2: Summary of enablers of volume flexibility at Engico.

Figure 9.1d shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels and short-term demand uncertainty.

‡ The use of overtime hours is classified as an enabler of volume flexibility as it is the only solution available to the plant to achieve labour capacity flexibility in spite of the shortcomings (negative benefits) of using it.

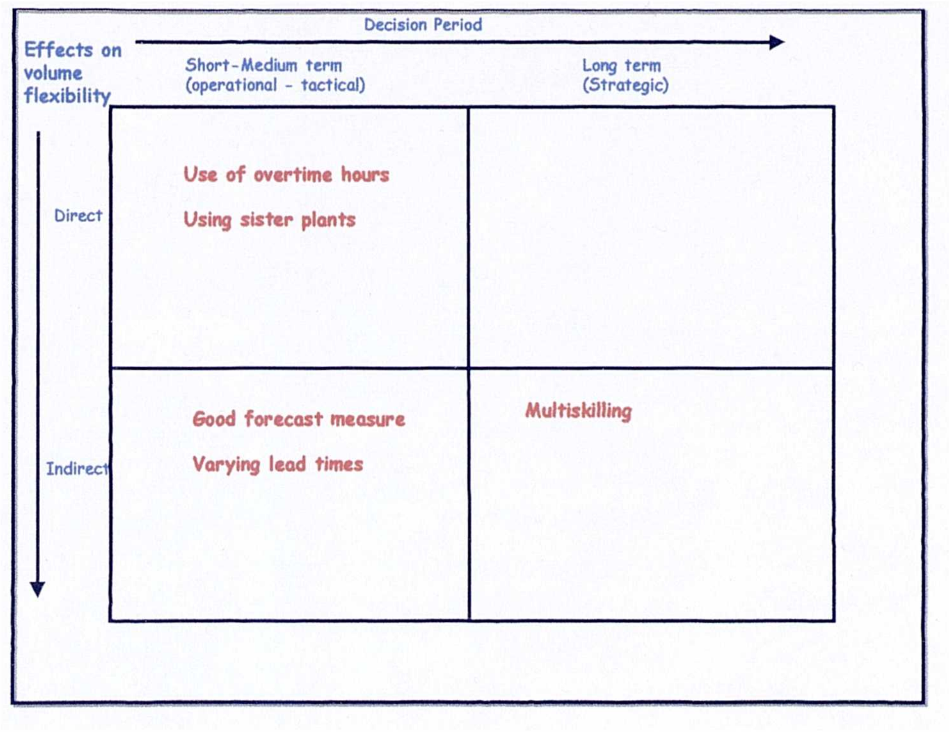

Figure 9.1d: Decision hierarchy framework and effects of enablers on volume flexibility in Engico

9.2 Case Study Analyses - Teleco

The General Manager Operations, was interviewed (the source of all the quotes cited in the case study). Data on the production plan for the plant and the contract agreement of the flexible working scheme (banked hours system) that was introduced into the plant were collected. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1 *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2 The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3 The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4 The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

9.2.1 Contextual Considerations

Teleco belongs to the Electronics sector. It engages in contract manufacturing and provision of telecommunication products and services. The plant employs about 110 employees directly involved in manufacturing operations and has a big design capability, employing a further 230 software and hardware engineers.

The plant manufactures printed circuit boards (PCBs) of various sizes in volumes up to about 100,000 units a year. These are either sold directly or introduced into enclosures. Teleco provides field services involving the installation and maintenance of products for its customers. It also provides management services. For example, it has a department that offers project management expertise and installation of security equipment for a major UK telecommunications company.

The plant has about 250 suppliers of different components. The average purchasing lead-time is 140 days. The average manufacturing lead-time is 4.5 days and the average customer lead-time is 40 days. All the plant's products are supplied as capital goods.

9.2.2 Demand Characteristics

Teleco relies on forecasts for production planning. The figure below shows the aggregate production plan for the plant based on firm orders and forecasts.

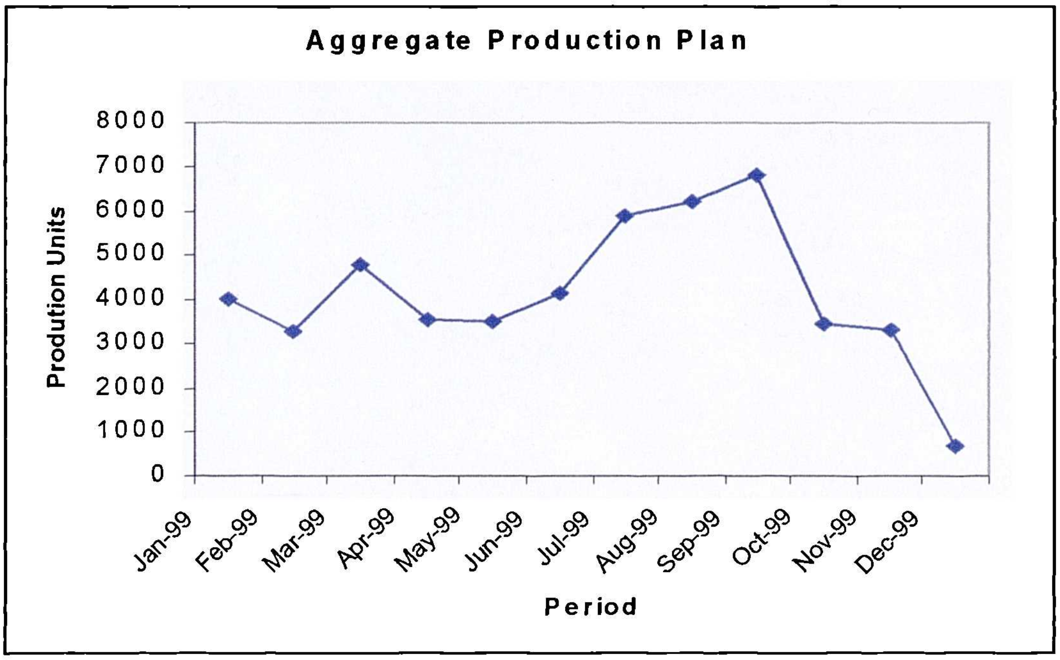

Figure 9.2a: Aggregate production plan for Teleco as at March 1999.

The above figure indicates that Teleco's busiest period appears to be between July and October. Beyond this period it becomes more difficult to forecast demand because of the highly uncertain nature of contracting business which the plant engages in.

9.2.3 Operation

Figure 9.2b shows the material flow for surface-mount PCB assembly

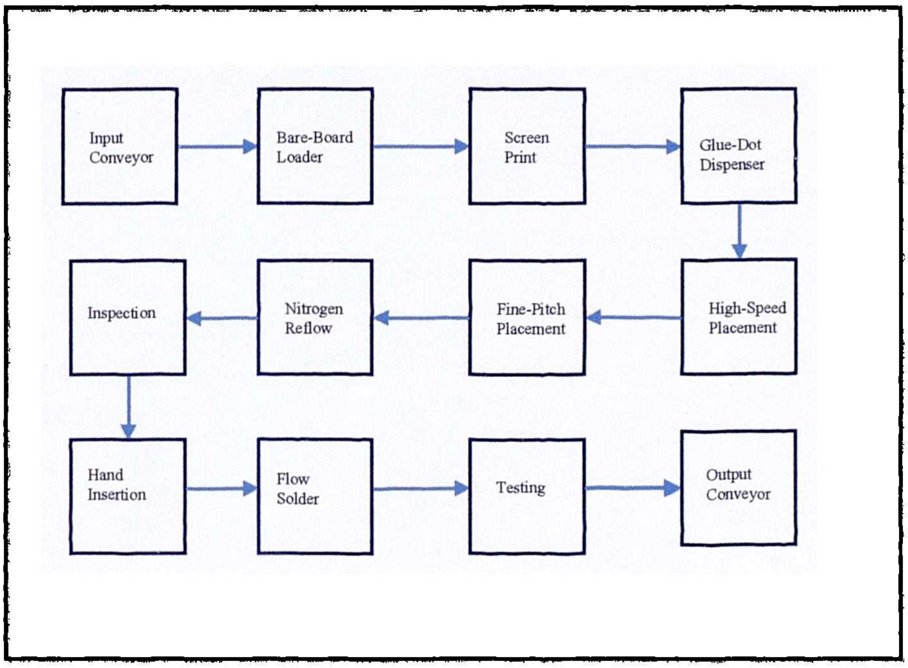

Figure 9.2b: Flow of operation for PCB assembly

The bare PCB boards required for manufacture are loaded and passed on for screen printing and then passed on to the glue-dot dispenser where solder paste is deposited on them. These boards are conveyed to the surface-mount machine for high-speed placement of components. More fine pitch placement then takes place on another surface-mount machine. The boards are then passed through a Nitrogen oven where the joints are heated up and solidified. These joints are then inspected for defects. The inspected boards are then passed on for more insertion of components done manually, depending on the type of PCB required. These are soldered and passed on for testing. Assembly of kits by inserting the PCBs into enclosures may be required, depending on customers' requirements. Otherwise the PCBs are sold directly to customers.

9.2.4 Drivers of Volume Flexibility

The figure below summarises the drivers of volume flexibility (conditions that make the plant require high levels of volume flexibility) and the causal factors of the drivers as identified from the interview analyses.

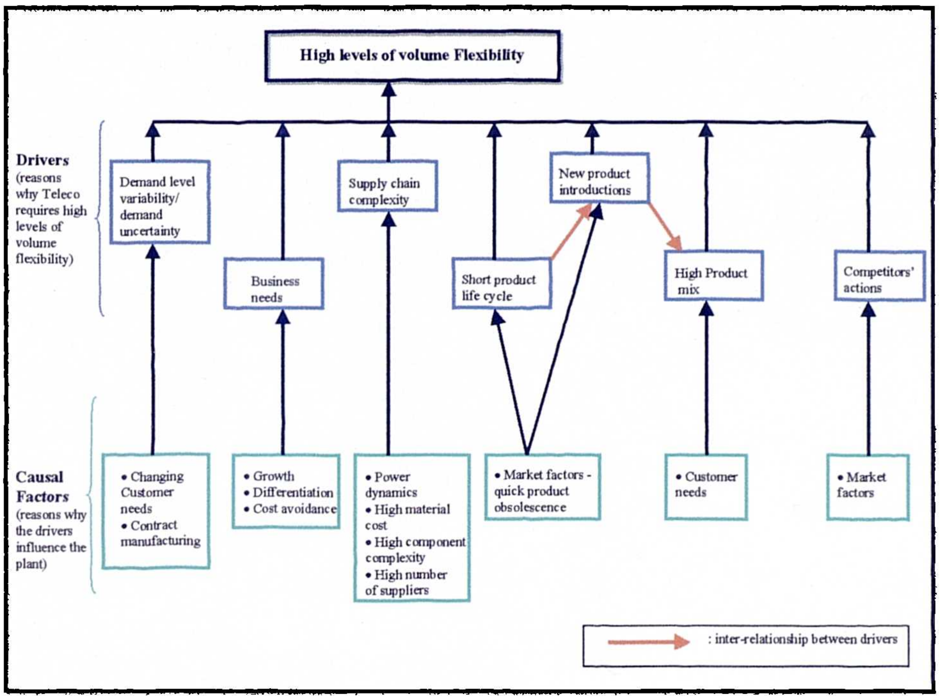

Figure 9.2c: Drivers of volume flexibility and their causal factors

High Variability and Uncertainty in Demand Levels

Figure 9.2a gives an indication of the level variability in the aggregate production plan for the plant. Teleco engages in contract manufacturing whereby orders might be won on the basis of bids, which have highly uncertain success rates creating some degree of demand uncertainty. Thus, Teleco relies on forecast for production planning. These forecasts, however, depend on the customer forecasts. Thus, forecast errors made by the customer are passed to the plant, which uses the information to make its own forecast. This increases further the degree of demand uncertainty.

Teleco's major customers have a powerful influence over the company. For instance, while the order time scale for one of its major customers has been coming down to say 5 days on some products, the customer has remained adamant in supplying the plant with monthly rather than daily forecasts. This has further increased demand variability and short-term demand uncertainty.

Business Needs

The plant's policy supports the need to have high levels of volume flexibility. The service side of the business is witnessing rapid growth to support the manufacturing business. In response to this, the plant is looking to develop the capability to provide a turnkey project service for its customers. Thus, it requires flexibility in all areas of its operation rather than just in manufacturing.

"For example, in our network service support group where we are on guaranteed response time of 1 hour, that encourages us to be quite flexible. So flexibility is not just about manufacturing, it's about all the things that sit around and support it".

It is the plant's policy to attempt to differentiate itself in a highly competitive environment in order to survive. Teleco believes that having high levels of volume flexibility will provide the plant with unique capabilities in the market place. The competition also places pressure on cost. By having high levels of volume flexibility, the plant is not only able to satisfy customer requirements on time, it is able to do so at reduced cost.

"Because even though our customers are saying we want something faster, it actually suits us because if you look at a manufacturing organisation, by doing things faster you can actually reduce the capital employed as a by product of that and it is clearly advantageous".

Supply Chain Complexity

Material cost accounts for about 95% of the product cost. Thus, the procurement strategy has a great influence on the ability to be flexible in the plant. The plant produces a wide range of printed circuit boards requiring thousands of different components.

"We have one PCB that we make currently with 1500 components on a supply base of 124 suppliers. What we would like them all to do is to be able to synchronise the arrival of the components on the front door step one-minute before I need them. Very challenging. You are not in total control of what is happening in 124 different factories".

This has implications for the procurement lead-time and the plant's ability to respond to customer requirements. Furthermore, the forecast errors inherited from the customers are passed on to the suppliers (the Forrester effect).

"The degree of error or deviation can either make our relationship with our suppliers a warm one or a very difficult one. The question then becomes where the responsibility for the wrong forecasts lie".

The volume of components purchased by the plant from some of its major suppliers often constitutes a small proportion of the supplier's business. This leads to arm's length relationships with this group of suppliers and limits the plant's impact and ability to reduce procurement lead times. It also further increases the complexity in the supply chain.

Short Product Life Cycle/New Product Introduction/Product Mix Changes

Products in the telecommunication and electronics industry typically have very short product life cycles. Short product life cycles and fierce competition lead to fast technological developments and new product introductions by companies operating in the industry. The different stages of the product life cycle affect demand level requirements for products in terms of variability and sometimes demand uncertainty. These drive the plant to require volume flexibility strategies.

"The interesting thing about today's market is that products can become mature in 3 months because they are often dead inside 2 years. Last year we introduced 126 new PCBs into the manufacturing facility and the fascinating thing is that out of the 126, already we are no longer producing 50 of them".

Changing customer requirements (e.g. different sizes of PCBs etc) drive Teleco to require high levels of mix flexibility. Where these changes have different volume implications, the plant would require the ability to adjust to relative volume changes within product mix (i.e. volume flexibility).

Competitors' Actions

The plant operates in a fiercely competitive market. The competitive criteria in the industry include having short customer lead time and fast new product introduction. Competing on these grounds requires the plant to have high levels of volume flexibility.

"Clearly to win in our market, competition is a driver for flexibility because there are a lot of people out there just as capable as we are so we have to work hard at thinking through how we can improve the process, and how we can improve the flexibility".

9.2.5 Enablers and Inhibitors of Volume Flexibility

The figure below summarises the enablers of volume flexibility (strategies that the plant employs to achieve volume flexibility), the inhibitors (factors that prevent the achievement of volume flexibility). It identifies the key implementation factors for the enablers (how the plant has gone about implementing successfully the enablers and overcoming the inhibitors to achieve volume flexibility).

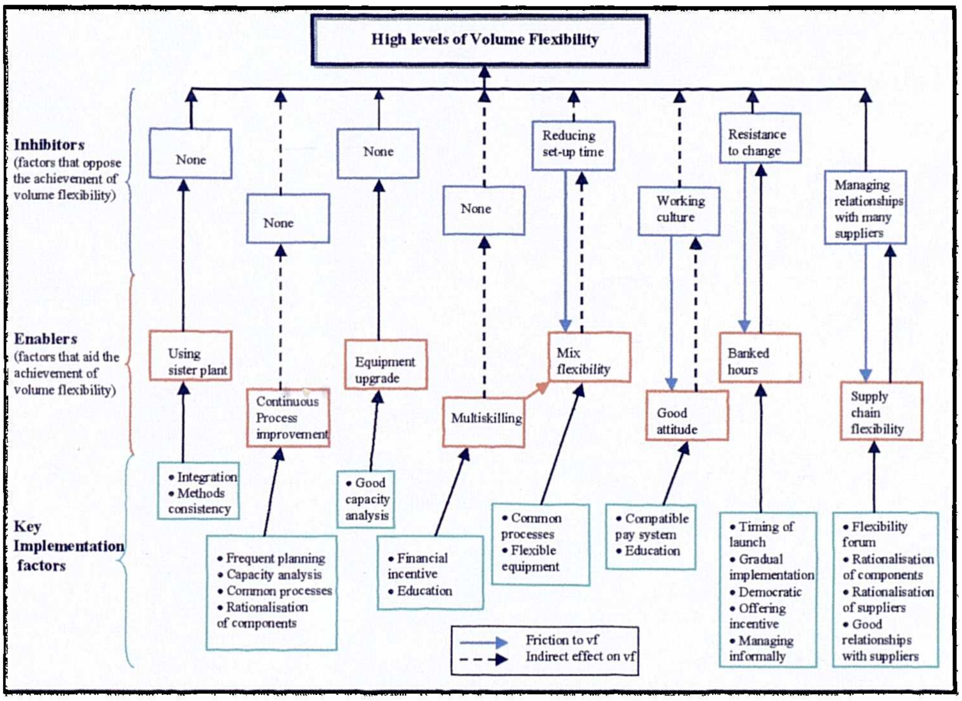

Figure 9.2d: Enablers and inhibitors of volume flexibility in Teleco

Sister Plants

The plant is able to move volumes of products easily across the two sites as the peaks and troughs occur. This is a tactical solution that gives Teleco short-medium term volume flexibility.

Implementation

In order to achieve the bi-directional capability, the plant maintains a consistency of methods across the sites. Although the plants are not identical, they are very similar. The processes and the surface mount machines used are very similar. This allows the movement of products quite rapidly between the sites. The sister plant has a localised manufacturing engineering capability but the design authority remains at the case study plant site, although the sister plant is allowed some freedom to change things. This dependency encourages integration.

Continuous Process Improvement

Changing customer requirements and increasing competition drive Teleco to engage in continuous process improvement. This solution is implemented as part of a strategy rather than an opportunistic tactical solution to achieve short-term volume flexibility. Amongst other things, a continuous improvement policy gives the plant dynamic flexibility in the long-term (Hyun and Ahn, 1992). It is, therefore, regarded as an indirect enabler of long-term volume flexibility.

Implementation

By identifying and focusing on areas requiring improvement and implementing changes, the plant is able to increase, albeit indirectly, its level of volume flexibility. For instance, an effective capacity analysis revealed the need to change the working hours system in the plant, hence the introduction of a banked hours system which gives the plant short-term volume flexibility. The ever-changing customer requirements also warrant repetitive, responsive and frequently carried out planning processes. Schedules are changed as soon as customer requirements change in order to avoid producing products that will not sell and more importantly to provide the volume flexibility that customers require.

The plant has invested a lot of time in engineering to identify common processes that would help to rationalise the number of components being used in manufacturing. A team of engineers called the Components Qualification Group formed within the plant is responsible for this activity.

"If you can find that on a particular PCB, instead of using 10 different varieties of resistor you can get away with 2, then you get far more volume flexibility".

Improving the process reduces the set-up time, cycle time and the lead times which all affect the levels of volume flexibility.

Equipment Upgrade

Fundamental to the achievement of high levels of volume flexibility in any plant is the availability of spare equipment capacity. The plant has invested heavily over the last 5 years in automation and additional capacity. Upgrading equipment has had a direct effect on the achievement of long-term volume flexibility in Teleco. Implementing this strategy required a thorough capacity analysis in the plant and a fairly good idea of future demand profile. In Teleco, the focus was to double the existing machine capacity at the time of investment.

"We deliberately invested in more capacity than we needed".

Mix Flexibility

The equipment purchased is highly flexible and efficient. It can handle different types of component as well as different sizes of board. In addition to this Teleco rationalised its processes such that there are common processes in the upstream part of the production operation. This gives the plant high levels of mix flexibility. With high levels of mix flexibility and a high production rate (in terms of volume/unit time), the plant is able to adapt quickly to relative volume changes within mix (i.e. volume flexibility).

Multi-skilling

The different processes in the plant require different skills. These include skills needed for the operation of the surface mount machines, inspection, manual insertion of components and the operation of the manual test equipment. The manual test capacity area tends to be the bottleneck operation when the plant is fully loaded. This is because it is a relatively slower operation compared to the other highly automated processes.

"When demand is so variable, what we can't afford is a situation where we are short of test capacity".

Implementation

Teleco engaged in a programme of upskilling its workforce so that it is able to move the operators around to augment capacity where necessary and achieve high levels of volume flexibility. The plant was able to carry out the multiskilling by educating the operators on the need for and benefits of multiskilling and rewarding multiskilled staff.

Good Attitude

Peoples' attitudes affect the way they think, the way they behave and the way they work. Getting the right attitude from the operators in accepting the changes was very important to the implementation of volume flexibility solutions such as the banked hours system in the plant. The attitude of the workers was, however, very difficult for Teleco to change because of the working culture that was entrenched in the system. According to the GMO, it was important for the plant to get this right before implementing any changes.

"All the people in the production environment have to understand what we are trying to do".

Implementation

Getting the attitude right is a long-term solution. The effect on volume flexibility is also not clearly defined. The plant educated the workforce through a series of training sessions and meetings in order to change their attitude. Also, Teleco employs pay systems that do not inhibit people if they work flexibly. These factors went a long way towards improving the attitude towards change. The pay systems were implemented when the company reviewed its working hours system and moved to the banked hours system.

Banked Hours System

During the peak periods the plant incurred excessive overtime cost and during demand slump, people sat around and got paid for doing nothing. It became clear that Teleco had to find a system that was attractive to people but would tackle these problems.

"Annual hours was a little bit too structured for us. We needed something that was a little bit more flexible and not quite as deliberate, and we came up with a thing called banked hours".

It was important for the plant to base the use of banked hours not only upon capacity requirements but also on the personal needs of the workers. The banked hours system is based on the philosophy that banking hours will be accommodated by employees being asked to take time off in lieu of hours being recovered at a later date. Implementing the system met with a lot of resistance from the operators (see Appendix 13 for copy of contract agreement).

Implementation

In order to implement the system, it was important for the plant to rework its shift pattern. A 3-shift system was introduced. The scheduled shift patterns provide volume flexibility to cope with variability in demand levels. The banked hours are called in to provide volume flexibility in relation to absenteeism, breakdowns and demand uncertainty due to production requirements over and above forecast.

Most of the people work either a 6-2pm shift, 2-10pm, or 7.45-4.30pm shift on Mondays to Thursdays. The idea was to be able to bank the hours on Friday. But the workers are paid for the full week. The maximum time that can be banked is 40 hours in any month and the minimum is 4.5 hours. Table 9.2.1 below shows the shift pattern at Teleco.

Shifts	Days	Working Pattern	Recovery hours
1	Monday - Thursday Friday	6am – 2pm	2pm - 4pm or 11.30am - 4.30pm
2	Monday - Thursday Friday	2pm – 10pm	12pm - 2pm or 9.30am - 11.30am
3	Monday - Thursday Friday	7.45am - 4.30pm	4.30pm - 6.30pm or 12.45pm - 5.15pm

Table 9.2.1: Shift pattern at Teleco

The 3 - shift system was introduced, as shown in the table above, to be flexible to cater for the different needs of the people. For instance, the plant has a lot of women with children in its employ that need to leave by 4.30pm to collect their children from school (shift 3). Typically, people in shift type 3 may be required to pay back hours banked, between 12.45pm and 5.15pm on a Friday. As shown in the table, generally hours can be paid back between Monday and Thursday in advance of the normal start time or after the normal finish time. The pay back period on a Friday depends on the type of shift. There is a choice to pay back on a Saturday, but this is entirely voluntary.

In order to get the deal through, the plant gave an incentive in the form of taking back only 3 hours for every 4 hours banked. Also, if at the end of the year there are outstanding banked hours not called in, then these are written off. Gradual implementation was necessary, as not all workers bought into it initially and management wanted to see how the system worked.

"We deliberately manipulated the situation that most people had some hours left at the end of the year and that allowed us to wipe them off and that encouraged those people who had not joined the scheme to join the following year. And very quickly we moved to the position in which 100% of the people have now accepted the banked hours system. We didn't force it on them. Management usually has this mandate to impose things on people. But we try to run a democratic organisation".

It was also an issue that the system was introduced when the workers were least likely to kick against it. According to the GMO,

"..we launched it at a time when the sun would shine".

It was also suitable for the plant because of the seasonal demand pattern that the plant experiences. The plant records up to about 40% of sales in the last quarter of the year so many of the hours banked are used up during this period. Although there are rules relating to the use of the banked hours system, the informal way in which it is being employed in the plant contributes to its successful implementation. The informal procedures tend to be more supportive of an individual's personal circumstances.

The banked hours system has been used successfully in achieving high levels of volume flexibility in the plant.

"Last year we banked 16000 hours during the course of the year and in the last quarter we called in over 14000 hours. Normally, in the last quarter we would work 20% overtime. The banked hours system actually saved me quite a lot of money".

Supply Chain Flexibility

Due to the huge material cost, high number and types of components required for production and the long procurement lead times, the plant could not limit its search for volume flexibility to operations within the plant.
"We've moved the flexibility issue back not only in our factory but also with our vendors".

Teleco needed to achieve supply chain flexibility to supplement the volume flexibility it was trying to achieve within the plant. Improving the flexibility of the supply network has provided the plant with long-term volume flexibility. This was, however, difficult to achieve for many reasons. One was the difficulty in managing relationships with a large number of suppliers.

Implementation

In order to resolve the complexity issue of the supply chain, Teleco launched a project about 3 years ago with a number of their suppliers. It was named the Teleco Flexibility Forum.

"We deliberately went and sat with various suppliers and talked about the issue of how to achieve greater flexibility".

The forum met regularly and developed together some interesting improvements in order to enhance flexibility. Combined with the work of the plant's component qualification group (discussed earlier), the forum came up with an improvement programme that helped, amongst other things, to rationalise the number of components.

Rationalising the number of components had a direct effect on the number of suppliers that the plant had. Reducing procurement lead-time and achieving supply chain flexibility require having a good relationship with vendors. By and large, it is rather difficult to manage and sustain these relationships if the supplier base is large.

"The diversity of what we make calls for a large number of suppliers. We use many types of component such as very discrete components, specialised components and custom components. We used to have about 4500 suppliers. We've now got about 150 major suppliers".

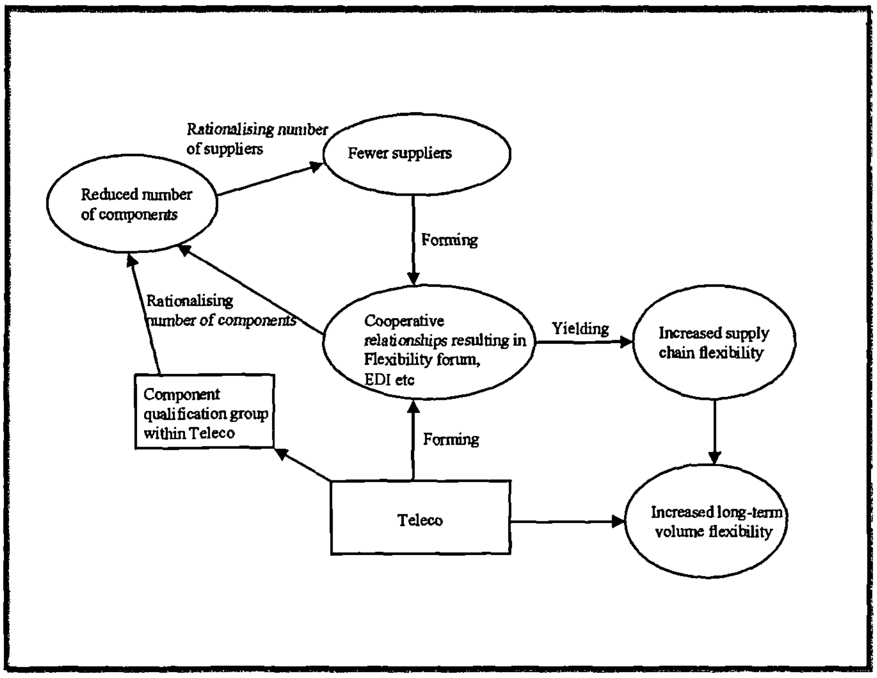

Figure 9.2e: Achieving supply chain flexibility in Teleco

The above model shows the relationships between the actions that Teleco has undertaken and the outcome of its actions in terms of achieving increased supply chain flexibility. This has also increased the levels of long-term volume flexibility of the plant due to a significant reduction in procurement lead-time. However, the plant recognises that there is still much efficiency that can be squeezed out of its supply chain.

"We are always looking into how you can reduce the supplier base to enhance our flexibility".

9.2.6 Summary

Table 9.2.2 summarises the insights provided to answer the first Research Question.

RQ1: Under what conditions does Teleco require high levels of volume flexibility? ***Concept used: Drivers.***

Drivers	Demand variability/ Uncertainty	Business needs	Supply chain complexity	Short product life cycle
Causal Factors	• Customer needs • Contract manufacture	• Growth • Differentiation • Cost avoidance	• Power dynamics • High material cost • Component complexity • Many suppliers	• Market factors – quick product obsolescence

Other Drivers	New product introduction	High product mix	Competitors' actions
Causal Factors	• Market factors	• Customer needs	• Market factors

Table 9.2.2: Summary of drivers of volume flexibility and their causal factors for Teleco.

Table 9.2.3 summarises the insights provided to answer the second, third and fourth Research Questions.

RQ2: What are the enablers and inhibitors of volume flexibility in Teleco?
Concepts used: Enablers and Inhibitors

RQ3: Why does Teleco use these particular enablers to achieve high levels of volume flexibility?
Concepts used: Benefits and Drivers

RQ4: How does Teleco use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used: Key implementation factors (KIF)

Enablers of Volume Flexibility	Sister plant	Continuous process improvement	Equipment upgrade	Multiskilling	Mix Flexibility	Good Attitude	Banked hours system	Supply chain flexibility
Drivers	• High variability in demand levels • Short-term demand uncertainty	• Competition • Changing customer needs	• Demand growth • Changing technology	• Demand variability • Product complexity • Short-term demand uncertainty	• Customer requirements • High set up	• Introduction of banked hours system	• High variability in demand levels • Excessive overtime cost • Demand uncertainty	• High material cost • High number & type of components • Many suppliers • Long procurement lead time
Benefits	• Provides volume flexibility	• Provides long-term volume flexibility	• Provides mix & volume flexibility (+) • Costly (-)	• Provides mix & Volume flexibility	• Aids volume flexibility	• Aids implementation of banked hours system	• Provides volume flexibility • Eliminates overtime • Provides working flexibility for different categories of workers	• Provides volume flexibility through reduction of procurement lead time
Inhibitors	• None	• None	• None	• None	• Reducing set up time	• Working culture	• Resistance to change	• Managing relationship with many suppliers
KIF	• Good integration • Methods & process consistency across sites	• Repetitive & frequent planning • Capacity analysis • Common processes • Rationalising number of components	• Good capacity and flexibility analysis	• Financial incentive • Education	• Flexible equipment • Multiskilled workforce • Common processes	• Compatible pay system • Education	• Timing of launch • Gradual implementation • Democratic • Incentive - Discounted pay back hours • Managing informally	• Flexibility forum • Rationalising number of components • Rationalising number of suppliers • Good relationship with suppliers

Table 9.2.3: Summary of enablers in Teleco

Figure 9.2f shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, short-term demand uncertainty, absenteeism and equipment breakdown.

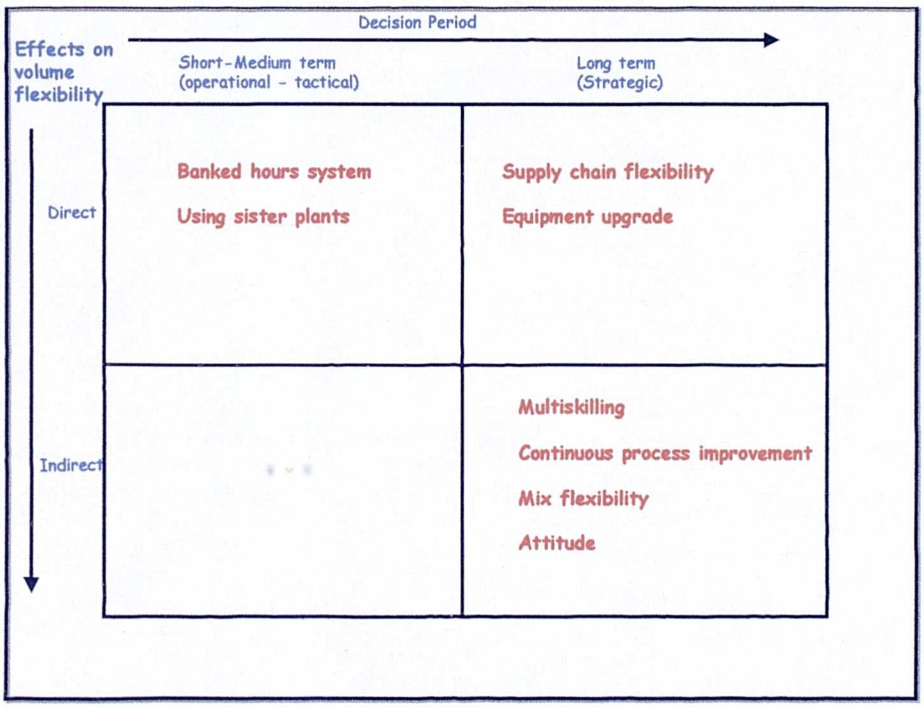

Figure 9.2f: Decision hierarchy framework and the effects of enablers on volume flexibility

9.3 Case Study Analyses - Proceco

The operations manager was interviewed (the source of all the quotes cited in the case study). Data on the aggregate production and sales achieved against plan were collected. The contract agreement of the flexible working scheme that was introduced into the plant was not made available. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1. *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2. The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3. The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4. The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

9.3.1 Contextual Considerations

Proceco belongs to the process sector. The plant produces a type of chemical from which consumer goods such as easycare shirts, fashionable clothes, video tapes, coca cola bottles, circuit boards, wine boxes, chocolate bar wrappers and yoghurt pots are produced. It employs about 248 people directly in production operation and 30 in design.

The plant has about 12 suppliers. The average purchasing lead-time is 90 days. The average manufacturing lead-time is 6 hours and the average customer lead-time is 14 days.

9.3.2 Market Characteristics

Most of the products produced in the plant are being sold in Europe and South Africa. Proceco has sister plants in China, India, Taiwan, Indonesia and Pakistan to serve the growing fibre market in Asia. The market operates on a 3-4 year cycle. Thus, the capacity strategy of the plant tends to follow a sort of stepwise capacity plan. During the time of a peak in demand about 4 years ago, additional capacity was built to cover the demand. The market is presently undergoing generally a slump in demand and overcapacity in the market place.

In Europe, the company has one major competitor and there are four big competitors globally. Generally, because of the nature of the process and the capital requirements, the barriers to entry into the market are quite significant.

9.3.3 Operations

The production process involves two separate multi-stage operations - the Oxidation Plant and the Purification Plant. The oxidation process comprises seven main stages.
Feed mix: The raw materials are added at the desired ratios and thoroughly mixed.
Reaction: Oxidation takes place continuously in a reactor which operates at 15 - 20 bar pressure and 200 - 210 degrees centigrade. Air from a multi-stage centrifugal compressor fitted with a gas expander turbine, oxidises the raw material to produce a slurry of the the chemical, which is then passed to a crystallisation process.
Crystallisation: The slurry pressure is brought down to a slight vacuum and its temperature to around 90 degrees centigrade, step by step in three crystallisers.
Separation: The cooled slurry is fed to rotary vacuum filters where a wet cake of the solid form of the chemical crystals is separated from the liquors.
Drying: The separated wet cake is fed to a rotary system steam tube drier in which the residuals are removed in a circulating stream of inert gas. The resulting dry crude is conveyed to a powder storage tank. The crude form of the chemical product is now available, but this requires further processing to provide the very pure product required by the plant's customers.

The crude chemical is purified by converting the major impurity into a soluble form, which is washed away leaving behind the insoluble but very pure form of the chemical. Because it has a continuous production system, the plant runs in theory 24 hours a day, 365 days a year.

9.3.4 Drivers of Volume Flexibility

Figure 9.3a below shows the conditions that drive Proceco to require high levels of volume flexibility and the factors responsible for these conditions.

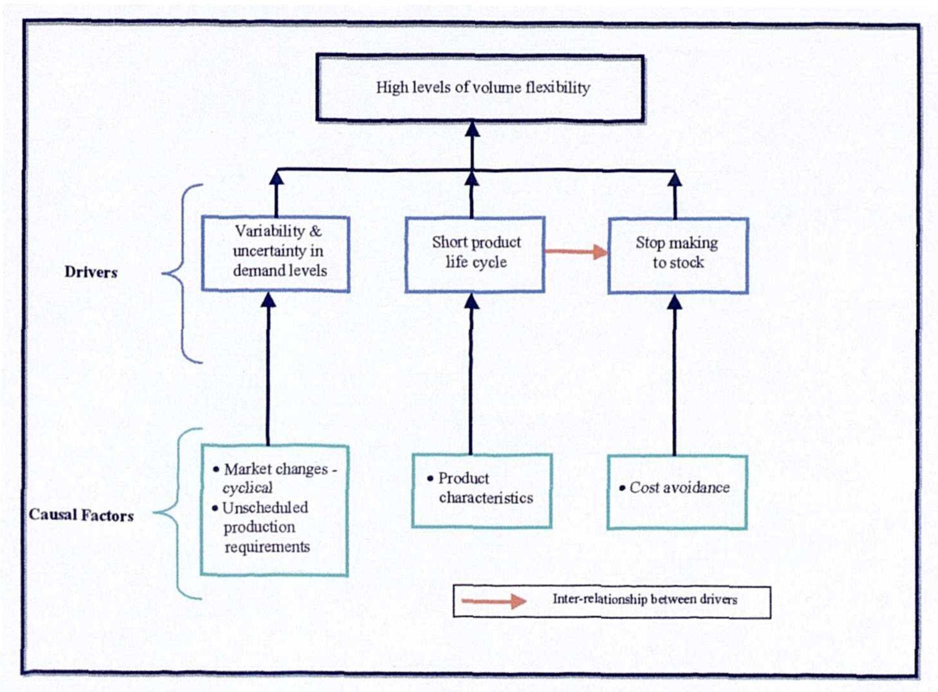

Figure 9.3a: Drivers of volume flexibility at Proceco

High Variability and Uncertainty in Demand Levels

The nature of the market in which the company operates dictates the demand requirements placed on the company. The market is cyclical, and it witnesses significant peaks and troughs in demand levels within each cycle. Thus, while Proceco might be tempted to invest in additional capacity during peak demand, it has to keep in focus future troughs in demand. In other words, it has to have volume flexibility on a long-term horizon. Although there is demand variability over a longer-term horizon, total demand (usually over a year) is fairly predictable. Unforeseen production requirements are other factors that cause short-term uncertainty in demand levels for the plant. *"When our boiler broke down, we didn't produce anything...."*.

Figure 9.3b shows the chart of production and sales achieved against plan for the plant between January 1998 and March 1999.

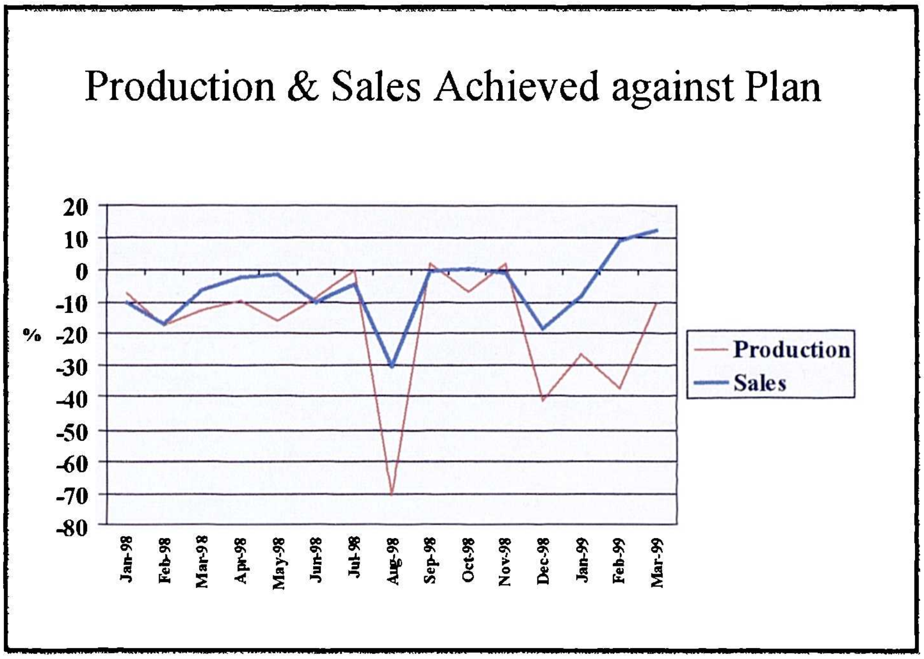

Figure 9.3b: Production and sales achieved against plan in Proceco

The figure shows that generally the actual production and sales achieved in the plant fell short of schedules over the period considered. For instance, the actual production and sales fell by as much as 70% and 30% respectively against plan for the month of August 1998. This highlights the high levels of forecast error and uncertainty of short-term demand levels that the plant experiences. Thus, the plant requires short-term volume flexibility strategies such as the use of the benefit hours system (or an annualised hours contract) in order to keep actual production as close as possible to plan.

Short Product Shelf Life/Stop Making to Stock

In the past Proceco had tried to put a lot of their product in storage to cope with demand fluctuations. The nature of the products makes it impossible for the company to stock the products for months because after about 6 months, the bags go solid. Also, the cost implications of storage and risk of wastage discourages making to stock. This forces the plant into limiting stock products and increasing the ability to be responsive to demand requirements. For a continuous production process, this is rather difficult to achieve because of the nature of the process. It is difficult to turn the equipment on and off. As argued previously (Oke, 1998), it may actually be cheaper to produce to stock than to switch the equipment or machinery on and off. However, this has presented a great challenge for Proceco in terms of achieving volume flexibility. The plant has sought and implemented various strategies, which enable it to achieve relatively high levels of volume flexibility without resorting to the high cost option of producing to stock.

9.3.5 Enablers and Inhibitors of Volume Flexibility

The figure below summarises the enablers of volume flexibility (strategies that the plant employs to achieve volume flexibility), the inhibitors (factors that prevent the achievement of volume flexibility). It identifies the key implementation factors (KIF) for the implementation of the enablers (i.e. how the plant has gone about implementing successfully the enablers and overcoming the inhibitors to achieve volume flexibility).

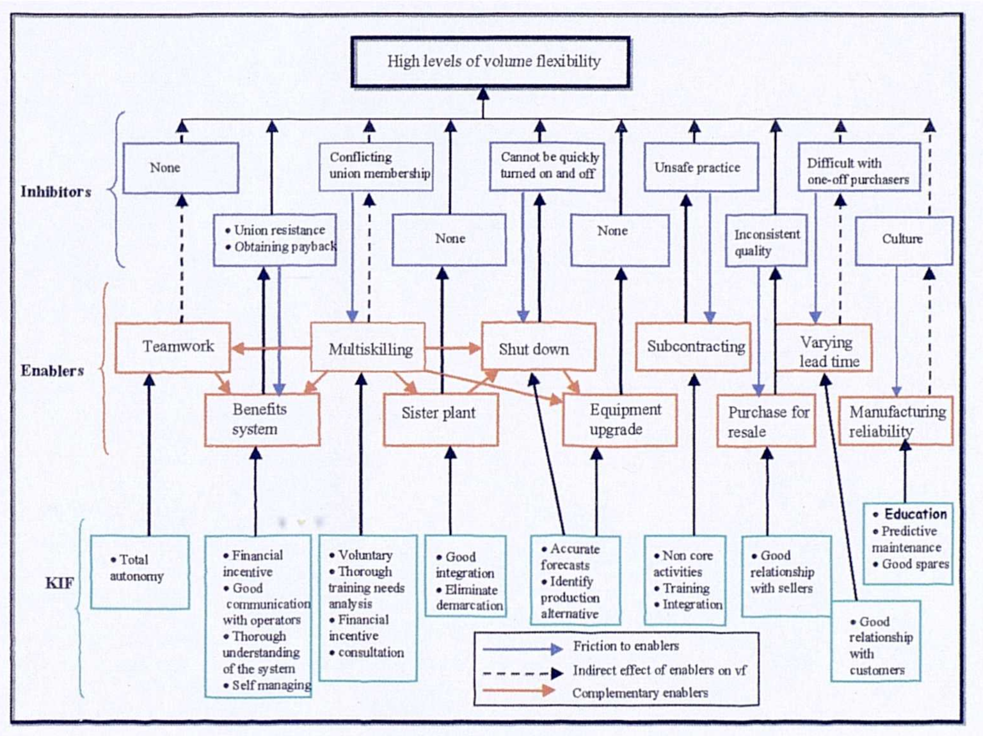

Figure 9.3c: Enablers of volume flexibility at Proceco

Multi-skilling

Multi-skilling was introduced into the plant in response to high variability being experienced in customer demand requirements. The idea was to give people skills to allow them to perform different tasks. It aids the achievement of other enabling strategies of volume flexibility such as the benefits system, use of sister plant and teamwork. For the successful implementation of the benefits system (or an annualised hours system), operators have to be multi-skilled, for instance, to provide cover for absenteeism. Multiskilling allows the movement of operators between different work areas or across plants, depending on the requirements. The success of teamworking as an enabler of volume flexibility in the plant depends on the varied skills, which the operators within a team possess. Multiskilling therefore enables, albeit indirectly, the achievement of volume flexibility.

Implementation

Multiskilling is a relatively longer-term solution to achieving volume flexibility. In order to implement the strategy, a thorough analysis of training needs for the plant was carried out to determine what additional skills were required by operators. This was based on historical demand loading and capacity availability (in terms of labour) as well as the forecasts for future demand requirements. The introduction of multi-skilling was done at about the same time as the introduction of the benefit hours system to curb excessive overtime expenses. Rather than stop overtime abruptly, the overtime hours were substituted for training hours and workers were paid overtime rates for these training hours. Signing up for training was done on a voluntary basis.

"So, if you could volunteer for these training courses, it meant more overtime".

Also, over three years the workers were paid about 14% of the basic salary when the idea of multiskilling and other changes (benefit hours system) were introduced into the plant. These factors helped in encouraging operators to sign up for courses, thereby increasing the overall skill level of the plant.

Inhibitors

A number of problems were encountered in implementing the multi-skilling strategy. This came mainly from the unions.

"There was some confusion that the idea was that we wanted everybody to know how to do everything".

They could see overtime disappearing in future. There was also the political issue with the unions because the workers belong to different unions.

"Historically, if you are clever, you became an Instruments and Electrical Engineering (IE) guy, if you are OK, you became a Mechanical guy, if you are not good, you became an operator".

The problem with the union was about membership. Different unions wanted to maintain their membership. They saw multi-skilling as a strategy that could cause a reduction or dilution of membership.

Management had a number of consultations and meetings with operators in order to overcome the resistance to the implementation of the changes. They tried very hard to keep out of the political games over membership involving the unions, but because the unions had become weaker over the years, management was able to reach an agreement with them relatively easily. The timing of implementation was also significant.

"Difficult to implement these changes when a plant is making money. When the market was flat in 1995/1996, we had the opportunity to say this is the best offer that we have got, we think it is a fair offer. It is giving people more skills. We think it is right for you, so we need to move in that direction".

Teamwork

Teamworking is a relatively short-medium term solution to the achievement of volume flexibility. The effect of teamworking on volume flexibility is, however, indirect as its effect is seen through other solutions such as multiskilling and benefit hours or an annualised hours system. The teamwork approach was introduced to complement the multi-skilling strategy. It was also in a way a response to some of the concerns raised by the unions over multi-skilling. Teamworking also provides an adequate medium for the implementation of the benefit hours system, which has a direct effect on volume flexibility.

Implementation

"... instead of making all our process guys Jacks of all trades, we have people who have just about one or two additional skills at the very basic level and we tend to mix them up within that section to form a team to get some flexibility".

Taking the oxidation process for example, instead of having an Instruments and Electrical (IE) guy and a Mechanical fitter in a team, the intention was to get rid of those two roles and put in a technician. The core skills of the technician might be Instruments and Electrical Engineering, and additional skills could be some Mechanical skills at least at the basic level. The aim was to get the mix right to create a team capable of running the plant in totality. The key factors for the successful implementation of teamworking were the availability of multiskilled staff and the total autonomy given to the teams to manage work in the team, prepare rosters and the like. The teamwork approach was actually significant in the successful implementation of the benefit hours system contract.

Benefit Hours System

The whole idea behind the introduction of the benefit hours system was to get rid of overtime which was running at about 25-30% for some people at the time.

"At the time we had big day and shift mechanical teams. When the plant is running smoothly, there is very little for these maintenance people to do, and the process people are quite busy. So you've got 8 people sitting around 24 hours a day answering the phone".

Implementation

The benefit time hours was calculated as follows:

Hours in a year 365 x 24 = 8760 hrs
Shift pattern must cover these hours (a continuous production process) but each shift cannot do more than allocated hours.
On a 6 shift pattern each shift does 8760/6 = 1460 hours per year.
The benefit time was based on a 36-hour working week (or about 1630 hours on an annual basis for 45 weeks)
The 1460 hours a year are the committed and scheduled hours which are required to cover predictable variability in demand and forecasts.
The 1630 hours a year are paid for, so each employee "owes" the plant 1630 – 1460 hrs = 170 hrs (or about 21 days).

The whole theory behind the system is that for each worker there are 170 hours on top of the committed hours which can be called in by the plant to cover for uncertainties such as unscheduled peak work loads and sickness or absenteeism. Operators work 9 days in a fortnight. For example, Monday to Friday, and Monday to Thursday, implying one day off which is used to build up their benefit or their bank. The supervisors keep the records of the banked hours. The arrangement is such that if someone is off sick within a shift, there are agreements that they will ring up someone who is on their team to come in and if he does, say, 8 hours, that is deducted from his banked hours. Thus, the system has a direct effect on the achievement of short-term volume flexibility.

To get the workers to buy into this, a payment of 14% of the basic salary was offered to them and spread over three years. A number of meetings were held with workers to explain how the system worked and to investigate the suggestions they had for implementing it. The understanding of the mechanism by the supervisors was vital to the successful implementation of the strategy. Local agreements were drafted for teams and managed by the teams themselves. So, it was left for the team to decide whom to call on to use the banked hours when required.

"Typically though, they would not call out someone who is in the middle of their 18 day break. They would call out someone who was at work for example in the previous day. The agreement has allowance for refusal. You can refuse about 3 or 4 times, but ultimately if your mates have used up say 100 hours of their time and you still have 170 hours, you will have to come in"

"The success of the system is really down to peer pressure. If a guy had a hard night and couldn't come in on Monday morning, it meant overtime and more money for his mates in the old days. So they thanked him for that. Now it is totally different. In terms of sickness, it is an absolutely tremendous system. We introduced this in February 1997, and up till then the sickness level was about 4%. After about 6 months, the level was zero".

Inhibitors

In addition to the problems discussed previously in implementing multi-skilling (since both systems were implemented simultaneously), the plant encountered some other problems in trying to implement the benefit hours system. Getting people for call outs was a major problem. Again, peer pressure has helped to reduce if not completely eliminate this problem in the plant.

Banked hours are also being used to train workers to continue with the up-skilling of the workforce. Generally therefore, the system has helped the company to cope with absenteeism, training and safety days and variability in production or business needs.

Sister Plant

The plant has two manufacturing units on site which perform basically the same type of operations. UNIT 1 was built in the 70s and UNIT 2 was built in the 80s to provide additional capacity due to the growth in the market at the time. Proceco is able to share loads between the two units on site depending on the requirements. This is a tactical solution having a direct effect on the achievement of short-medium term volume flexibility.

Implementation

Changes that were introduced into the company (i.e. multi-skilling and teamwork) encouraged the removal of demarcation between the two plants UNIT 1 and UNIT 2 on site, which were originally run independently. It, therefore, became easier to move people across the plants in response to the loading requirements.

"For example, UNIT 1 at the present is experiencing a shut down and overhaul, so we would take people across the plants. We are trying to move across the boundaries and discourage the traditional feeling of being specifically a UNIT 1 worker to being a UNIT 1 and a UNIT 2 worker. But we have to be careful with that since we still want core plant members to have some kind of identity and pride in their plants".

Shut down

Having a sister plant means that when demand falls, the company can actually shut down one of the plants while the other one runs to balance capacity with load. The capability to do this provides Proceco with a medium-term solution to achieving volume flexibility by being able to cut down on production in line with requirements. It can be used to cope with medium term demand uncertainty.

"If we wanted to make 50,000 tonnes, and we can only sell 30,000 tonnes, we would decide which plant to shut down, how long we will shut it down for. We will try to go into shut downs with doing some maintenance work. What we wouldn't want to do is to shut down a plant for 3 days this week, and then next week we have to start it up due to increase in demand".

Implementation

It was important to identify a production alternative before employing the 'shut down' strategy at Proceco. Shutting down for Proceco means shutting down an entire manufacturing unit, hence the production alternative it uses is the second manufacturing unit. However, because of the difficulty of switching on and off associated with a continuous production system, shutting down relies heavily on relatively accurate demand forecasts of slump in demand.

Equipment Upgrade

When a plant is shut down, it provides an opportunity to overhaul and upgrade the equipment in the plant. Equipment upgrade is done to provide additional capacity for the plant to enable the plant to cope with more load when demand picks up. The timing of the upgrade is, however, determined by the cyclical pattern of industry demand. If demand continues to grow *"...people can start considering green field sites"*. This strategy is a relatively long-term solution having a direct effect on the achievement of long-term volume flexibility.

Implementation

Having a relatively good forecast helped to determine the timing of upgrade. It was usually planned for when the demand was relatively low. It was also important for Proceco to identify an alternative production unit to continue with normal production during the time of upgrade. Having a multiskilled workforce also helped in that operators could be moved between the units to carry out tasks other than their main tasks.

Sub-contracting and Contract Labour

Sub-contracting is another strategy that is employed by the plant to cope with demand fluctuations. Subcontracting is a long-term solution to achieving volume flexibility because it is done as part of a strategy involving selection, evaluation and appointment of subcontractors.

Implementation

Proceco employs an engineering contractor who provides contract staff for non-core activities in the plants (e.g. scaffolding work). The plant also takes some contract labour on the management side, say on projects using a local agency.

"We actually name the individuals that we want to the agencies. Could be people who used to work here and have left".

Sub-contracting and using local agencies to provide contract labour have been successfully implemented by the plant to increase and decrease capacity as required. However, most of the lost time incidents recorded by the plant have come from the contract labour *(Inhibitor)*. To overcome this problem, Proceco has shifted contract staff safety responsibility from the sub-contracting companies to teams within the plants to which the contract staff are attached. The contract staff are given the same safety training courses that company staff go through and are fully integrated. Sub-contracting also tends to be very expensive for the company.

"By removing demarcation and encouraging multi-skilling, we won't need to do much sub-contracting in the future".

Purchase for Resale

Most of the orders from the Far East have been met by purchasing for resale (PFR). If they are not able to meet customers' requirements, the plant can resort to buying from other producers from as far as America to keep their customers happy. PFR is a tactical solution that has a direct effect on the achievement of short-medium term volume flexibility in the plant.

"...For example in the past, when our boiler broke down, we didn't produce anything, so what we did was to put our customers on allocation. We bought PFR just to keep the customers happy. We can actually buy from our competitors as well".

Implementation

Proceco has good relationships with sellers, which make it possible for the plant to employ the strategy of purchasing for resale in a tactical way to achieve volume flexibility. However, there is always the problem of inconsistent product quality associated with the strategy of PFR. Hence Proceco uses this strategy only as a last resort.

Varying Lead Times

The plant is often able to negotiate lead-times with its customers. This reduces the need for internal volume flexibility.

Implementation

Proceco has a very good relationship with its customers. There are customers with long term contracts and others that just make one-off purchases. Relationships with the former are naturally closer. The plant runs a rigorous customer complaints procedure and encourages customers to use it. Because of changing specifications for end products, the plant has been working closely with some of its customers in Europe, looking at new specifications to help develop the customers' products.

The market in which the plant operates is limited.

"Although there is a lot of stuff flooding in from the Far East, they are pretty unreliable. They know they probably pay more with us, but generally we are more reliable".

"It comes down to the confidence they have in us. We keep them informed of potential problems, transportation problems and the like".

Manufacturing Reliability Programme

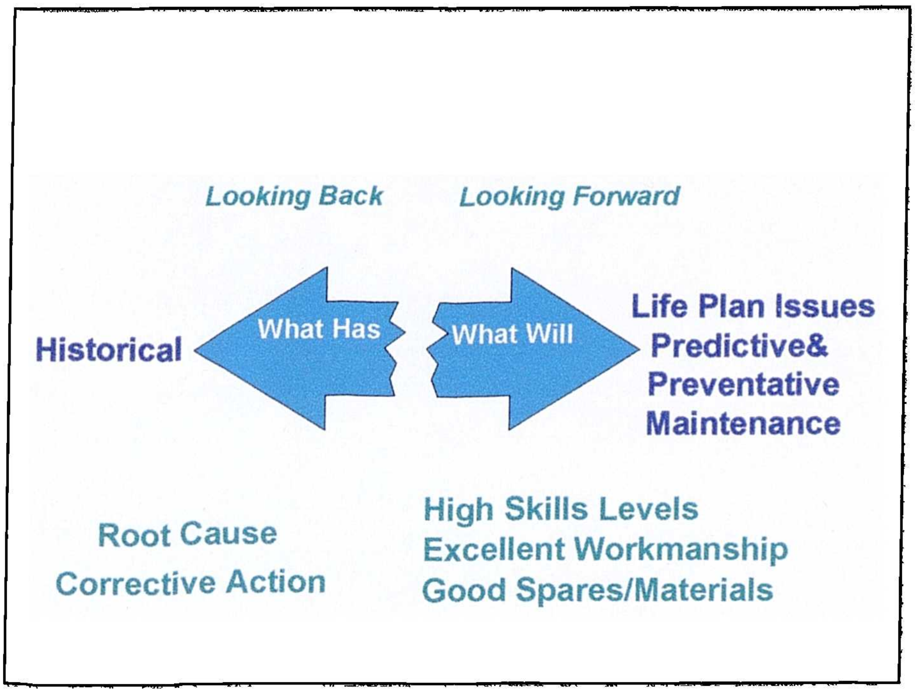

Figure 9.3d: Model for manufacturing reliability programme at Proceco

In view of the high incidence of equipment breakdown and subsequent effect on the production output of the plant, the plant introduced a manufacturing reliability programme as shown in the figure above. Achieving long-term volume flexibility is only one of the benefits that Proceco gains by embarking on a manufacturing reliability programme. The effect of the programme on volume flexibility is, however, indirect.

Implementation

The historical analysis of previous breakdowns is carried out to identify the root causes and the corrective action that was required. This helps to put a predictive and preventative maintenance plan or programme in place to avoid future equipment breakdown.

Having a multiskilled workforce, people with core maintenance skills and excellent workmanship is vital to the successful implementation of the programme in the plant. So are having good and available equipment spares and materials.

Inhibitors

Implementing the reliability programme initially was difficult in the plant because of the lack of a maintenance culture in the plant. With education, training and ownership of equipment transferred to teams, the plant was able to change attitudes towards maintenance.

9.3.6 Summary

Table 9.3.1 summarises the insights provided to answer the first Research Question.

RQ1: Under what conditions does Proceco require high levels of volume flexibility?
Concept used to answer this question: Drivers

Drivers of Volume Flexibility	High variability and uncertainty in demand levels	Short product life cycle	Stop making to stock
Causal Factors	• Market Changes - Cyclical • Unscheduled production requirements	• Product characteristics	• Cost avoidance

Table 9.3.1: Drivers of volume flexibility and their causal factors at Proceco.

Table 9.3.2 summarises the insights provided to answer Research Questions Two, Three and Four.

RQ2: What are the enablers and inhibitors of volume flexibility in Proceco?
Concepts used: Enablers and Inhibitors

RQ3: Why does Proceco use these particular enablers to achieve volume flexibility? Or what makes Proceco choose these enablers to achieve volume flexibility?
Concepts used: Benefits and Drivers

RQ4: How does Proceco use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used: Key implementation factors (KIF)

Enablers of Volume Flexibility	Multiskilling	Teamwork	Benefit Hours System	Sister Plant	Shut down
Drivers	• Demand variability • Short-term demand uncertainty	• Complement multiskilling • High variability in demand levels	• Demand variability & uncertainty • Eliminate overtime	• High variability in demand levels • Plant shut down or equipment upgrade	• High variability in demand levels • Equipment upgrade
Benefits	• Provides volume flexibility • Gradually eliminates overtime	• Provides volume flexibility	• Provides volume flexibility • Low absenteeism • Provides training and safety days • Eliminated overtime and cost	• Provides volume flexibility	• Provides volume flexibility
Inhibitors	• Conflicting union membership	• None	• Union resistance • Obtaining payback	• None	• Cannot be quickly turned on and off.
KIF	• Consultations • Right timing • Voluntary basis • Thorough training need analysis • Financial incentive	• Total autonomy • Multiskilling	• Good communication & consultations • Understanding of the system • Financial incentive • Self managing- peer influence • Multiskilling & teamwork	• Good integration • Remove demarcation • Upskill workforce and encourage mobility	• Multiskilling & mobility • Identify production alternatives

Table 9.3.2: Enablers of volume flexibility at Proceco

Enablers of Volume Flexibility	Equipment Upgrade	Subcontracting	Purchase for resale	Varying lead times	Manufacturing Reliability Programme
Drivers	• Growth in demand • Technology	• Demand variability and uncertainty • Non core activities	• Demand variability and short-term demand uncertainty • Equipment upgrade/shut down	• High levels demand variability	• Equipment breakdown
Benefits	• Provides volume flexibility • Costly (-)	• Provides volume flexibility (+) • Costly (-)	• Provide volume flexibility (+) • Costly (-)	• Provides volume flexibility	• Provides volume flexibility through preventing breakdowns
Inhibitors	• None	• Unsafe practice	• Inconsistent quality	• Difficult with one off purchasers	• Culture
KIF	• Accurate forecasts • Multiskilling & mobility • Identify production alternative	• Subcontract non core activities • Safety training for subcontractor's staff • Integration of subcontractor's staff	• Good relationship with sellers	• Good relationship with customers	• Education • Identifying root cause • Corrective action • Predictive & Preventative maintenance • Multiskilling • Good spares

Table 9.3.2: Enablers of volume flexibility at Proceco

Figure 9.3e shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short – medium term (operational – tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, short-term demand uncertainty, absenteeism and equipment breakdown.

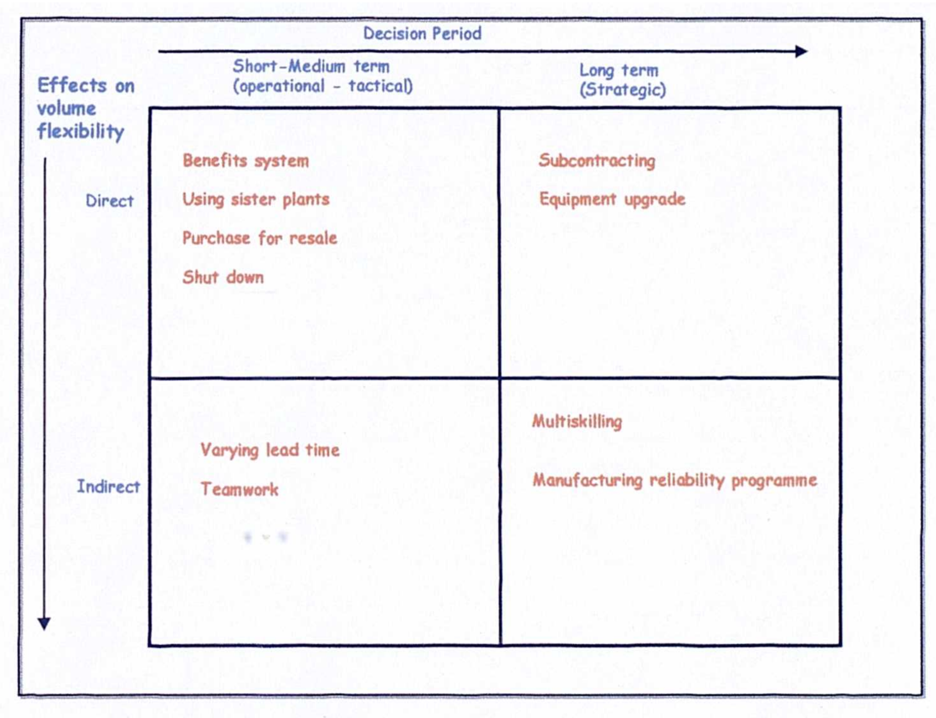

Figure 9.3e: Decision-hierarchical view and effects of enablers on volume flexibility

9.4 Case Study Analyses – FonGoods

The manufacturing manager was interviewed (the source of all the quotes cited in the case study). Data on the aggregate demand profile for the plant was collected. The contract agreement of the flexible working scheme that was introduced into the plant was also made available. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1. *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2. The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3. The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4. The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

9.4.1 Contextual Consideration

The plant belongs to the household products and general goods sector. It produces materials, laminates for decorative surfaced boards and plastic extruded products used for furniture. The plant has 105 employees directly involved in production operations.

FonGoods supplies its products all over the world with about 70% exported and 30% supplied to the UK. With about £16 million turnover, the plant produces an average of between 10 to 11 million square metres of materials a year. It has about 38 suppliers, mostly based overseas. The average purchasing lead-time is 14 days. The average manufacturing lead-time is 3 days.

9.4.2 Market Characteristics

FonGoods supplies and has close links with Board and Foil Manufacturers. The plant has a range of products contained within an edging library where matches to the major board manufacturers can be quickly identified. Some of the product ranges are more tailored to specific customers, while most customers order from a range of about ten standard products. The average customer lead-time is 10 days for UK customers (but customers could actually have the delivery the same day, usually from stock). For overseas customers, the lead-time varies from one to three weeks. This is due to fixed sailing times.

FonGoods is a market leader in the UK in the production of edging materials. It has quite a good profit margin on its products so can be very competitive in terms of price. Good investment in technology has further increased the barriers to entry and reduced threats of potential competitors.

9.4.3 Operation

The manufacturing operation consists of impregnation of the raw material (paper) with resins to give the paper a strength that is enough to use on the edges of boards. Depending on the customer requirements, the impregnated paper can be put in work in progress, passed to embossing or put through the laminator. The laminating part accounts for a small volume of the company's business. The paper is then cut to the required sizes, packed and dispatched or put into finished products stock.

9.4.4 Drivers of Volume Flexibility

Figure 9.4a below shows the conditions that drive plants to require high levels of volume flexibility and the factors responsible for these conditions.

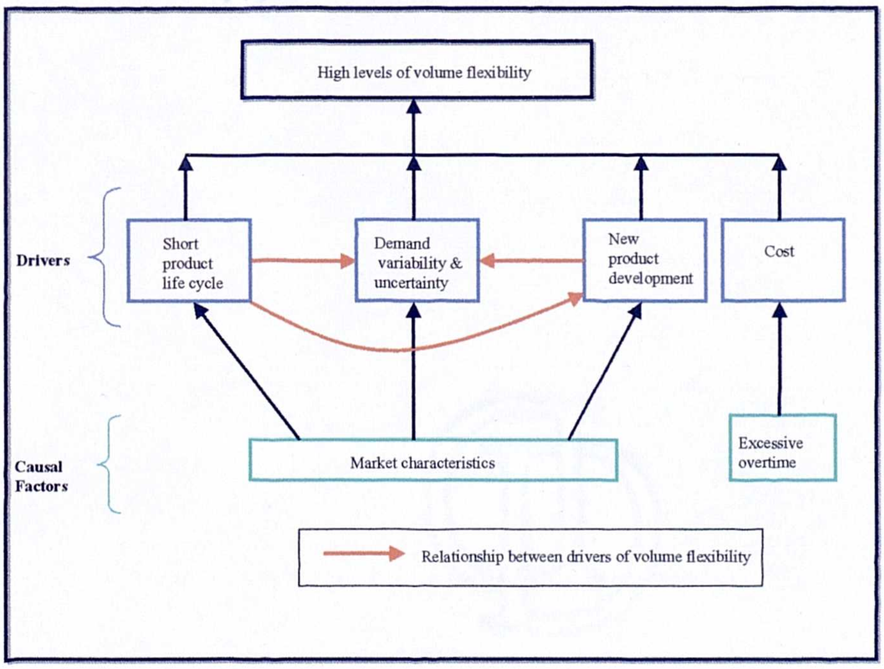

Figure 9.4a: Drivers of volume flexibility at Fongoods

Demand Variability and Uncertainty

The plant experiences high fluctuations in customer demand levels within the month (weekly) and within a given year (monthly) as shown in figure 9.4b. The figure shows the aggregate demand profile for the plant from January 1997 to April 1999. Within a given year, say 1998, demand ranges from as high as over one million square metres in October 1998 to as low as over 500,000 square metres in December 1998. However, there is less variability in yearly totals. In other words, the yearly total demand is fairly predictable. Looking over the years, although consistently high sales were recorded in the months of May and October, there is no clear seasonality in the demand profile.

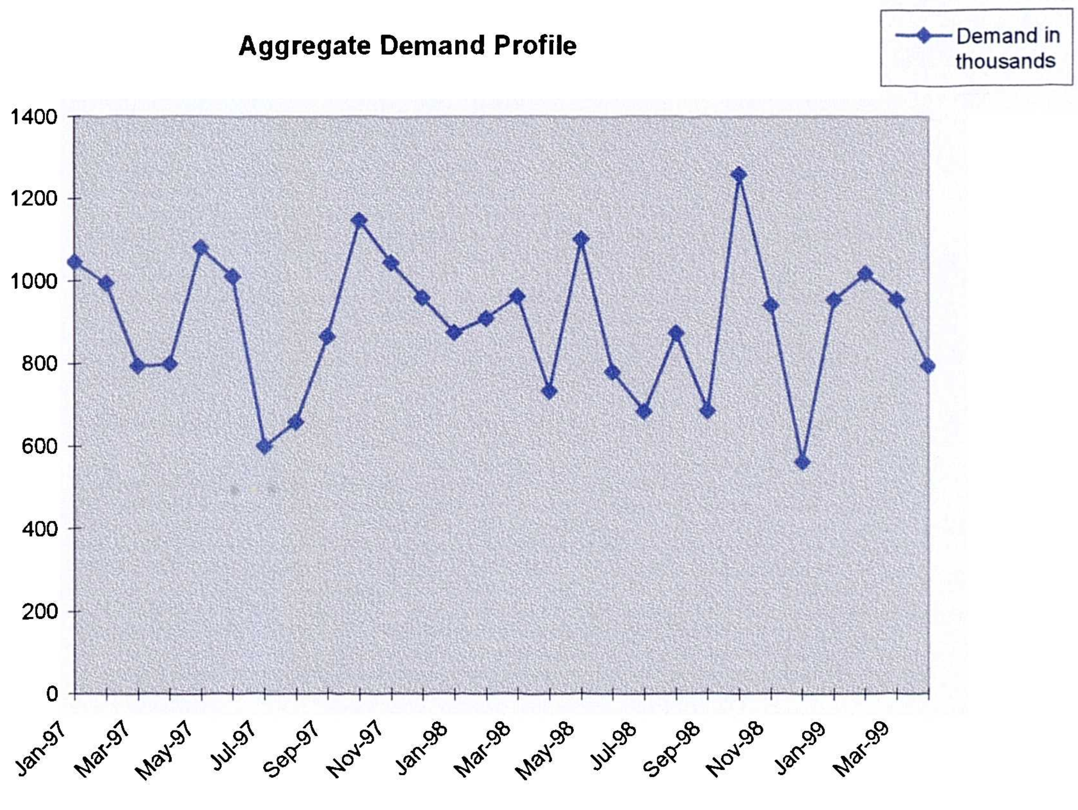

Figure 9.4b: Aggregate demand profile for FonGoods.

Changes in end users' requirements result in short-term demand uncertainty for FonGoods' products. These changes tend to shorten the life cycle of existing product ranges and influence the development of new products by the company to satisfy the market requirements. The attendant gradual decline in the demand levels for existing product ranges and increase in the demand for new products have implications for production volumes in the plant, hence the need to have high levels of volume flexibility.

Excessive overtime hours resulting in high labour costs is another driver of the need for a volume flexibility strategy such as the banked hours system in the plant. This is further explained in the following section.

9.4.5 Enablers and Inhibitors of Volume Flexibility

The figure below summarises the enablers of volume flexibility (strategies that the plant employs to achieve volume flexibility) and the inhibitors (factors that prevent the achievement of volume flexibility). It identifies the key implementation factors (KIF) for the implementation of the enablers (i.e. how the plant has gone about implementing the enablers and overcoming the inhibitors to achieve volume flexibility).

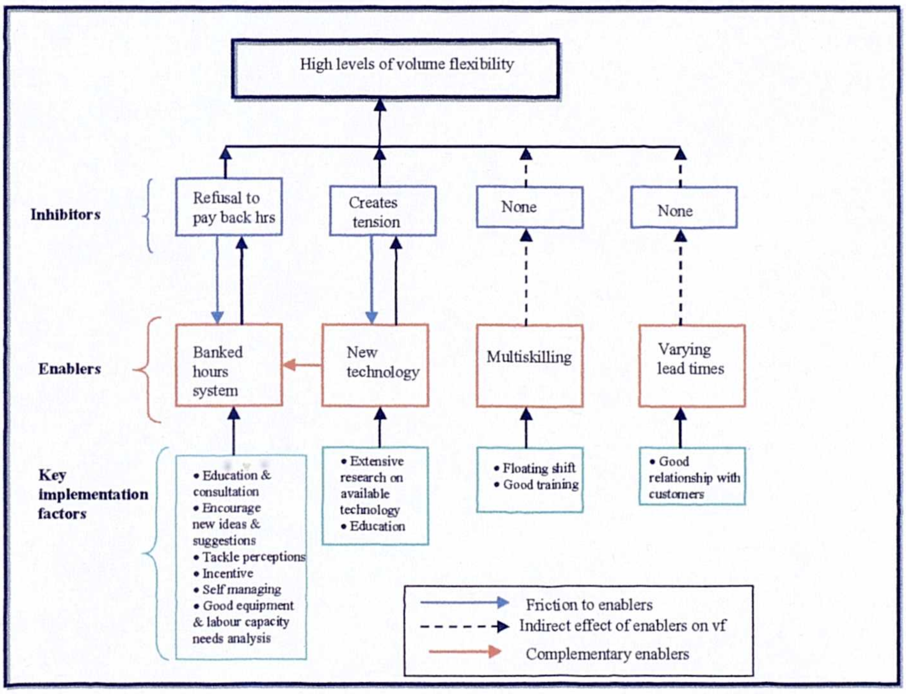

Figure 9.4c: Enablers of volume flexibility at FonGoods

Banked Hours System

High variability in demand levels, high overtime bills of about £400,000 to £600,000 per annum, low productivity in spite of excessive overtime hours, short-term demand uncertainty and the widening gap between shop floor and management were the drivers behind the implementation of the banked hours system. The use of the banked hours system is a tactical solution that has a direct effect on the achievement of volume flexibility in FonGoods.

Prior to the introduction of the system, the working week and payment of wages were based on four days (Monday – Thursday). There was no normal work and pay on the

Friday. When the demand level increased, Friday work was paid as overtime. In reality what was happening was that people were slowing down the work during the week that working on Fridays became the norm rather than the exception. Thus, what the plant had hoped to save by making Friday a non-working and non-paying day was actually being spent on overtime hours' expenses.

"Sometimes, we asked them to come in on Friday, most times we asked them to stay at home. When this happened, they only saw that they were being laid off again, not bothering about the gain in money that they had in overtime the following week. Some people were getting 4 days wage, and peoples' lives were unstable. There was a lot of conflict. Inevitably a change had to happen".

Implementation

With the banked hours system, the working week was made over four days rather than five. People work four normal days (on a scheduled basis to provide volume flexibility for known variability in demand levels) but are paid for five. So if they are not required on a Friday, they put their hours in the bank. A maximum of 5 days or 40 hours can be banked in a month. These hours are paid back to provide volume flexibility to cope with uncertain production demand changes or for cover in the case of absenteeism. Generally, overtime is completely eliminated but may be granted if an individual who has exhausted his banked days is required for extra work. The table below shows a snapshot view of the record of bank hours for Mr Joe Bloggs.

Joe Bloggs Bank Hours

Balance	2.5

Credit (banked)				**Debit (Payback)**			
Date	**Day**	**Shift**	**Hours**	**Date**	**Day**	**Shift**	**Hours**
08/05/98	Friday	Nights	8	22/08/98	Weds		5
28/08/98	Friday		8	27/09/98	w/ending		10
11/09/98	Friday		8				
23/10/98	Friday		1.5				
		Total	**25.5 (17.5)**			**Total**	**15**

Table 9.4.1: Typical shift and banked hours schedule at FonGoods

Discount is given as an incentive on hours banked (i.e. 8 hours banked, 5.5 hours paid back), therefore the effective credit hours for Joe Bloggs is 17.5 hours. The record above shows that Joe can only be called out to work for an extra two and half-hours before running into working overtime. Rather than let this happen, people with the most or more banked hours are approached first when payback time is required.

The successful implementation of the banked hours system in the plant depends on a number of factors. Informal talks were held with the machine operators to try and get their feelings about the impending change. Education and communication were vital.

"So we sat down and came up with a list of what is expected from a banked hours system and what people will get out of it. We then talked with the unions and they felt it was a good idea".

The management had several consultations and meetings with the unions and operators to discuss various issues before an agreement was reached. Some of the resistance to implementation, which was experienced, came from the part of the factory where there was a lot of mistrust. People had the perception that

"...the company doesn't give something and not take something back".

The management needed to educate the workforce and tackle their perceptions.

"It was important also for us to clarify what was in it for the company as well - we don't have to pay overtime, however, you get a week's wage guaranteed every week".

Having spare capacity on the machine was vital to the successful implementation of the banked hours system.

"You've got to have spare capacity on the machine otherwise you can't get the payback".

The machines must not be the constraint in terms of production capacity for the system to work. From the plant's perspective it might be difficult to implement such a system in an operation that runs normally 3 shifts 5 days a week such that the only spare available is the weekend. It might be difficult to call people to pay for the banked hours on a weekend. Also, FonGoods carried out a thorough labour requirement analysis required for the production operation.

"You've got to have the right number of people for the banked hours system to work. If you have too many people you will be saving more banked hours than you need".

By auditing the number of banked hours versus payback, the plant was able to determine the required number of people needed in the system. This resulted in the layoff of 12 people.

The banked hours system was implemented gradually moving from the machine section over a period of time to the cutting and the packing areas. This enabled the plant to monitor the progress and success of the system and it raised the interests of others that were yet to join at the time.

"Of course you would have the problem of people asking why they can't be on that system. They would always think it is better".

Incentives in terms of discounting hours paid back are given to workers to encourage and motivate them. So bank hours paid back during the week or Saturdays are reduced by 1.5 times (i.e. 8 hours banked, 5.5 hours to work). Bank hours paid back on Sunday are reduced by 2 times (i.e. 8 hours banked, 4 hours to payback). Also bank hours owed at the end of the calendar year are written off for a fresh start in the New Year. These incentives have been significant in the successful implementation of the banked hours system for FonGoods.

Fongoods encouraged informal and self-management of the system. The informality of the system enables local arrangements to be made for cover and call outs. If a worker is off in a particular section, somebody else might be called in to use his own banked hours to cover. Because of peer pressure, this happens only for genuine reasons. There were, however, some problems in implementation.

Inhibitors

The biggest problem that the plant has experienced with the system was getting people to give back or pay back banked hours. In order to deal with this problem, the plant negotiated with the unions to put some rules and regulations in place as a disciplinary procedure if somebody refuses to give back their banked hours. So, initially individual discussions would take place on how to reduce their level of banked hours to an acceptable level. If this does not succeed, the banked hours contract is not extended. The individual thus reverts to the old system of working and being paid for four days (Monday – Thursday) with no chance of overtime working on Friday.
"This is not a big problem though, 99% of the time, the system works fine".

The banked hours system has enabled the company to increase its flexibility to deal with fluctuating demand and uncertainty in demand levels. Productivity and motivation of the workers have increased and absenteeism has fallen. The workers are more eager to work and ideas and suggestions flow freely on the shop floor.

"There was a time we had quite a large order and we required people to give in their banked hours on a weekend. They refused and proposed to reshuffle the shift pattern and work 5 blocks of 12 hours shift instead during the week. So, instead of working 8 hours a day, they worked 24 hours on all machines using their banked hours to get the order out of the door. So, sometimes we may not get everything that we ask for, but we get suggestions".

Multi-skilling

Generally, most of the workers are skilled in particular areas. They work in teams limited to a particular work centre. However, there is a group of workers who are multi-skilled and can work on several machines and work centres. This group constitutes the floating shift and they are employed in various process areas to provide additional capacity when required. Multiskilling aids the banked hours system but the effect is felt over the longer term because it is done as part of a strategy and not as an opportunistic solution. Implementing multiskilling in FonGoods involved the provision of good training for the workforce.

Varying Lead Times

Although not often used, FonGoods has no problem at all varying lead times to provide it with a cushion during peak demand periods. This reduces the need for internal volume flexibility in the plant.

Implementation

FonGoods has a good understanding with its customers. *"It is more like a partnership"*. To cater for their overseas customers, the plant has multi-lingual personnel on site that can speak to different customers in different countries. FonGoods has 5 major customers that make up about 80% of the sales volume. These major customers are all overseas and are more flexible with the customer lead-time. Because the plant offers volume discounts, customers are more willing not only to place orders but also to be positively responsive to variations in lead times.

New Technology

It was explained earlier that the availability of spare capacity on machines is significant for the successful implementation of the banked hours system. For FonGoods, heavy investment in new technology has been responsible for the availability of the needed spare capacity. *"We've got the best cutting and packing lines that money can buy"*. The high efficiency of the machines implies that the plant runs 4 days and 3 shifts on average on machines, with one day to spare. The main machine works 3 shifts, 4 days a week. The cutting lines are run on 2 shifts, 4 days a week. There exists a mini night shift, which can be called in depending on the requirements. In addition, therefore, to the one-day spare (on Fridays), there is extra capacity (one extra shift a day) on the cutting lines. This enables the plant to be able to vary its capacity reasonably to cope with demand fluctuations, provided that sufficient labour hours are available. However, investing in new technology was part of a strategy in FonGoods and therefore provides long-term volume flexibility.

Implementation

To implement the strategy, FonGoods carried out extensive research on available technology. This enabled the plant to invest in the most suitable type of equipment for its operations.

Inhibitors

Initially, installing new equipment created tension amongst operators as they could see their jobs disappearing. FonGoods, therefore, carried out a good education programme to allay operators' fears. Where operators had to be laid off, the plant introduced a voluntary and good redundancy package, which helped to maintain good relationships between management on the one hand and both the retained and redundant staff on the other hand.

9.4.6 Summary

Table 9.4.2 summarises the insights provided to answer the first Research Question.

RQ1: Under what conditions does FonGoods require high levels of volume flexibility?
Concept used: Drivers

Drivers of Volume Flexibility	Short product life cycle	Demand variability and uncertainty	New product development
Causal factors	• Market changes i.e. changing customer taste	• Changing customer requirements	• Changing customer taste

Table 9.4.2: Drivers of Volume Flexibility in FonGoods

Table 9.4.3 summarises the insights provided to answer Research Questions Two Three and Four.

RQ2: What are the enablers and inhibitors of volume flexibility in FonGoods?
Concepts used: Enablers and Inhibitors

RQ3: Why does FonGoods use these particular enablers to achieve high levels of volume flexibility? Or what makes FonGoods choose these enablers?
Concepts used: Benefits & Drivers

RQ4: How does FonGoods use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used: Key implementation factors (KIF)

Enablers of Volume Flexibility	**Banked hours System**	**Multiskilling**	**Varying lead times**	**New Technology or equipment upgrade**
Drivers	• High variability in demand levels • High overtime bills • Low productivity • Gap between shop floor & management	• High levels of volume flexibility • Localised skill base	• High variability in demand levels	• Growth in demand • Need for spare capacity
Benefits	• Provide volume flexibility • Low absenteeism • Increased productivity & motivation	• Provides volume flexibility through floating multiskilled team (+). • Limited to floating team (-)	• Provides volume flexibility	• Provides volume flexibility +) • Aids banked hours system (+) • Costly (-)
Inhibitors	• Refusal to pay back hours	• Not problematic	• Not problematic	• Creates tension amongst workers initially.
Key Implementation Factors	• Education & consultation • Tackle perceptions • Incentive – discount payback hours • Gradual implementation • Good equipment and labour capacity analysis • Self managing – peer pressure • Rules & regulation to discourage refusal to pay back hours.	• Dedicated team members as a floating shift. • Good training	• Good relationship with customers • Volume discounts • Multi-lingual personnel on site for overseas customers • Reduced customer base. 5 major ones.	• Educate workers • Introduce voluntary and good redundancy package. • Extensive research on available technology

Table 9.4.3: Enablers of volume flexibility in FonGoods.

Figure 9.4d shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, absenteeism and equipment breakdown.

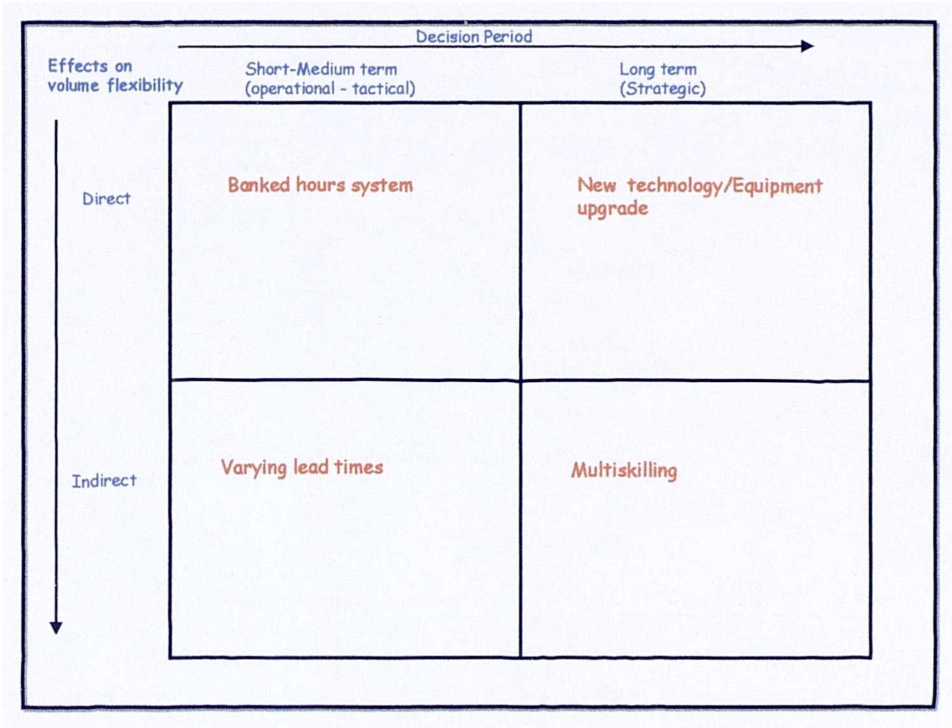

Figure 9.4d: Decision-hierarchical view and effects of enablers on volume flexibility

9.5 Chapter Summary

This chapter has carried out the within-case analyses of four of the eight plants selected for the case studies (i.e. Engico, Teleco, Proceco and FonGoods). In each of the cases, the contextual factors of the plant and the characteristics of the market in which the plants operate are discussed. Where data are available, the aggregate demand profiles and production plans of the plants are presented.

Data analyses of interview transcripts were carried out by thematic coding and content analyses to identify emerging themes and concepts that provide insights into the Research Questions (Eisenhardt, 1989; Miles and Huberman, 1994; Yin, 1994).

The analyses revealed various conditions that drive the plants to require high levels of volume flexibility (*Drivers of volume flexibility – RQ1*). The drivers identified include *high demand level variability, shortening product life cycle, competition and high uncertainty of demand levels* (Slack, 1987; Swamidass and Newell, 1987; Oliff and Marchand, 1991; and Hyun and Ahn, 1992). The analyses, however, reveal that these drivers are not applicable to all the plants studied.

The analyses also identified the factors that aid and prevent the achievement of volume flexibility in the plants studied (*Enablers and Inhibitors RQ2*). Enablers identified include the use of *banked hours system, multiskilling, using sister plants and sub-*

contracting (Adler, 1987; Kohler, 1989; and Grey and Corlett, 1989). The plants generally do not have problems implementing many of the enablers to achieve volume flexibility. For the banked hours system, inhibitors to implementation include *union resistance and obtaining payback hours from operators*.

Further analyses were carried out to investigate why some plants use some solutions to achieve volume flexibility and other plants use other solutions (RQ3). The analyses reveal that a plant chooses to use a particular enabler depending on the market conditions which it is exposed to (i.e. *drivers* – e.g. *high variability in demand levels*). The plant continues to use the enabler or desires its use in the future because of the perceived gains from the use of such a strategy (e.g. *benefits* from the use of *banked hours system* include *elimination of overtime and its attendant costs and reduced absenteeism*).

Finally, analyses were carried out to investigate how the plants actually implement the enablers and overcome the inhibitors to achieve volume flexibility (*Key implementation factors – RQ4*). For instance, in order to implement the benefit hours system, Teleco generally *rewarded its operators financially, had extensive communications and consultations with union members and operators and the implementation was be done in a gradual manner* (Tranfield and Smith, 1990).

The next chapter will describe the within-case analyses carried out at the four other case study plants.

Chapter 10 – Research at Foodco, Lachstone, Plastico and Electco.

10.0 Introduction

This chapter is divided into four main sections. Each section discusses and analyses the research carried out in the remaining four plants selected for the case studies (Foodco, Lachstone, Plastico and Electco). In each of the cases, the manufacturing manager or the production manager was interviewed and some quantitative data were collected. The within-case analyses were carried out in line with the Research Questions for the research project. The cases have been described and analysed in the following sequence:

1. Contextual considerations/Description of operations/Market characteristics – to provide insights into why some factors (e.g. drivers and enablers of volume flexibility) are more important or used in some plants than in others
2. Drivers of volume flexibility – to identify the drivers of volume flexibility in the plants and the causal factors for the drivers (RQ1)
3. Enablers of volume flexibility – to identify the enablers and the inhibitors of volume flexibility and to explain how the plants implement the enablers to achieve volume flexibility (key implementation factors)
4. Summary of analyses

10.1 Case Analysis - Foodco

The manufacturing manager was interviewed (the source of all the quotes cited in the case study). Data on the annual production requirements were collected. The contract agreement of the flexible working scheme (annualised hours contract) that was introduced into the plant was not made available. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. Focus was on identifying the following:

1. *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2. The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3. The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4. The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

10.1.1 Contextual Considerations

The plant belongs to the food sector. A food processing plant, it has two main units defined by the nature of the products. These are the wet food and the dry food units. The dry food unit is the newer of the two and has more stock keeping units (SKUs). Forecasting demand for its products is more difficult. The lines in the two units are run 24 hours a day, 5 days a week.

The plant employs 168 people directly involved in production operations. Foodco has about 100 suppliers and the average purchasing lead-time is 7 days. The average manufacturing lead-time is 1 day and the average customer lead-time is 3 days.

10.1.2 Market Characteristics

The plant belongs to a large multi-national company, which has several other manufacturing sites. The plant supplies its product direct to the group's central distribution warehouse from where supplies are sent directly to customers. Another company within the group handles orders, marketing and sales and final distribution. While the end customers for the plants' products are the big UK retailers, to a very large extent, the plant's direct customer is the sister company within the group. The plant also makes some products for export.

Some of Foodco's products are clear brand leaders in the UK market. However, the focus of competition for the plant has widened from just competing in the market place to competing with other plants within the group, particularly since there is pressure on the group to close down some of its plants within 5 years.

10.1.3 Operation

Harvested seeds are supplied, checked for quality and screened for impurities. Before the seeds are stored, they are dried to reduce the moisture content allowing them to be stored without fear of deterioration. Once dried, various batches are blended to maintain uniformity and stored in vast silos ready for use. When required, the seeds are taken to the mill where they undergo several processes to reduce them to the flour form of the product. This is mixed with other ingredients to produce a wide range of the plant's wet food (wet food unit) and dry food products (dry food unit).

10.1.4 Drivers of Volume Flexibility

Figure 10.1a below shows the drivers of volume flexibility in Foodco and the causal factors for these drivers.

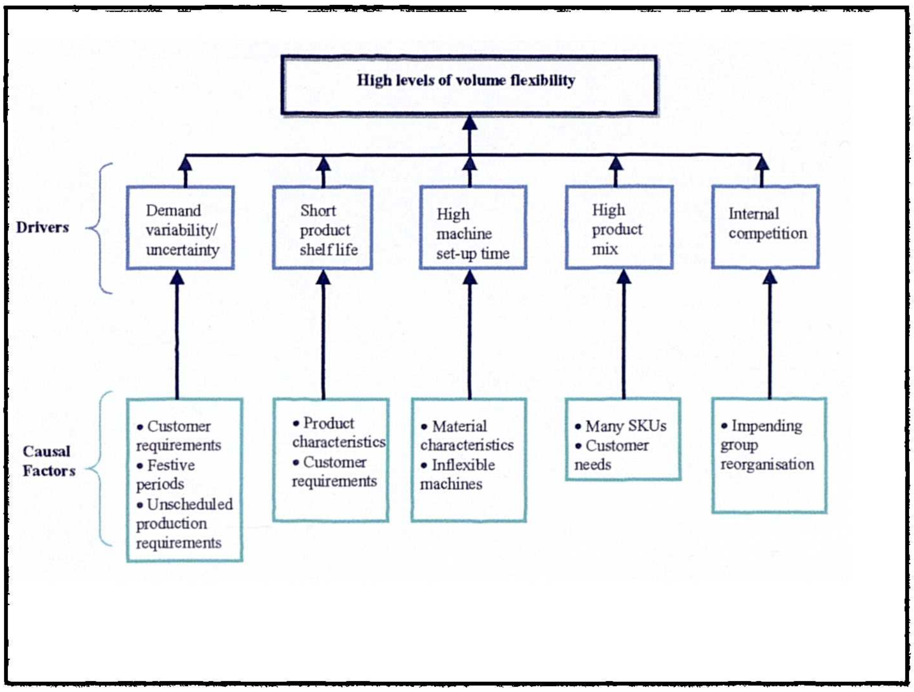

Figure 10.1a: Drivers of volume flexibility in Foodco

Demand Variability and Uncertainty

Figure 10.1b below shows the annual production requirements in terms of running hours per week for one of the main units in the plant. The figure gives an indication of the demand variability that the plant experiences. Generally, the average running hours per week tend to increase in the latter part of the year (periods 7 to 12) indicating some level of demand seasonality.

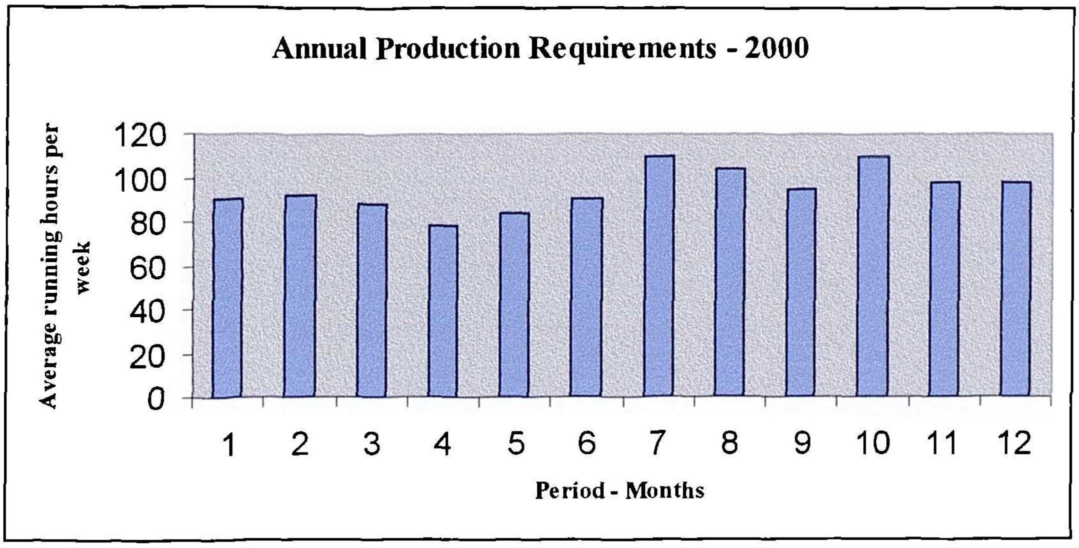

Figure 10.1b: Annual production requirement of Foodco

The plant is relatively busier towards the end of the year to cater for an anticipated surge in demand levels over Christmas. The plant had tried to employ overtime hours to cope during the peak periods. This was problematic. First, there was the cost of using it.

"People liked the overtime for a few weeks, and then they start to make choices when it goes on for a long time because the peak periods go on for a long time. Then it became difficult to get people when the plant needed them".

Labour was unavailable and absenteeism went up. The plant had to employ a flexible strategy such as an annualised hours contract to cope with predictable peaks and troughs in demand levels and short-term demand uncertainty. How it implemented the strategy is explained in section 10.1.5. Variability also exists within the peak periods, but total demand, usually over one year, is fairly predictable.

Order sizes range from as low as 100 kilograms to as high as 1000 kilograms and there are variations in the mix of products as well. These call for flexible equipment and strategies that can handle efficiently small and flexible batch sizes. The plant has been able to achieve the required flexibility in the dry food unit (Section 10.1.5) but the wet food unit is incapable of producing in small batch sizes.

Short Product Shelf Life

The average shelf life of the plant's products is about 9 months. As a first approximation this is fairly comfortable and the plant could afford to make for stock. However, because the supermarkets would not take a product with less than three-quarters of its shelf life left, the plant is left with a shorter time to deliver its products. Thus, the length of time that the products stay in stock is relatively short. The implication of this is that although the actual shelf life of the products is relatively long, the effective shelf life (about 2 months from the plant's point of view) drives the plant to require flexible strategies.

High Product Mix/High Machine Set-up Time

The plant runs generally on weekly batches in the wet food unit and on daily batches in the dry food unit. Weekly production restricts the flexibility of the plant, especially in the wet food unit, as it is impossible to handle efficiently many SKUs.

In the wet food unit, the machines are older and highly inflexible in terms of the capability to handle smaller batches and do quick changeovers. There are other constraints, like cleaning times and size change times.

"For example some of the chemicals we use for cleaning have a minimum contact time, so you can't do anything about that. That restricts the mix. So we tend to do weeks of different types of products rather than days".

These factors drive the plant to require flexible strategies, such as the use of an annualised hours system (to provide tactical volume flexibility) and upgrading equipment (to provide long-term volume flexibility). Both have been fully implemented in the dry food unit. The annualised hours system, which is a tactical solution used to achieve volume flexibility, is the only strategy of the two that has been implemented in the wet food unit.

Internal Competition

The group to which the plant belongs is planning to shut down a number of sites. This puts Foodco under some kind of pressure to perform or be closed down. The focus, therefore, of competition has widened from just competing in the market place to competing with other plants within the group. Innovative ideas are being generated within the plant in order to cut cost and improve the bottom line. This sort of internal competition has driven the plant to implement many innovative strategies including volume flexibility strategies such as an annualised hours contract.

10.1.5 Enablers and Inhibitors of Volume Flexibility

This section discusses the solutions, which the plant employs to cope with the drivers of volume flexibility discussed in the previous section.

"The first point of call is to make the lines work better (process efficiency), second is to see whether the product can be produced anywhere else on the site (sister unit plant on site). Third is using extra hours (annualised hours contract). Fourth point of call which is one we have investigated but have dismissed this year is to go onto a 7 day running".

Figure 10.1c summarises the enablers (strategies used to achieve both short-term and long-term volume flexibility) in the plant. It highlights the inhibitors or problems encountered in implementing these strategies and discusses how the strategies have been implemented (key implementation factors).

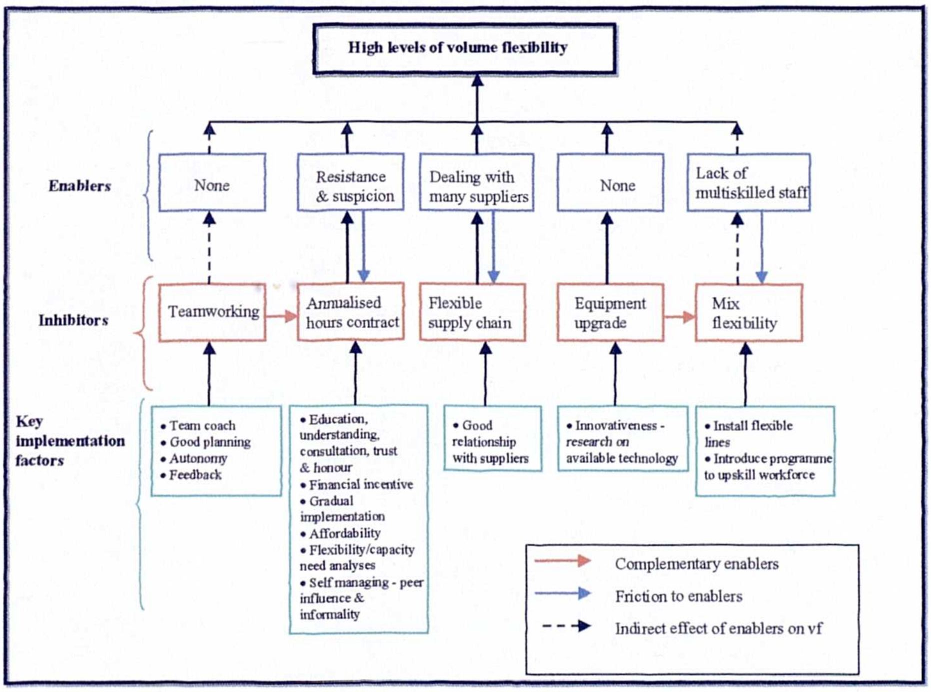

Figure 10.1c: Enablers of volume flexibility at Foodco

Teamworking

Teamworking was introduced in the plant to remove demarcations and encourage better relationships amongst the workers on site, to improve performance and to increase responsibility and ownership. Although it was not originally intended to be a direct enabler of volume flexibility in the plant, the strategy facilitated the successful implementation of annualised hours system which provides high levels of volume flexibility.

Implementation

The strategy was not problematic to implement but it owes its success to various factors. The move to the teamwork system took about 12 months of planning. The planning was conducted by a steering group, which met regularly to define the modality of the system. Setting up of improvement groups, which were cross-shift and cross-functional was the first physical step to changing. Based on the recommendations of the improvement and the steering groups the teamwork system was introduced into the plant. Significant to the success of the teamworking system implementation is the appointment of a team coach who oversees the overall activities of the team. The team coaches are adequately trained to perform their duties. The teams are given total autonomy in the way they set their targets and choose their leaders. A feedback system was also introduced for evaluation of performance against targets.

Annualised Hours Contract

Prior to the introduction of an annualised hours system, the plant had depended on the use of overtime hours to cope with variability in demand levels. The trouble with that was because demand tends to stay up for a long time during the peak season, the zeal to work overtime hours drops after a few weeks. It was becoming difficult for the plant to get people when they needed them, the level of absenteeism went up and from a management perspective, it was difficult to forecast the labour cost per year.

"We couldn't predict accurately how much it was going to cost us".

Implementing an annualised hours system was Foodco's solution to the problems.

Implementation

With the system an individual worker is contracted and paid for a year to work 1900 hours. 1750 hours are rostered and committed. The distribution of these hours depends on the predictable variability in demand levels over the year. The remaining 150 hours are called reserved hours and the worker can be called to use these hours when required to cover uncertain or unpredictable changes in demand level requirements including an increase in demand levels over and above forecast, absenteeism and equipment breakdown. However, the aim of the plant and all workers is not to use these reserved hours. Annualised hours contracts work well if the total demand over the planning period (usually one year), is reasonably predictable.

"The less predictable your demand is, the more reserved hours I guess you will have to have or the less rostered hours you will put in".

Thus, it was important for the plant to have some degree of predictability of their customer demand levels. This provides visibility for both management and staff and planning can be done a year in advance so that everybody knows which team is on which week for the entire year.

A number of factors were responsible for the successful implementation of the strategy in the plant. The system was implemented gradually. At the time it was introduced, there were five factories on site, so it was implemented in one factory first. The successful running of the system led to its full implementation across the entire site.

Having teams that work efficiently in the plant facilitated the implementation of the system. The teams set rosters and they can change start and finish times. There is no clocking system and the system is run informally and self managed. Regarding the reserved hours, teams decide in the main when to use them. This improves productivity and morale as people spend less time at work.

It was important for Foodco to have adequate preparation for the launching of the system.

"We had nine months to prepare for it. We talked to the workforce, educated them in various things about what we were trying to do, why we were doing it, we showed them various schemes, and in fact whatever information they wanted, they got".

Extensive consultations, negotiations and meetings were held with workers and unions to sell the idea to them. Having implemented the system, the successful running of it also depended on building the trust between the management and operators. Management had to trust the teams and operators not to exploit the system.

For the successful implementation of the scheme, the plant had to decide how much flexibility it needed in its system and also how much money it could afford to pay. In other words, they carried out comprehensive flexibility and capacity needs analyses.

These helped to determine the number of committed and reserved hours per worker that was to be agreed upon.

With the introduction of the annualised hours scheme, the plant moved from weekly to monthly pay. In order to reduce the financial effect of this on the workers, the company offered to finance people through their first two or three months pay. So when they came off hourly pay, they gave them for instance a month's pay in their last hourly pay cheque and then took the money back over the next three months, interest free.

Inhibitors

In spite of the apparent good implementation procedure undertaken by the plant, they ran into a number of problems. People who were making a lot of money on overtime obviously did not want to buy into it.

"In terms of pay, we didn't generally have problems with those people whose basic pay originally was say about £11,000. With the new scheme, they got paid about £14,000, so they are better off although they used to have some overtime on top of the £11,000. The problem was people who were working excessive overtime hours and were making like £21,000 in the case of operators and engineers making up to £35,000. They were the ones who moaned the most".

Getting the scheme implemented met with a lot of resistance and suspicion. *"The operators reluctantly accepted it in the first department. The engineers were essentially saying, "no way""*. This is probably because the deal went against people's paradigm of working. That is,

"...I come to work, I get hourly pay, I can choose when I have my holiday, I can choose when I do my overtime. You now want to tell me what hours I am going to work every week, what weeks I can take off during the year and I've got no chance of earning overtime, it's just not on".

With more consultations and education, the operators reluctantly accepted the deal. But with continued resistance from the engineers, the system had to be forced in.

"Our Managing Director stood up in front of them and said I could fill the football ground across the road with new applicants for your engineering jobs, you either vote now on this deal or I'll put an advert in the paper for your jobs".

Supply Chain Flexibility

Yield is an important factor for the business. Low yield of raw materials could impair the ability of the system to meet production volume requirements. Yield also has implications for planning and scheduling in the plant.

Implementation

The plant works closely with the farmers in the upstream end of the supply chain to improve the yield of the seeds.

Foodco has many suppliers but chooses to have a very close relationship with only those that supply specialised materials. Other suppliers that represent about 80% of the total number of suppliers supply off-the-shelf products which are easily obtainable. The close relationship that the plant has with its specialised suppliers enables it to enjoy a relatively short purchasing lead-time (7 days), and a reduction of time wasted on quality control and flexibility.

"We've got a good relationship with most of our suppliers and they give us the flexibility that we need".

Equipment Upgrade/Investment and Mix Flexibility

Due to the changing market requirements and the requirements for more SKUs, the plant required a flexible plant capable of producing many SKUs within a week as opposed to running weekly batches, as is the case in the wet food plant. Foodco also needed a plant that could run smaller order sizes as sizes of orders were falling. The minimum order size that was possible was 750 kilograms. The result was an innovative idea that led to the installation of mixers (dry food unit) which were primarily used in pharmaceutical plants. The mixers were more expensive than normal food mixers. But not only could these mixers change over quickly between different SKUs, they had the capability of running batch sizes as low as 100 Kilograms. By investing, therefore, in new equipment, the plant was able to achieve mix flexibility on the one hand with the capability to produce efficiently many SKUs. On the other hand it was able to achieve long-term volume flexibility because of the ability to handle more variable order sizes. It could also be argued that achieving mix flexibility, as described above, has an indirect positive effect on volume flexibility, as the plant is able to adjust quickly to relative volume changes within mix.

10.1.6 Summary of Analyses

Table 10.1.1 summarises the insights provided to answer the first Research Question.

RQ1: Under what conditions does FoodCo require high levels of volume flexibility?
Concept used to answer this question: Drivers

Drivers of Volume Flexibility	Demand variability and uncertainty	Short product shelf life	High machine set-up	High Product mix	Internal competition
Causal Factors	• Demand peaking at festive periods • Customer requirements • Unscheduled production requirements	• Product characteristics • Customer requirements	• Inflexible machines • Material characteristics	• Many SKUs • Customer needs	• Impending group reorganisation

Table 10.1.1: Drivers of volume flexibility in Foodco.

Table 10.1.2 summarises the insights provided to answer Research Questions Two, Three and Four.

RQ2: What are the enablers and inhibitors of volume flexibility in Foodco?
Concepts used: Enablers and Inhibitors

RQ3: Why does Foodco choose to use these particular enablers to achieve volume flexibility?
Concepts used: Benefits and Drivers

RQ4: How does Foodco use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used: Key implementation factors (KIF)

Enablers of Volume Flexibility	Team working	Annualised hours system	Supply chain flexibility	Equipment Upgrade	Mix Flexibility
Drivers	• Grow relationship across site • Increase responsibility and ownership • Performance improvement	• High variability in demand levels (in seasons) • High absenteeism • Poor visibility of Labour cost • Unavailable labour for peak periods	• Yield factor	• High Seasonal demand • High product mix • Inflexible machine • Smaller batch sizes	• High product mix
Benefits	• Facilitated annualised hours system	• Lower absenteeism • Little management input required • Provides volume flexibility • Can budget easily for year	• Provides volume flexibility • High yield of raw materials	• Provides volume flexibility	• Aids volume flexibility
Inhibitors	• None	• Resistance and Suspicion	• Many suppliers	• Not problematic	• Lack of multiskilled staff
Key implementation factors	• Team coach • Self assessment • Planning • Training • Feedback system • Autonomy	• Education, understanding and Consultation • Gradual implementation • Financial incentive • Affordability • Capacity need analysis • Self-managing - Peer influence and informality	• Good relationship with small number of specialist suppliers	• Innovativeness – research on available technology	• Flexible equipment • Programme to upskill workforce

Table 10.1.2: Enablers of volume flexibility in Foodco.

Figure 10.1d shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, short-term demand uncertainty, absenteeism and equipment breakdown.

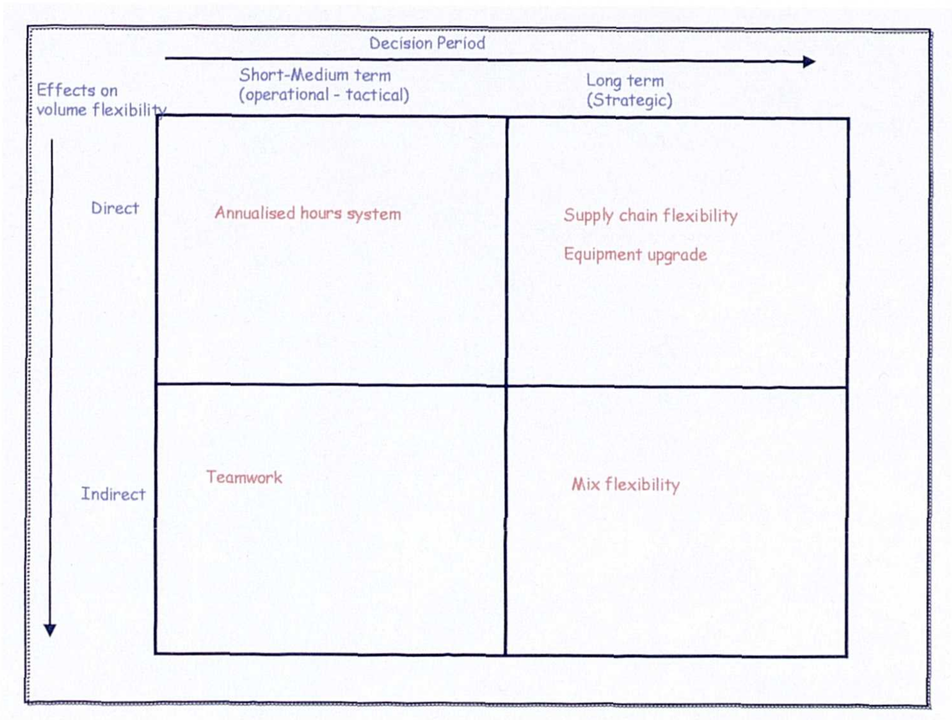

Figure 10.1d: Decision hierarchy view and the effects of enablers on volume flexibility

10.2 Case Study Analysis – Lachstone

The manufacturing manager was interviewed (the source of all the quotes cited in the case study). Data on the weekly production plan and daily actual production against plan were collected. The contract agreement of the flexible working scheme (annualised hours contract) that was introduced into the plant was not made available. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1. *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2. The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3. The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4. The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

10.2.1 Contextual Considerations

Lachstone belongs to the Engineering consumer sector. The plant has other sister plants, one in the UK and in Europe, in France and Germany. The turnover of the plant is about £20 million. The product range includes goods, which are predominantly storage cabinets, sliding door units, pedestals that go with desks and, systems furniture. There are 135 people on site, 85 of whom are direct employees carrying out value added work, and the remainder of whom are indirect and support staff.

The plant has about 32 suppliers of components and raw materials. The average purchasing lead-time is 10 days, the average manufacturing lead-time is 20 days and the average customer lead-time is 40 days.

10.2.2 Market Characteristics

Lachstone supplies the professional services market. It concentrates on the FTSE 100 customers and has contracts with top management and financial consulting firms in the UK. The plant sells through a dealer network that has its own installation and offers the possibility of moving furniture around, dismantling it, reconfiguring it and adding new bits to it. One of the challenges to Lachstone in design is, therefore, to be able to produce furniture that is easy to reconfigure.

10.2.3 Operations

The figure below describes simply the plant's operations and the material flow through the production system.

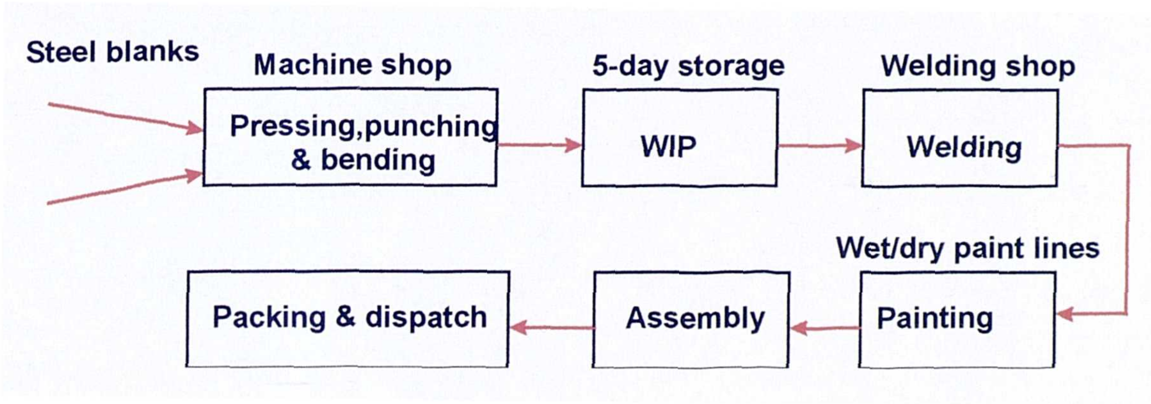

Figure 10.2.1: Lachstone's production process chart

Steel blanks come in as raw materials and are put through the pressing, punching and bending processes in the machine shop. The shop operation is run on a weekly batch production, so the prccessed steel is put into work in progress (WIP). Upon receipt of product orders, the processed materials are called up from the WIP and passed on for welding, and then unto the painting lines where wet or dry paint is applied, depending on the customer requirements. The painted material is then assembled, packed and dispatched. From the WIP down to packing and dispatch, the operation runs daily on a make-to-order basis.

10.2.4 Drivers of Volume Flexibility

The figure below shows the conditions that drive Lachstone to require high levels of volume flexibility and the factors responsible for these conditions.

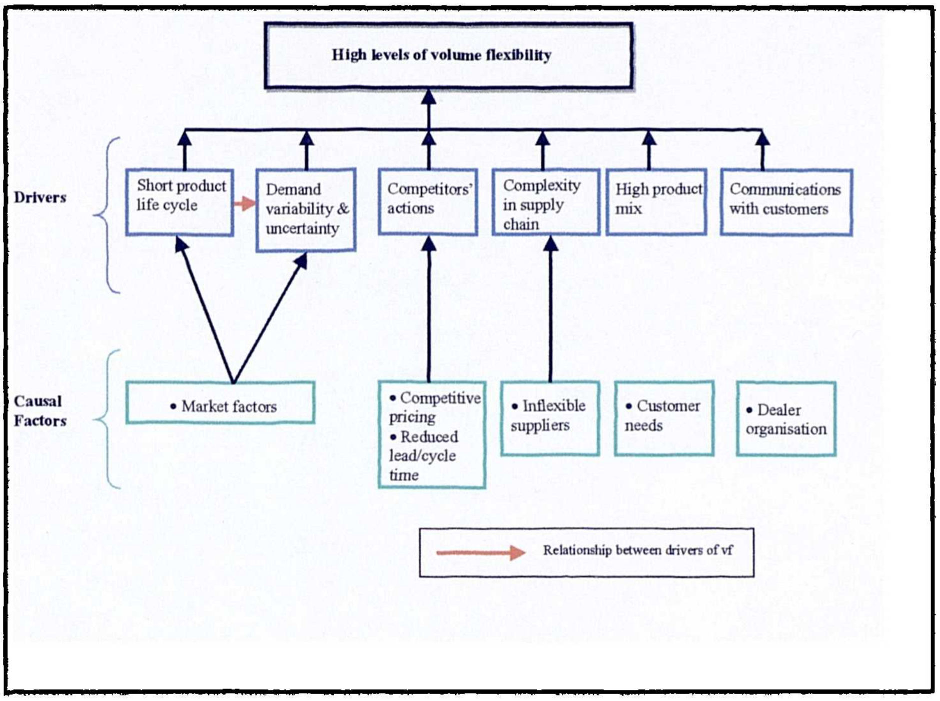

Figure 10.2b: Drivers of volume flexibility in Lachstone

Demand Variability and Uncertainty/Short Product Life Cycle

The changing nature of the market place and the attendant different organisational changes like downsizing, amalgamating departments, movements from one operation to the other, all affect people's working environment. Organisations respond to these changes in many ways. These changes have implications for investment in furniture by organisations and a knock on effect on the order sizes for the plant.

"What that means is that over a period of time you set up from a manufacturing point of view to make very efficiently very high volumes, and over a period of time, when that product dies you still have this very low volume, very big peaks and troughs in capacity needs as a new product picks up".

Downsizing or amalgamating departments may imply high variability in levels of demand for a particular product range.

"For example if we look at cabinets, our target is to produce 1500 cabinets a week. For the first quarter of the year, our lowest was 1192, and our highest was 1781. When we had 1781 units, our overtime went up".

Figure 10.2c below shows the aggregate weekly production plan and available capacity for Lachstone over a 9 week planning horizon.

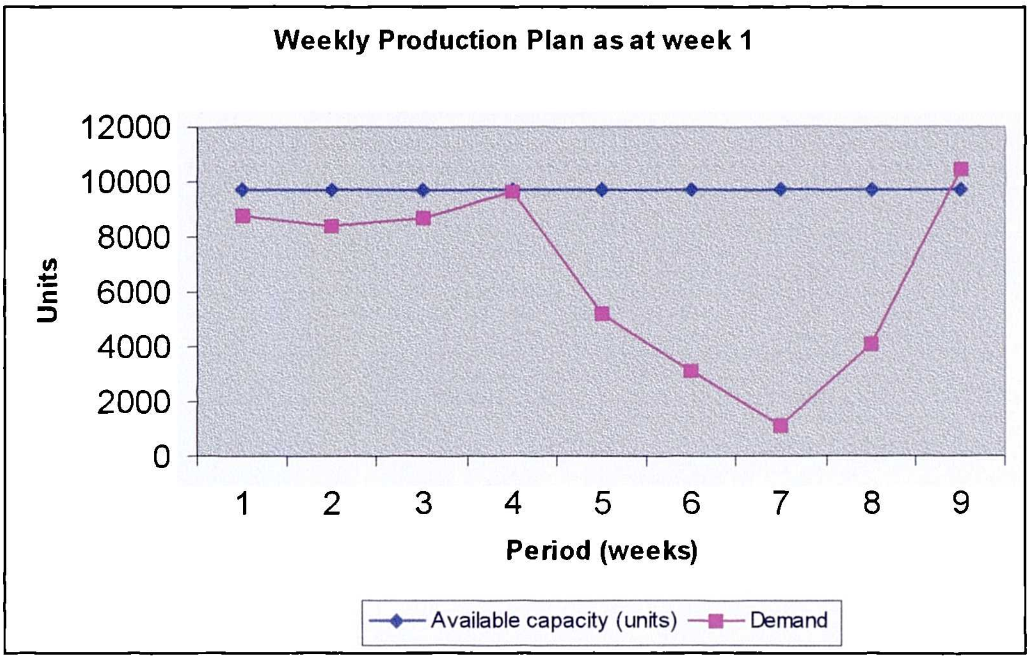

Figure 10.2c: Aggregate weekly production plan for Lachstone.

The figure above gives an indication of the variability in demand levels that Lachstone experiences. The plant has adequate capacity (in terms of labour and machine hours) to cope with expected demand from weeks 1 to 8. Only in week 4 would the plant be able to match demand with available capacity and thus operate at its highest efficiency. The plant has excess capacity over expected demand between weeks 4 and 8. Demand in week 9 is expected to overshoot available capacity by more than 500 units. The implication of the above is that the plant requires a flexible strategy that would enable it to contract its capacity in line with the expected fall in demand between weeks 4 and 8, and expand the capacity in week 9 to cope with the expected surge in demand for that week.

Lachstone also experiences variability in demand levels on a daily basis. Figure 10.2d shows the daily production profile.

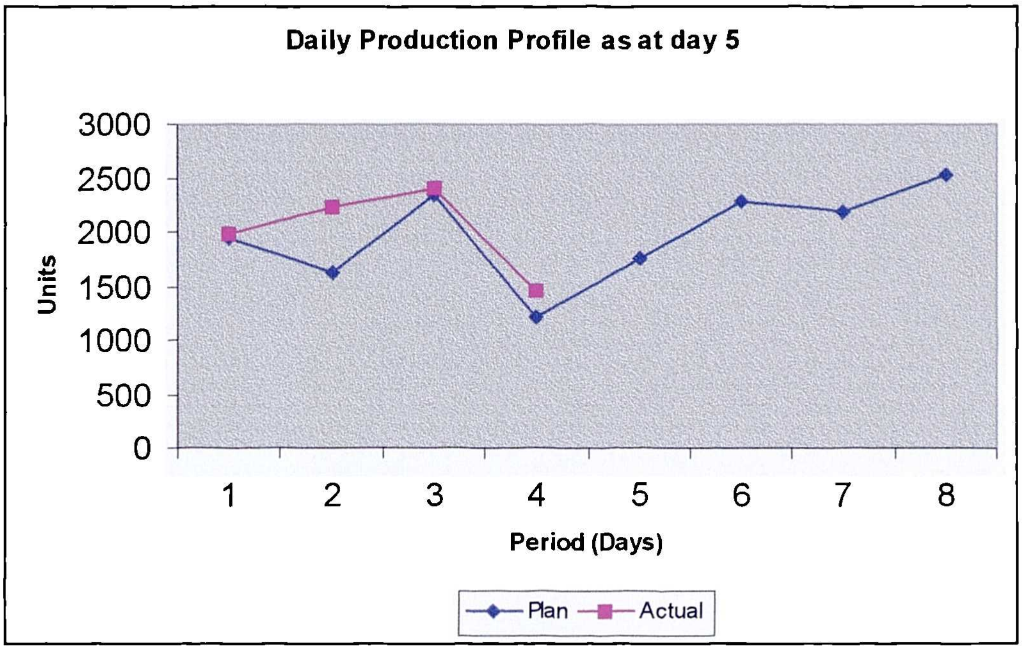

Figure 10.2d: Daily production profile for Lachstone

The figure above shows that variability exists on a daily basis. In terms of the plan or forecast, it ranges from about 1200 units (in day 4) to about 2532 units (in day 8) over two weeks. In terms of actual production, it ranged between 1447 units in day 4 and 2389 units in day 3. The relationship between the planned and actual production also highlights the levels of short-term uncertainty in demand levels at least on a daily basis, especially in day 2. However, over a period of one year the total demand is fairly predictable (no available data to support this).

Competitors' Actions

The market in which Lachstone operates is highly competitive

"You've got to be able to deliver it when required otherwise you don't get the business. We have managed to pinch some business from our customers because our lead-time is down to about 4 weeks".

There is also a lot of pressure on cost. *"Prices are coming down, so the costs have to come down"*. Therefore, rather than having 5 days' worth of work in progress on the shop floor, part of the machine shop is being sub-contracted to reduce the cycle time, and flexible strategies are now being employed to reduce the cost of overtime and excess capacity. In other words, the competitive nature of the market place is driving the plant to require volume flexibility strategies. Although it is sometimes possible for Lachstone to transfer work to its sister plants, there exists internal competition within the group.

"The sort of competitive environment we have in the group puts pressure on us to do everything to be flexible".

Supply Chain Complexity

The long customer lead-time (about 40 days on average) could sometimes be attributable to late deliveries of raw materials from suppliers. The plant deals with over 30 suppliers making it very difficult to develop a close relationship to enhance the effectiveness of the supply chain.

"Our suppliers are not reactive enough to our requirements. They are not as flexible as we would want them to be".

This is forcing the plant to look beyond their organisation to implement strategies that will result in a more flexible supply chain.

High Product Mix

Due to changing customer requirements, the product mix varies widely in terms of sizes and colours. This has volume implications in the plant.

"We offer about 30 – 40 paint finishes because this is what the market is demanding. These vary with order sizes".

Communications with Customers

The plant sells its products through a dealer network. The dealer is also responsible for obtaining orders from customers and translating these to the plant. The transfer of the demand information triggers planning and scheduling and subsequent production in the plant. Thus, errors in order information will result in excess or insufficient production. This forces the plant to require volume flexibility strategies to meet quoted lead-time effectively.

"I would say 15 – 20% of the orders that come through from our dealer organisation need cleaning".

10.2.5 Enablers and Inhibitors of Volume Flexibility

Figure 10.2e below summarises the enablers of volume flexibility (strategies that the plant employs to achieve volume flexibility) and the inhibitors (factors that prevent achievement of volume flexibility). It identifies the key implementation factors (KIF) for the implementation of the enablers (i.e. how the plant has gone about implementing the enablers and overcoming the inhibitors to achieve volume flexibility).

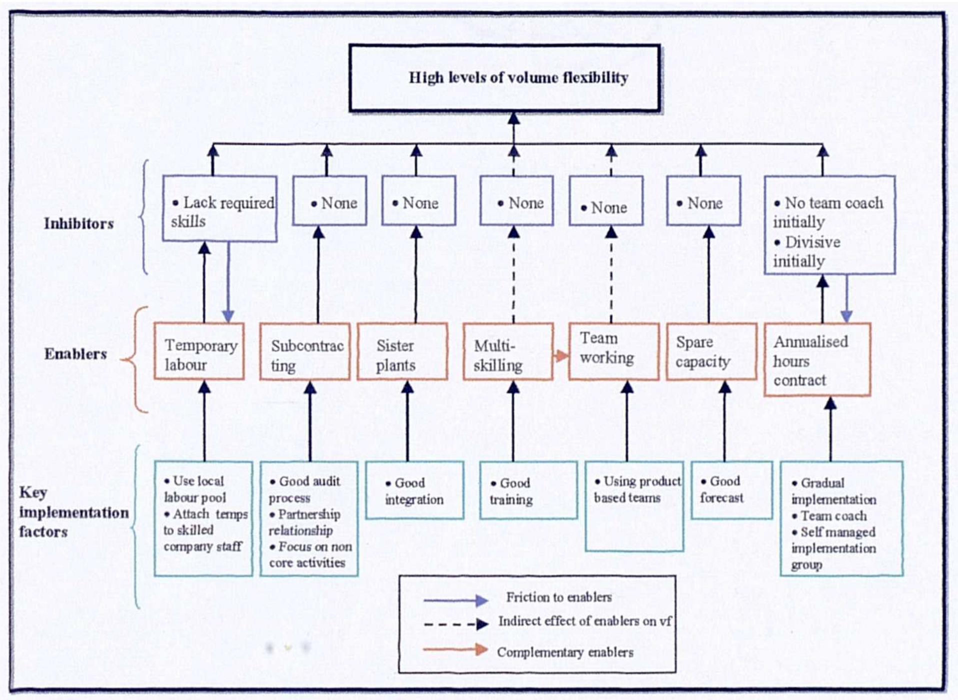

Figure 10.2e: Enablers of volume flexibility in Lachstone

Use of Temporary Labour

The plant makes use of temporary labour to supplement capacity when required. This strategy is a tactical solution to providing short-medium term volume flexibility.

Implementation

The plant uses the local labour pool from which temporary labour can easily be brought in within 24 hours if needed. They are retained, sometimes for as long as 6 weeks, depending on the demand level requirements. The job requires skills, so the temporary labour are usually attached to some experienced company staff in the particular shift in which they are required.

Sub-contracting

Rather than carry out the entire punching process in-house, Lachstone sub-contracts this activity to a sub-contractor. In order to reduce the cycle time and increase flexibility, the machine shop needs to be run on a daily basis rather than the weekly batch runs that the plant operates presently. Lachstone is trying to achieve that by sub-contracting the entire punching process so that rather than buy sheets of blank steel, they will be purchasing punched blanks directly from sub-contractors. So, Lachstone uses subcontracting as part of a strategy to provide long-term volume flexibility.

"We would like to increase our sub-contracting activities, particularly in the press shop. We want to specialise in doing things that other people can't do well i.e. the personalisation of our products (painting, styling and assembly)". In other words, non-core activities are preferably sub-contracted.

Implementation

There are a number of key factors that aid the successful implementation of subcontracting in Lachstone. The plant employs a good audit process, which is used to select who to use. The number of sub-contractors employed has also been kept to a minimum (only four for the press shop activities), hence it has been easy to manage and develop good relationships with them. Treating the sub-contractors as partners and having very close relationships with them has increased the responsiveness of the sub-contractors to Lachstone's demand, thereby providing the plant with some volume flexibility.

Sister Plants

The plant has a sister plant in the UK and others in Germany and France. Lachstone is able to send orders to any of these plants when it becomes extremely difficult to cope.

"This gives us an edge over our competitors. Some of our competitors don't have repeated manufacturing possibilities. We are able to buy from our sister plants from France and Germany to cope".

Having sister plants also provides the flexibility to reduce the effect of changing customer taste and of having products at the dying stages of the product life cycle.

"For example we have a product that is dying off in France, so we looked at the market and found that the product was still selling in the UK. So, we transferred the production of that product from France to the UK. But sometimes, we have to outsource, especially if the sister plants do not have the manufacturing capability".

Using sister plants in this way is possible because of the good integration, which Lachstone has achieved with its sister plants.

Multi-skilling/Teamworking

Coping with fluctuations in the plant is about training people in the right task. The aim of the plant is to be able to move people from one end of the plant to another depending on demand requirements. This is achieved by having multiskilled staff.

"What we try to do is to train people one operation up and one operation down at the minimum so that we know we can move people".

When people are multi-skilled, it becomes easier to have teams that are able to work on any process within the factory.

The plant believes it would be more responsive to customer requirements if it moved from a process-based organisation to a product-based one. So, rather than having people working specifically in different process areas, there will be teams across the factory making a particular product. Typically, a team would consist of multi-skilled workers who can work on a range of processes from the raw material stage (the press shop) down to the finished product stage (assembly, packing and dispatch). For such a strategy to work, the plant believes that people have to be clear about what their expectations are and to have good measures in place. The workers have to be adequately trained (multi-skilled), must be focused on continuous improvement and must be able to exchange opinions in a positive way. Multiskilling and teamworking are seen as complementary enablers having an indirect effect on the achievement of volume flexibility in Lachstone.

Spare Capacity

The plant operates on a two shift system (6am – 2pm; and 2pm – 10pm). It was essential for the plant to be able to manage their budgeted capacity on 2 shifts. This gives them some slack on a possible third shift (night) when required. Using a third shift is, however, a last resort.

"We try not to go to the limit. Rather, we look for options for processes within the budgeted capacity. Keeping the slack available is vital for us".

Flexi – Time Contract/Annualised Labour Hours Contract

Lachstone introduced the flexi-time strategy to provide labour capacity flexibility. It was introduced as a result of the need to cut the cost of overtime. With the flexi-time strategy the workers worked a minimum of 30 hours a week but were paid for 39 hours a week. They therefore banked 9 hours per week. 30 hours a week were available to cover scheduled variability in requirements within the week. The banked hours (9 hours) were used to cover short-term uncertainty (e.g. demand levels over and above weekly forecast and absenteeism).

Implementation

In implementing the flexi-time strategy, the plant started out with a trial group on the shop floor. It was important to get it right first before switching the strategy to the entire plant. This turned out to be a good decision because, as it turned out, the demand was constantly rising so the people on this scheme were now working more than 50 hours a week, which was over and above the flexibility that was built in. The number of people was inadequate to cope with the load being placed on them. A re-evaluation of the system was done and the approach was changed after about 18 months to an annualised hours scheme.

Under the annualised hours scheme, a worker gets paid for 43 hours a week (or 1935 hours a year). 40 of those hours are what the plant expects them to work every week (or 1800 hours a year). The 40 hours are used to cover predictable variability in production plans and schedules. The extra 3 hours a week (or 135 hours a year) are banked and called for when necessary to cover short-term demand uncertainty. Although it is referred to as an annualised hours contract, the new working system bears much resemblance to the discarded flexi-time strategy. On the surface it looks as if the plant has less flexibility than before, but the increase in the minimum time (from 30 to 40 hours a week) that can be worked provides additional capacity. The plant has run this scheme successfully on another trial group of workers and is in the process of transferring the scheme across the entire organisation.

Inhibitors

Starting the implementation of the annualised hours contract with a trial group was problematic. The team was seen as very different.

"...The other problem was that we didn't identify a team coach. We expected too much of the team to manage themselves. But it was useful because as you get these things wrong, you learn a great deal".

To manage implementation problems, Lachstone introduced a group, which it called the self-managed team implementation group. This group had representatives from management and shop floor. Problems were discussed, and the group came up with priority action plans to solve the problems.

"One of them being to put a coach in place, to look at plant maintenance and move to annualised hours for the entire plant. The strategy is very beneficial to us and we will continue to use it. What it means is that it reduces the overtime".

Although the plant still uses limited overtime, the rate has reduced from about 16% before the introduction of annualised hours to about 5% on average.

10.2.6 Summary

Table 10.2.1 below summarises the insights provided to answer the first Research Question.

RQ1: Under what conditions does Lachstone require high levels of volume flexibility?
Concept used to answer this question: Drivers

Drivers of Volume Flexibility	Short product life cycle	Demand variability and uncertainty	Competitors' actions	Complex supply chain	High product mix	Communication with customers
Causal Factors	• Customer requirements	• Customer requirements	• Cost pressure • Reduced lead-time/cycle time	• Inflexible suppliers • Many suppliers	• Customer requirements	• Dealer organisation

Table 10.2.1: Drivers of volume flexibility in Lachstone.

Table 10.2.2 summarises the insights provided to answer Research Questions Two, Three and Four.

RQ2: What are the enablers and inhibitors of volume flexibility in Lachstone?
Concepts used: Enablers and Inhibitors

RQ3: Why does Lachstone use these particular enablers to achieve volume flexibility?
Concepts used: Benefits and Drivers

RQ4: How does Lachstone use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used: Key implementation factors (KIF)

Enablers of Volume Flexibility	**Temporary labour**	**Subcontracting**	**Sister Plant**	**Multiskilling**	**Teamworking**	**Spare Capacity**	**Flexi-time/Annual hours**
Drivers	• High variability in demand levels	• Reduction of cycle time • Non core activity	• High variability in demand levels • Short product life cycle	• High levels of demand variability • High product mix	• High levels of volume flexibility	• High demand levels	• High levels of demand variability • Excessive overtime cost
Benefits	• Provides volume flexibility	• Provides volume flexibility	• Provides volume flexibility • Provides competitive advantage	• Provides volume flexibility • Aids effective teamworking • Aids annualised hours system	• Provides volume flexibility • Aids flexi-time system	• Provides volume flexibility (+) • Costly (-)	• Provides volume flexibility • Cuts overtime cost
Inhibitors	• Lack required skills	• None	• None	• None	• None	• None	• No team coach initially • Divisive initially
Key Implementation Factors	• Local labour pool • Attached to skilled company staff	• Good audit process • Partnership relationship	• Good integration	• Good training	• Multiskilling • Product based rather than process based teams	• Good forecast	• Gradual implementation • Self managed implementation group • Team coach

Table 10.2.2: Enablers of volume flexibility in Lachstone.

Figure 10.2f shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump, and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, demand uncertainty, absenteeism and equipment breakdown.

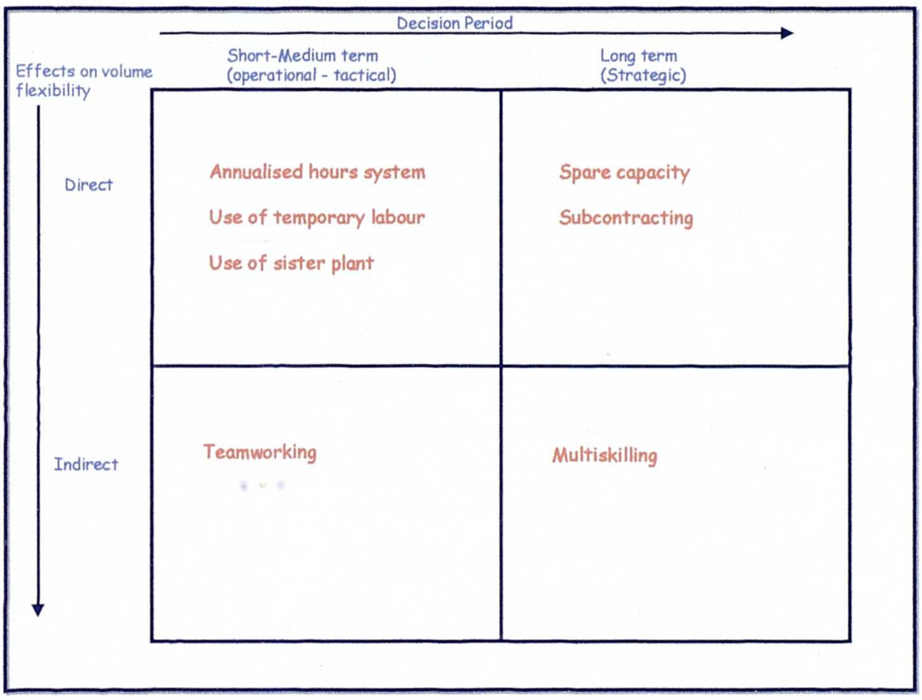

Figure 10.2f: Decision hierarchy view and effects of enablers on volume flexibility

10.3 Case Study Analysis - Plastico

The business process manager was interviewed (the source of all the quotes cited in the case study). Data on the annual production requirements was collected. The contract agreement of the flexible working scheme (annualised hours contract) that was introduced into the plant was not made available. The interview lasted about 2 hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1 *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2 The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3 The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4 The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

10.3.1 Contextual Considerations

The plant belongs to the household and general goods sector. Plastico is part of a large multi-national organisation, which has plants in Europe, Asia Pacific, North and South America. Employing over 12,000 people, the total net sales of the companies in Europe and the US in 1998 was over £6.8 billion. Plastico employs 650 employees involved directly in production operations.

The plant produces packaging materials used in packing food items such as turkey and cheese. Plastico has about 12 suppliers. The average purchasing lead-time is 7 days, the average manufacturing lead-time is 10 days and the average customer lead-time is 10 days.

10.3.2 Market Characteristics

Plastico supplies the big food companies in the UK that pack the birds using the wraps and bags produced by Plastico. The plant also has direct contact with the major food retailers in the UK to design packing solutions.

The plant has competitors in the UK and on a European basis. It tries to differentiate itself by focusing on a particular segment. The plant dominates the segment in which it operates. However, if it gets to a price competitive situation it would either use technology or leverage to overcome the threat. It would not go for head to head price competition. This is because it would not sacrifice its high gross margin of about 50 - 60%.

10.3.3 Operations

The main operation involves the extrusion of specialist polymers (purchased as raw materials) to various forms of multi-layer plastic conversion, printing and packing for dispatch. Another part of the operation involves putting resins in, blowing the bubble, folding and winding up the finished product.

10.3.4 Drivers of Volume Flexibility

Figure 10.3a below shows the conditions that drive Plastico to require high levels of volume flexibility and the factors responsible for these conditions.

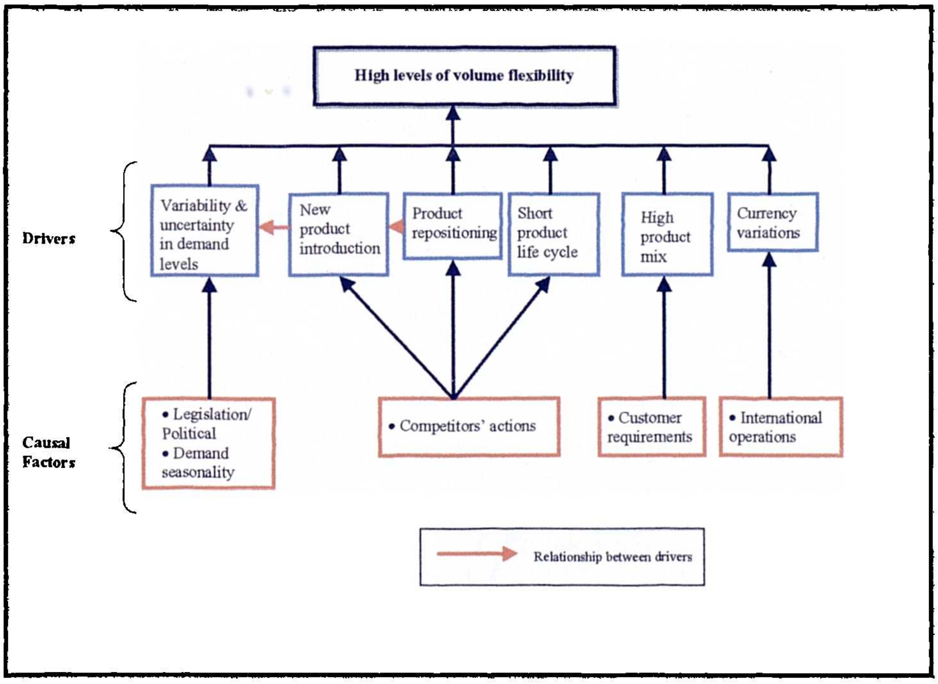

Figure 10.3a: Drivers of volume flexibility in Plastico

Variability and Uncertainty in Demand Levels

Demand is seasonal and peak sales are recorded during the Christmas and Easter period in the UK. Within these periods demand is highly variable and subject to very short lead times. However, this variability is relatively predictable. Legislation has also created uncertainty in demand levels for Plastico. For example, the plant had just launched a new beef bag designed in such a way that it could take beef on the bone. The bags are multilayered and patches are designed to be resistant to bone puncture. The business was witnessing a significant growth in volume in the UK in 1994/1995, but demand plunged thereafter because of the BSE beef crisis. That part of the plant's portfolio was significantly exposed as everyone was moving away from beef on the bone because of the ban on it.

Figure 10.3b below shows the aggregate demand forecast against actual production for Plastico. The patterns of the monthly forecasts and actual production reveal that the plant experiences variability in demand levels on a monthly basis. For instance, between January and June 1999 actual production ranged from as low as 19,000 units in February to about 30,000 units in March. The figure also shows that there are short-term demand uncertainties especially in February and April when actual production fell short of forecast by as much as 28% and 15% respectively. However, over the year these tend to "average out" such that total yearly demand is reasonably predictable.

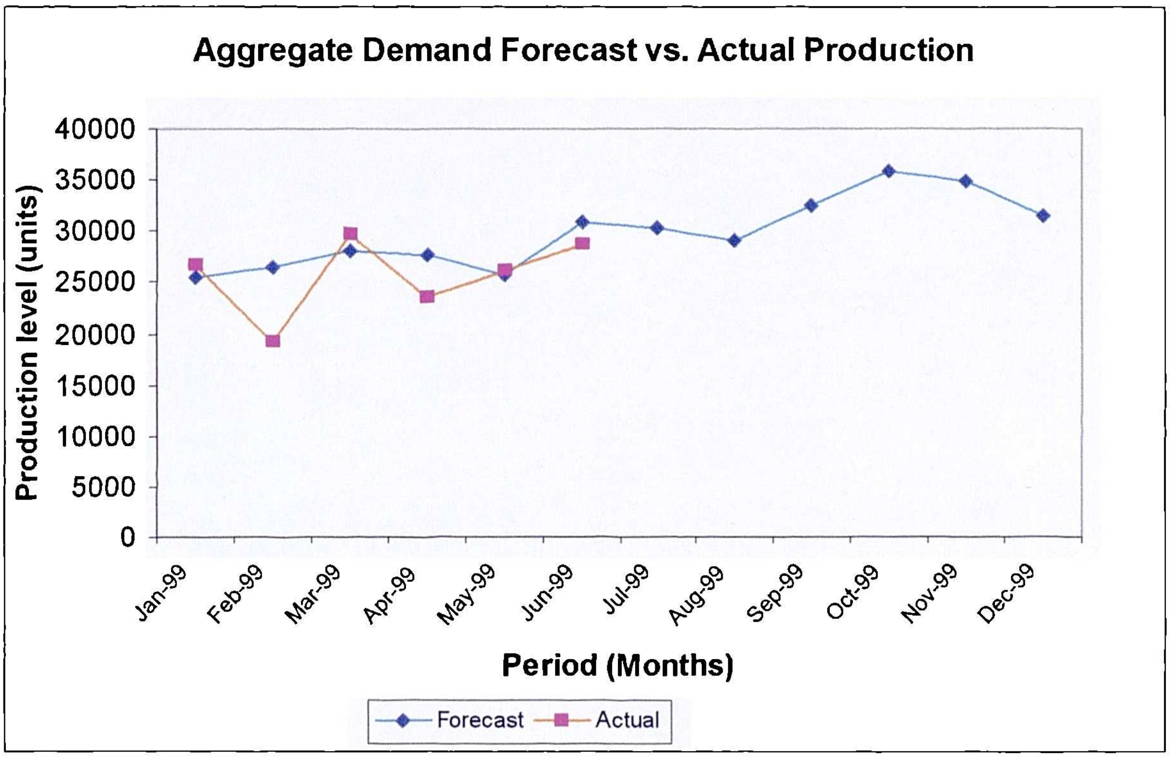

Figure 10.3b: Aggregate Demand Profile for Plastico: Forecast vs. Actual

Product Repositioning/Short Product Life Cycle/New Product Introduction

In response to competitors' threats, Plastico has a strategy of either defending its market share, repositioning its product, exiting the segment altogether or introducing new products. These all require that the plant has high levels of volume flexibility. In order not to be exposed to competition, the plant ensures that no product in its portfolio is more than 2 years old. That is, it is deliberately shortening the product life cycle. This leads to more frequent new product introductions, a deliberate strategy to ward off competition. The implication is that Plastico experiences at different times, variations in production volumes due to new and dying products. This strategy requires that the plant has the ability to adjust to relative volume changes within product mix (i.e. volume flexibility).

High Product Mix

There are various mixes of the finished product at each stage of the production process. Product mix can range from about 60 types of units at the raw material stage to about 280,000 at the finished product stage. This reflects the high changes in customer requirements. They may differ only in size, thickness, prints, designs and the like. Because there are varying volume requirements for these products, it is important for the plant to have the ability that would enable it to adjust quickly to relative volume changes within the mix.

Currency Variation

The increase in the strength of the pound relative to other currencies has had effects on the production volume of the plant. The last stage conversion of products is now being done near the market place because it is possible and more attractive to do it there.

"As a result of the currency movement, we are doing the customisation closer to the market while the initial value added operations are being held back in the capital intensive plants here".

The currency movement has meant that the plant's production output has fallen and it has moved from being a finishing plant (at least for the European Markets) to providing the expertise to areas nearer the market. It is able to do this successfully via the company's network of sister plants throughout Europe.

10.3.5 Enablers and Inhibitors of Volume Flexibility

The figure below summarises the enablers of volume flexibility (strategies that the plant employs to achieve volume flexibility) and the inhibitors (factors which prevent the achievement of volume flexibility). It identifies the key implementation factors (KIF) for the implementation of the enablers (i.e. how the plant has gone about implementing the enablers and overcoming the inhibitors to achieve volume flexibility).

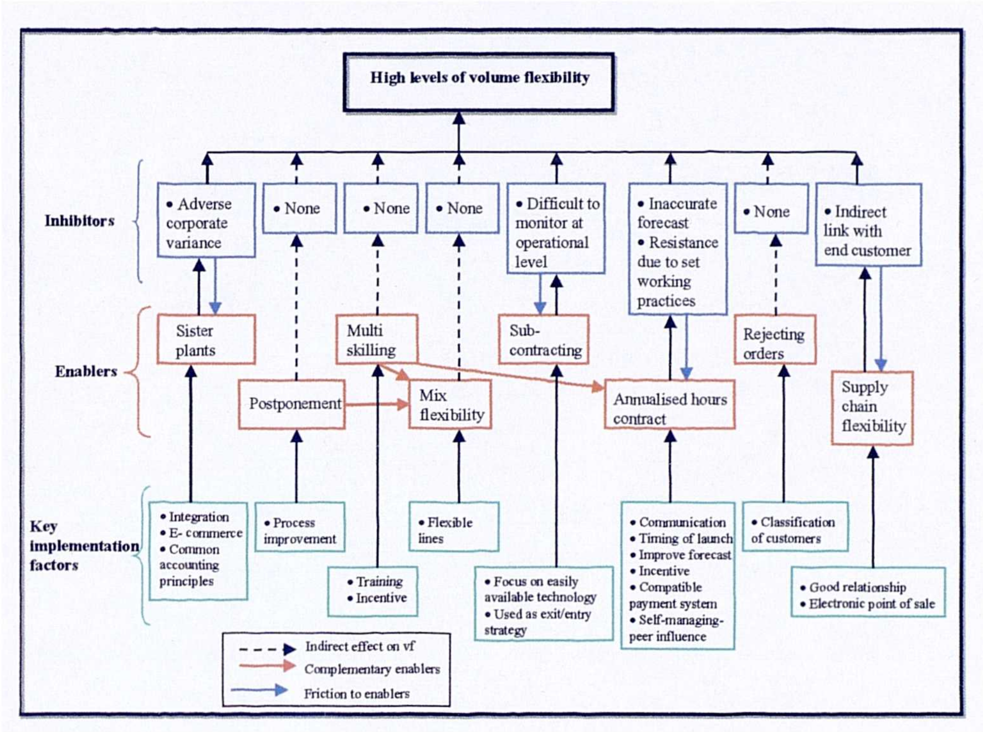

Figure 10.3c: Enablers of volume flexibility in Plastico

Sister Plants

Plastico is one of a network of plants in Europe that belong to a single parent company. Much of the volume flexibility that Plastico has is due to the network of plants. The plants are fully integrated with each other. The policy of the company is such that the plants have moved away from operating as single plants so that solutions to demand variability are being shared across the organisation.

Implementation

"What we've done is to unify the European customer service group so that they all meet regularly, they share a lot and this is important in being able to move work around because they all see that they are actually in a common pot of work".

The plants have a common view of the order book, common European cash point, electronic scheduling system, all facilitated by integration of servers making the networks relatively convenient for accessing information. These enable quick decisions to be made in terms of allocating loads across the network of European plants.

Inhibitor

Buying in from sister plants may lead to an adverse variance corporately, especially if one takes into consideration the different accounting principles being used in the different countries in which the company operates.

"So, what we've done is to have systems that work on management accounts so that you make decisions on a flat playing field".

Although not all the sister plants produce similar products or have similar processes, it is possible to move products between the plants either in the finished form or the semi-finished form.

"We have lots of intermediate products coming in at different levels from our sister plants that allow us to do a lot based on different volumes".

Supply Chain Flexibility

Having an effective supply chain has also provided the plant with volume flexibility. Managing the supply chain effectively is vital for Plastico because of the high number and types of components that the plant uses at various stages of the production and the indirect contact it has with its end customers.

Inhibitor

Achieving the smooth flow of products and information in the supply chain has been problematic because the plant produces directly for the converters who then pack the final products (beef, cheese etc.) for the grocery retailers. Thus, changes in requirements by the grocery retailers are not easily and correctly transmitted to Plastico.

Implementation

To overcome the problem discussed above, the plant has been proactive in its effort to have a closer relationship with the grocery retailers. So, although the plant still supplies to the converters, it has a good working relationship with the end customers. This is facilitated by the use of the electronic point of sale system that monitors the stock levels of the retailers.

Postponement/Multiskilling/Mix Flexibility

The plant has carried out a number of process improvements in order to be able to respond better to customers' requirements. Although the end products are customised, as one moves back up to the bill of materials they are actually increasingly common (i.e. adaptable to different uses). The production process is now such that there is a de-coupling point along the process. Semi-finished products are held at this de-coupling point.

"As orders come through, we will be pulling from the semi-finished stage. So we tend to hold at about 3 levels back so that we don't lose much if the orders don't come through. If we look at our planning system, there is a lot of actual orders, and a lot of potential orders two levels back".

At the de-coupling point, the semi-finished products can still be converted into a wide range of finished products. Thus, the actual cycle time of getting the final products to dispatch is reduced. This has an effect on volume flexibility. Also, the plant is able to produce quickly a variety of products, which gives it high levels of mix flexibility.

With a wide range of products produced on different lines and with the products being subjected to varying demand levels, it was important for the plant to increase the skill levels of its workers (multiskilling) so that it was possible to move people around based on loading requirements. Multiskilling thus enables the achievement of volume flexibility.

"A lot of the negotiation was based on taking away traditional department boundaries and removing demarcations where engineers and fitters will run machines.. ".

To encourage multiskilling, workers' salaries are increased each year based on the level of skills that they have acquired over the previous year. So, having a multiskilled workforce has helped Plastico to achieve high levels of mix flexibility since, for example, the same set of workers is able to handle different lines required for different products.

"It is now possible for us to move manning traditionally based on set ups increasingly to work across areas whereby, if we are quiet here, it's quite a normal thing to work in the busy areas".

Sub-contracting

Plastico has used sub-contracting as part of a strategy to achieve long-term volume flexibility.

Inhibitor

At the operational level, subcontracting has not been very successful. The reason for this is that because most of the plant's products are bespoke, having a portion of the supply chain made outside introduces blind spots, which are difficult to monitor. There is also the problem of different accounting rules for transferring ownership at the operational level.

Implementation

Normally the plant would sub-contract when the technology is transferable and when the capital to invest or the equipment sets are relatively simple and available in the market place. Plastico would also subcontract when the way of carrying out a particular process generally is not unique and there are lots of people who are capable of performing the operation at lower labour cost or reduced cycle time.

"For example, we have a number of people locally who have equipment to cut particular gauges of films. We don't want to make capital investment in such things as film extraction and slitting equipment lines that we know other people can do. So, what we are doing is we are sub-contracting out a middle portion of the converting until the volume and the growth is there in a particular market segment that we can understand. We will do that at various points in the life cycle".

The plant has also used subcontracting as an exit strategy where it needed to retain its market position and handle the falling demand volumes. For instance, for a particular segment it went ahead and actually dismantled the equipment on the floor, sub-contracted the activity and was able to put new lines in the same place, rather than go for a greenfield site.

Annualised Hours Contract

The plant moved from the use of overtime to the strategy of an annualised hours system to cope with requirements on manning levels. The principle is that an individual worker is committed to work 1700 hours a year (set a year in advance). This is scheduled to cover predictable demand variability due to seasonal fluctuations within the year. Typically, an operator would be expected to use a higher proportion of the 1700 hours during the Christmas season. Then there are an extra 200 hours which management can choose to vary and call in to cover short-term demand uncertainties that may arise within the year. For instance, an unexpected increase in demand levels over and above forecasts (e.g. the lifting of the ban on beef on the bone). These hours may also be used to cover absenteeism. Thus, the individual is paid for 1900 hours a year but committed to work a minimum of 1700 hours.

Implementation

In order to implement the strategy successfully in the plant, management had a series of consultations with the unions and workers. Meeting with the unions was vital, as 95% of the workers were union members.

"For about 8 months, we spoke to every member of the workforce on a one to three, one to five basis. We explained the changes that were taking place about the pound, about the market place, that we couldn't afford to continue to work on an overtime basis, that we wanted to have long term investment in the site and it was important to have security of employment".

The timing of the introduction was also important in the successful implementation of the strategy. It was implemented at a time when the parent company was going through a merger programme, so there was the general feeling that things were going to change anyway.

To get the workers to move away from overtime working, the plant paid a lump sum amount of £5000 as an incentive to each worker. As part of the agreement, the workers were required to acquire a new range of skills so that they can be moved around the factory in line with demand requirements. The initial lump sum payment cost the plant about £2 million to £3 million.

It was important to change the payment system to be compatible with the strategy.

"We had to make the employees believe that their best interest was in acquiring skills and in a way moving away from us hiring them for the hours worked, and to end up with a relationship with them whereby we looked at the quality of work and their skill base to arrive at pay levels".

Planning for the annualised hours system is done a year ahead. It is, therefore, important for Plastico to get its forecasts right as much as possible. However, this has posed a problem for the plant in the past. It ended up with a huge number of extra hours paid for but unused. This, however, was good for the workers. There was also a particular year when the extra hours were not sufficient to cope with the increase in demand. Rather than introduce overtime hours, the plant transferred work to Italy to cope with the demand requirements.

"..If we see it dropping off, we have the capability to access the other locations' order books and their material management systems and we would actually reset the parameters of the MRP run.... ".

Inhibitors

It was very difficult for operators who had worked for say over 20 years to adapt to the annualised hours system because of their set ways of working. The system was self managed and managed informally. With pressure from their peers, these operators were able to change their work practices. Peer pressure within the system has also reduced staff sickness and small accident complaints.

"Other contemporaries tend to turn round and say, "no I saw his hand, he is not that bad, why am I being called in to cover out of my 200 hours because if I don't do anything, I get paid for them", so what actually happens is that you saw lost time on small accidents come down enormously".

Rejecting Orders

The plant has in the past had to reject orders to cope during peak demand periods. This reduces the need for internal volume flexibility. However, only orders of a certain class of customers have been or can be rejected. Customers are classified as either A, B or C customers. 'A' customers are strategic, able to grow, high margin and particularly dominate their segment and are capable of improving the plant's processes. 'B' customers are not as big as 'A' customers but generally have similar characteristics. 'C' customers are generally small, niche players and usually buy in low volumes.

Plastico will do anything not to prejudice 'A' and 'B' customers. If Plastico is overloaded with orders from the three classes of customers, 'C' customers' orders will be rejected or penalised by raising the cost. The plant tries to achieve at least 95% delivery performance against requested dates for A and 92% for B customers. Thus, if meeting 'C's requirements will make Plastico underperform these objectives, orders to 'C' customers may have to be rejected.

10.3.6 Summary

Table 10.3.1 summarises the insights provided to answer the first Research Question.

RQ1: Under what conditions does Plastico require high levels of volume flexibility?
Concept used to answer this question: Drivers

Drivers of Volume Flexibility	High variability and uncertainty in demand levels	New product introduction	Product repositioning	Short product life cycle	High product mix	Currency variations
Causal Factors	• Legislation and Political • Demand seasonality	• Competitors' actions	• Competitors' action	• Competitors' actions	• Customer needs	• International operations

Table 10.3.1: Drivers of volume flexibility in Plastico

Table 10.3.2 summarises the insights provided to answer Research Questions Two, Three and Four.

RQ2: What are the enablers and inhibitors of volume flexibility in Plastico?
Concepts used: Enablers and Inhibitors

RQ3: Why does Plastico use these particular enablers to achieve volume flexibility?
Concepts used: Benefits and drivers

RQ4: How does Plastico use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?
Concept used: Key implementation factors

Enablers of Volume Flexibility	Sister Plants	Supply Chain Flexibility	Postponement	Multiskilling	Mix Flexibility	Subcontracting	Annual Hours	Rejecting Orders
Drivers	• Demand variability and short-term demand uncertainty	• Components complexity • Customer requirements	• High product mix • High variability in demand levels	• High product mix • Demand variability and short-term demand uncertainty	• High product mix • High variability in demand levels • Short product life cycle	• High variability in demand levels • New product introduction • Dying products	• Demand variability and short-term demand uncertainty • Excessive overtime cost	• High demand from priority customers
Benefits	• Provides volume flexibility	• Provides long-term volume flexibility	• Aids mix and volume flexibility	• Aids mix and volume flexibility	• Aids Volume Flexibility	• Provides long-term volume flexibility • Market segment retention for dying products • Avoids need for greenfield site	• Provides volume flexibility • Reduced labour cost • Reduced staff sickness and accidents complaints.	• Aids volume flexibility (+) • Loss of potential business (-)
Inhibitors	• Adverse corporate variance	• Intermediate goods producer	• None	• None	• None	• Difficult to monitor at the operational level	• Inaccurate forecast • Resistance due to set working practices	• None
Key Implementation Factors	• Integration • Common order book • Common accounting principles	• Good relationship with direct and indirect customers • Introducing electronic point of sale system	• Common upstream processes • Good process improvement programme	• Good training • Financial incentive	• Postponement • Multiskilled workforce • Flexible lines	• Focus on areas where technology is easily available and • transferable	• Communication • Timing of launch • Good forecast • Financial incentive • Compatible payment system • Multiskilling • Self-managing - Peer pressure	• Classification of customers • Increase price for non-priority customers

Table 10.3.2: Enablers of volume flexibility in Plastico

Figure 10.3d shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump, and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, demand uncertainty, absenteeism and equipment breakdown.

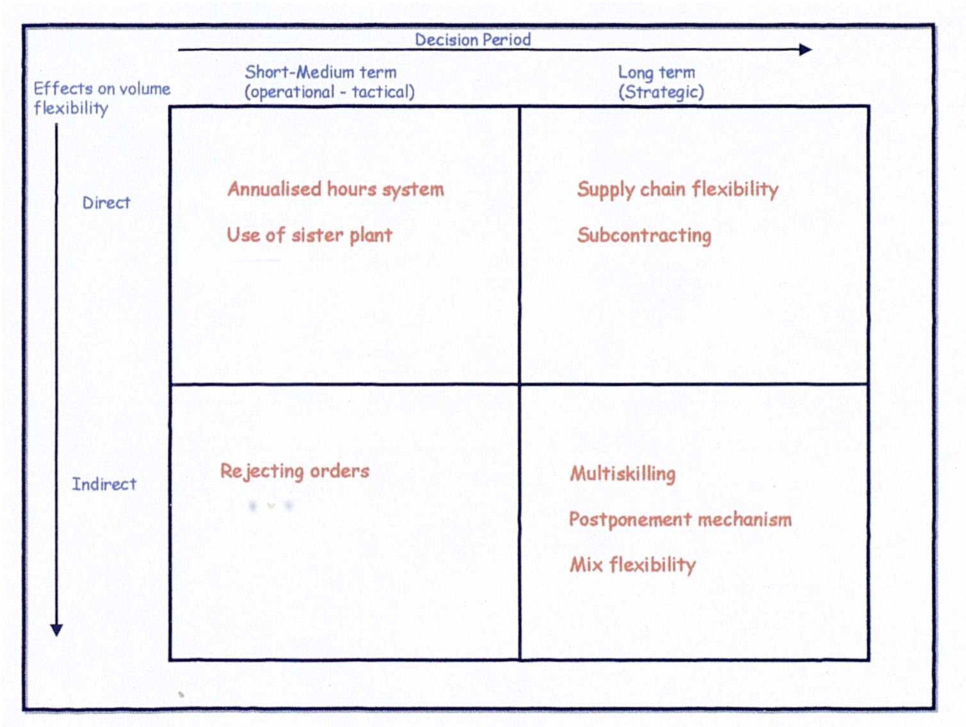

Figure 10.3d: Decision hierarchy view and the effects of enablers on volume flexibility in Plastico

10.4 Case Study Analysis - Electco

The plant was selected for the case study because of its extensive use of subcontracting strategy. Unlike the other plants, Electco does not possess the manufacturing capability in-house. It is, therefore, treated as a minor case study.

The manufacturing manager was interviewed (the source of all the quotes cited in the case study). No data was available for collection. The interview lasted about one and half hours and it was audio taped. Verbatim transcription of the tapes was carried out. Content analyses were carried out to identify the concepts relating to the Research Questions. The focus was on identifying the following:

1. *Drivers* of volume flexibility in the plant (i.e. why does the plant need volume flexibility?) – Research Question One
2. The *enablers and inhibitors* of volume flexibility (i.e. what factors aid and prevent the achievement of volume flexibility?) – Research Question Two
3. The *benefits* of using the enablers (i.e. why does the plant use these particular enablers?) – Research Question Three
4. The *key implementation factors* (i.e. how does the plant implement the enablers?) – Research Question Four

10.4.1 Contextual Considerations

Electco belongs to the electronics sector. Electco's main business involves contract design and manufacture of systems for the defence industry. The systems are mainly used in ships, submarines and helicopters.

Electco has about 50 employees involved in manufacturing operations and design activities. It has about 160 suppliers of different electronic components. The average purchasing lead-time is 112 days, the average manufacturing lead-time is 30 days and the average customer lead-time is 240 days.

10.4.2 Market Characteristics

80% of the plant's sales go to the UK Ministry of Defence and 20% is exported. The plant is a low volume producer, probably due to the nature of its product. Depending on the type of system required, production volume could range between 3 systems a year, 2 a month (for helicopter systems), and one every two months (for submarine systems).

The market in which Electco operates is not very competitive, although for a small proportion of its business, i.e. the provision of spares and repairs, there does tend to be more competition. For relatively bigger contracts, competition usually takes place early in the process, the design stage. The ministry would typically award an initial study contract to a number of companies since there could be up to five major different technologies in the same piece of equipment, so they tend to go to specialists. When a design is won and completed, because the Ministry of Defence owns the design rights, in theory it should put the package out to tender for subsequent systems manufacture. In practice, though, it usually awards the contract to the designer of the system. This is because, usually for an individual system, there is a lot of hidden know-how, which doesn't show up very well on the design documentation. So, a different company, other than the one that designs the system may find it difficult to manufacture.

Electco generally makes to order. Procurement takes about three-quarters of the customer lead-time. Contracts tend to run for a very long period of time. For instance, the plant built 48 systems (one order equals 6 in a batch) over a period of 14 years.

"There is no way you are going to get 8 identical orders over this period. Basically I would say we are a tailoring company. Everything we build can be classified as being unique. Very few are repetitive".

10.4.3 Operations

The plant's policy is to subcontract as much manufacturing as it can, so it does not have the machinery and capital equipment for system manufacture and assembly. However, it has some small on-site capability for modifications, repairs and prototype manufacture. The system construction consists of cabinets and sub racks which enclose printed circuit boards (PCB). The bulk of the value and the complexity is in the PCB assembly which is sub-contracted. The plant is able to make the cabinets and the sub racks.

For a system's manufacture, the components are purchased, sent to the assembler or subcontractor to get the board assembled and then brought back to site for testing and final placement or assembly in cabinets and shelves. The plant is presently experimenting with a turnkey assembly.

10.4.4 Issues of Flexibility

Flexibility is an important issue for the plant. However, it is more mix rather than volume flexibility. Huge variety changes rather than volume changes drive the plant.

"Volume is really not an issue because we know how many we are going to make in advance. But the individual items of the orders will change. Manufacturing produced 6000 systems last year. That was probably about 600 manufacturing orders. The average number of changes on each of those was 6".

The fact that a particular contract typically takes years to build further reduces the need to require high levels of volume flexibility within a year. On the other hand, within the contract period and a given or fixed order volume, the plant requires high levels of mix flexibility. One of the reasons for this is component obsolescence. Components used in PCB build may have a very short life cycle. When changes occur in the type of components to be used in building a system, it leads to a hierarchy of problems going from simple changes of components through to redesigning the board. This eats into the lead-time.

Electco does not require high levels of volume flexibility but it employs extensively an interesting enabler of volume flexibility (i.e. sub-contracting). Therefore, the subsequent analysis has not been focused on drivers of volume flexibility but has been undertaken to provide a rich insight into the implementation of subcontracting in manufacturing plants.

10.4.5 Sub-contracting

Figure 10.4.1 below shows the key implementation factors and reasons for the use of the subcontracting strategy to achieve manufacturing objectives in Electco.

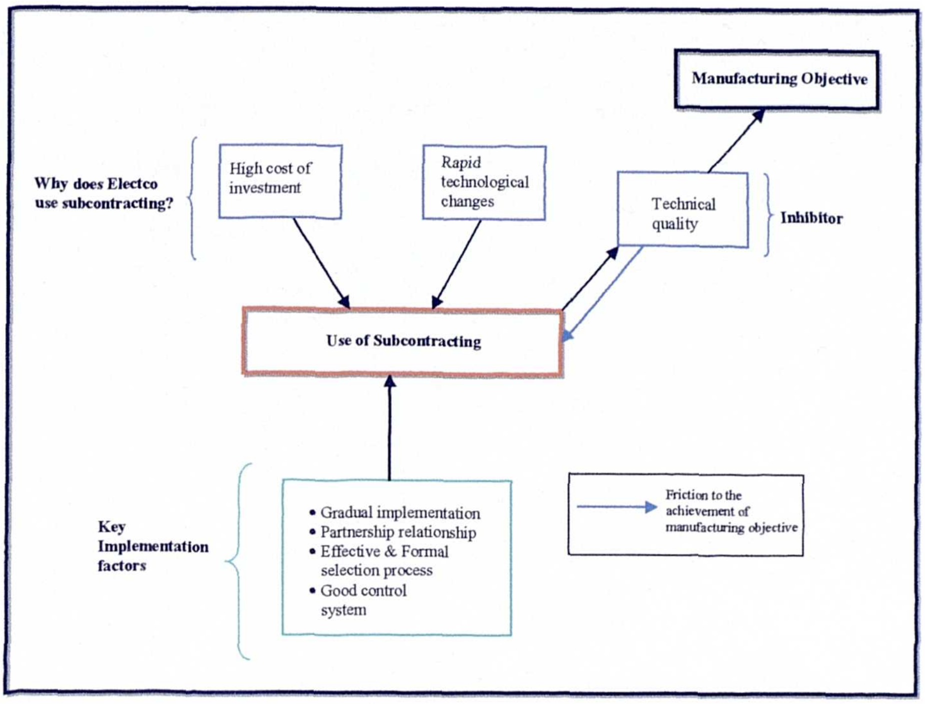

Figure 10.4a: Why and how Electco use subcontracting to achieve its manufacturing objective

Why Electco adopted the Subcontracting Strategy

Generally, Electco adopted a subcontracting strategy because the strategy was perceived to be cost effective. The plant did not want to incur the general overhead management cost of running a workshop for relatively small and variable batches of work. Also, technology was moving on and it was quite difficult to keep up with technology for a small operation. For instance, PCB manufacture technology has moved on from the days of hand assembly to the use of expensive and highly sophisticated surface mount technology. Also, the new types of PCB have joints which can only be inspected using very expensive X-ray machines. Electco does not have the volume to be able to invest in the required equipment, where the volume producers of electronics and telecommunication products now drive the business.

"You have to be very strong to be able to invest a lot of money in specialist equipment and plant to be able to keep up with the changes in technology. Unless you can get the volume through that plant, it is very difficult".

For PCB assembly therefore, the plant engages the services of subcontractors in the telecommunications industry as well as companies making personal computers. In the area of cabinets, shelves and console construction, which is more mechanical, the issue of cost and technology also applies. The plant uses specialist companies who use CNC programmable general-purpose tools. However, for the assembly of PCBs into cabinets and shelves, there are so many complexities involved that it has been difficult for the plant to get an outside firm to perform the operation properly. Technology is also moving away from the traditional way in which the plant performs the placement or assembly process. This is because the decreasing sizes of PCBs make them very difficult to handle. Therefore the plant is in the process of outsourcing this operation as well. In effect the plant is hoping to concentrate on the core activity of its operation which is the design of the systems and then managing the downstream or outsourced processes.

Electco's experience of subcontracting has been generally good. This is due to the effective process it employs to implement the strategy.

How does Electco Implement Subcontracting?

As discussed above, processes are being outsourced in a gradual manner. First, it was the PCB assembly, which was relatively easy because there were many plants that could do it effectively, then it moved on to shelves and it is planned to outsource the assembly of PCBs into cabinets. The gradual implementation is important because it gives the plant the opportunity to learn from and improve on mistakes.

Having a partnership relationship with the subcontractors, and understanding and working within their limitations are important for the successful implementation of the strategy. This was managed by keeping the number of subcontractors for a particular process relatively small.

"We believe that you do require a lot of liaison with the sub-contractor and even a certain amount of development of their process. You can't afford to do that with a large number of sub-contractors".

Relationships differ, however, with different subcontractors. For those subcontractors who are low volume producers themselves, Electco's business means a lot to them. The plant has a very close relationship with this category of subcontractors. For others, the plant's business is relatively small, so the relationship with this category of subcontractors tends to be more difficult. However, these contractors still tend to keep on reasonable terms with Electco because of the influence of Electco's parent company. The relationship with component suppliers is very different.

"For instance we have troubles with the component suppliers because relative to them, we are small. You are dealing with firms like Intel. You have to accept what they are offering. They don't even notice us. In fact they deal with distributors".

The process of selecting a subcontractor for a particular process is formal. It is not done through an open auction or tender and picking out the lowest bid. The first step is to find a subcontractor who has the right technology and process that the plant has a need for. This is done through a particular department in the plant that looks at the possible companies and contacts them. Sometimes this is advertised. The next stage entails a presentation by the potential subcontractor to the purchasing department. The quality department then sends them a questionnaire that is a fairly detailed requirement of their ISO standards certification. Their financial standing is checked and the usual credit checks are performed to determine if they are safe to work with. This results in a visit to the subcontractor's site to check their operations, and their control processes as well as to ascertain if the company could deliver to the required quality standards. The process is rigorous, formal and fully documented. After selecting and engaging a subcontractor in business, the formal process of auditing continues. This time it takes the form of control systems put in place to monitor performance.

The control system used by the plant is referred to as the vendor rating system. Reject rates (failed through testing) and delivery performance are the main criteria for assessing the performance of subcontractors by the plant. The subcontractors are classified into 5 categories of vendor from A to E (High to low performers), so they each get a rating done periodically. If a subcontractor is consistently 'E' rated for several weeks and months it may not mean that they are incapable but that they are in trouble and are cutting costs. 'E' rated subcontractors are cautioned and invited for discussions initially. If the bad performance continues, they may be dropped.

10.4.6 Summary

Table 10.4.1 below summarises the reasons why Electco adopted the use of subcontracting to achieve its manufacturing objectives and how the plant has gone about implementing the strategy of subcontracting.

It is pertinent to note that none of the Research Questions are directly addressed in this case study as Electco does not have a requirement for high levels of volume flexibility. However, the case provides useful insights into the use of the subcontracting which has been found to be an enabler of volume flexibility in the other plants studied.

Strategy (enabler)	Subcontracting
Drivers (Why does Electco use subcontracting?)	• Investment cost avoidance • Inability to keep up with rapid technological changes
Benefits	• Provides flexibility • Fewer overheads
Inhibitors	• Technical quality
Key implementation Factors (How does Electco use subcontracting?)	• Gradual implementation • Partnership relationship • Effective and Formal selection process • Control System

Table 10.4.1: Subcontracting as an enabler of manufacturing objectives in Electco

10.5 Chapter Summary

This chapter has carried out the within-case analyses of the remaining four of the eight plants selected for the case studies (i.e. Foodco, Lachstone, Plastico and Electco). In each of the cases, the contextual factors of the plant and the characteristics of the market in which the plants operate were discussed. Where data are available, the aggregate demand profiles and production plans of the plants were presented.

Data analyses of interview transcripts were carried out by thematic coding and content analyses to identify emerging themes and concepts that provide insights into the research questions (Eisenhardt, 1989; Miles and Huberman, 1994; Yin, 1994).

The analyses revealed various conditions that drive the plants to require high levels of volume flexibility (*Drivers of volume flexibility – RQ1*). The drivers identified include *high demand level variability, shortening product life cycle, competition and high uncertainty of demand levels* (Slack, 1987; Swamidass and Newell, 1987; Oliff and Marchand, 1991; and Hyun and Ahn, 1992). The analyses, however, reveal that these drivers are not applicable to all the plants studied.

The analyses also identified the factors that aid and prevent the achievement of volume flexibility in the plants studied (*Enablers and Inhibitors – RQ2*). Enablers identified include the use of *an annualised hours system, multiskilling, using sister plants and sub-contracting* (Brewster and Connock, 1985; Adler, 1987; Kohler, 1989; and Grey and Corlett, 1989). The plants generally do not have problems implementing many of the enablers to achieve volume flexibility. For the *annualised hours system*, inhibitors to implementation include *resistance and suspicion by operators, gradual implementation* leading to *division, and getting yearly demand forecasts wrong.*

Further analyses were carried out to investigate why some plants choose to use some solutions and other plants use other solutions to achieve volume flexibility. The analyses reveal that the choice of which solution or enabler to use depends on the market conditions which the particular plant is exposed to (i.e. *drivers* – e.g. *high variability in demand levels*). The plant continues to use the solution or enabler or desires its use in the future because of the perceived gains from the use of such a strategy (e.g. *benefits* from the use of an *annualised hours system* include *elimination of overtime and attendant cost and, reduced absenteeism - RQ3*).

Finally, analyses were carried out to investigate how the plants actually implement the enablers and overcome the inhibitors to achieve volume flexibility (*Key implementation factors – RQ4*). For instance, in order to implement the *annualised hours system*, one of the plants *rewarded its operators financially, had extensive communications and consultations with operators* and the implementation was done in a *gradual manner* (Tranfield and Smith, 1990).

The next chapter will describe the cross-case analyses carried out to compare the results of the within-case analyses of the eight plants.

Chapter 11 – Cross-Case Comparison

11.0 Introduction

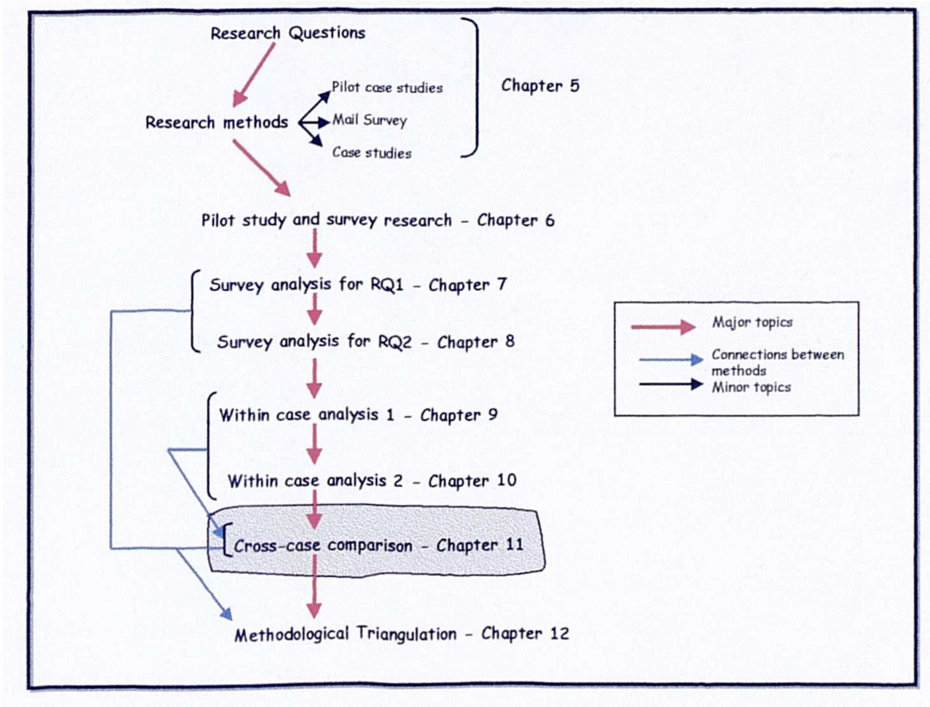

Figure 11.0: Road map for empirical research. Chapter coverage shaded

This chapter describes the cross-case analyses. Themes identified from the within-case analyses (in respect of the Research Questions) are selected and checked for similarities and differences across the cases. Thus, cross-case analyses involve the search for patterns in the within-case analyses and identify differences and similarities in order to determine any literal or theoretical replication logic in the cases.

This chapter has been divided into four main sections. Section One presents and compares the drivers of volume flexibility in the plants studied as well as their causal factors (RQ1). Section Two presents and compares the enablers and inhibitors of volume flexibility in the plants (RQ2), specific reasons for using the enablers in each plant (RQ3) and how the enablers are being used to achieve high levels of volume flexibility (RQ4). Section Three discusses further analyses carried out. Section Four summarises and concludes the cross-case comparison.

In order to provide explanations for any similarities or differences observed in the cross-case analyses, relevant quantitative data on the plants was obtained from the BFA database and is presented in Table 11.0 below.

Details	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Ownership	Japanese parent company	Joint UK/Foreign parent company	US Parent company	Continental European Parent company	Joint UK/ Foreign company	US Parent company	US Parent company	Joint UK/Foreign parent company
Sector	Electronics	Engineering Capital	Process	Household and general goods	Food	Engineering consumer	Household and general goods	Electronics
Product	Telecommunication systems: PCB assembly and Product/system test	Contract mechanical component manufacture	Chemicals for consumer goods: oxidation and purification of chemical	Materials for the furniture industries: Paper impregnation and coating, slitting and packing	Wet and Dry food products: Ingredient mixing and milling, packing into glass jars or sachets	Office furniture: Press work, welding, painting, assembly and packing	Packaging material for the food industry: Plastic extrusion and conversion	Products for the defence Industry: manufacture of sub-assemblies.
Classification of product	Capital goods = 100%	Intermediate goods = 50% Consumer goods = 50%	Intermediate goods = 100%	Intermediate goods = 100%	Inter. goods = 2% Consumer goods =98%	Capital goods = 100%	Capital goods = 10% Intermediate goods = 90%	Capital goods = 98% Inter. goods = 2%
Size	No. of employees – Production - 110 Design - 210	No of employees - Production = 290 Design = 100	No of employees - Production = 248 Design = 30	No of employees Production = 105 Design = 1	No of employees - Production = 168	No of employees - Production = 85 Design = 3	No of employees Production = 650 Design = 5	No of employees - Production = 50 Design = 1
*PLT	140 days	45 days	90 days	14 days	7 days	10 days	7 days	112 days
*Average MLT	4.5 days	15 days	6 hours	3 days	1 day	20 days	10 days	30 days
*Average CLT	40 days	50 days	14 days	10 days	3 days	40 days	10 days	240 days
Suppliers	250	160	12	38	100	32	12	160

Table 11.0: Contextual considerations of case study plants. *Source: BFA database*

* PLT = Average purchasing lead-time; MLT = average manufacturing lead-time; CLT = average customer lead-time

11.1 Drivers of Volume Flexibility – Cross Case Comparisons

Table 11.1 presents the drivers of volume flexibility across the *plants as identified from the case study analyses (RQ1).

Drivers (RQ1): *factors that drive the case study plants to require high levels of volume flexibility*	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico
High variability in demand levels	✔	✔	✔	✔	✔	✔	✔
Short- term demand uncertainty	✔	✔	✔	✔	✔	✔	✔
Long-term demand uncertainty	✔	✔	✕	✕	✕	✕	✕
Business needs	✔	✕	✕	✕	✕	✕	✕
Supply chain complexity	✔	✔	✕	✕	✕	✔	✕
Communication with customers	✕	✕	✕	✕	✕	✔	✕
Short product life cycle	✔	✔	✕	✔	✕	✔	✔
New product introductions	✔	✕	✕	✔	✕	✕	✔
Short product shelf-life	✕	✕	✔	✕	✔	✕	✕
High product mix	✔	✕	✕	✕	✔	✔	✔
Competitors' actions	✔	✕	✕	✕	✔	✔	✕
Stop making to stock	✕	✕	✔	✕	✕	✕	✕
Currency variations	✕	✕	✕	✕	✕	✕	✔
High machine set-up	✔	✕	✕	✕	✕	✕	✕

Table 11.1: Applicability of volume flexibility drivers across case studies
✕ - Not applicable; ✔ - Applicable

Table 11.2 presents the drivers of volume flexibility and their causal factors (where applicable) as analysed in the within-case analyses (Chapters 9 and 10). In the discussion that follows, each of the drivers is considered in turn and their applicability across the cases is discussed. Evidence is sought to determine whether there are generic or specific reasons for any differences or similarities observed in the applicability of volume flexibility drivers to the plants.

* Electco has been excluded from this list because the plant has no requirement for volume flexibility

RQ1 (Drivers)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico
High variability in demand levels	Caused by: • Customer needs	Caused by: • Reduced order book • Stop to multi year order	Caused by: • Market Changes	Caused by: • Changing customer needs	Caused by: • Demand peaking at festive periods • Customer requirements	Caused by: • Customer requirements	Caused by: • Demand seasonality
High uncertainty of demand levels (long and short term demand uncertainty)	Long and short term demand uncertainty. Caused by: • Nature of business - Contract manufacturing • Unscheduled production requirements	Long and short term demand uncertainty. Caused by: • Political changes • Indirect link with end customer - Subcontractor to main contractors • Contract manufacturing • War	Short-term demand uncertainty. Caused by: • Unscheduled production requirements	Short-term demand uncertainty. Caused by: • Changing customer requirements • Unscheduled production requirements	Short-term demand uncertainty. Caused by: • Changing customer requirements • Unscheduled production requirements	Short-term demand uncertainty. Caused by: • Changing customer requirements	Long and short-term demand uncertainty. Caused by: • Legislation and political • Changing customer requirements
Business Needs	• Growth • Differentiation • Cost avoidance	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Supply chain complexity	• Power dynamics • High material cost • Component complexity • Many suppliers • Long procurement lead-time	• Long procurement lead time • Many suppliers	Not applicable	Not applicable	Not applicable	• Inflexible suppliers • Many suppliers	• Component complexity • Poor visibility of downstream supply chain
Communication with customer	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Caused by: • Dealer organisation	Not applicable
Short product life cycle	• Market factors - Changing technology	• Market factors – quick product obsolescence	Not Applicable	• Market factors - Changing customer taste	Not Applicable	• Customer requirements	• Deliberate action to ward off competitors

RQ1 (Drivers)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico
New Product introduction	Caused by: • Market factors	Not Applicable	Not Applicable	Caused by: • Changing customer taste	Not Applicable	Not Applicable	Caused by: • Competitors' actions
Short product shelf-life	Not Applicable	Not Applicable	Caused by: • Product nature	Not Applicable	Caused by: • Product nature • Customer needs	Not Applicable	Not Applicable
High product mix	Caused by: • Changing customer needs	Not Significant	Not Applicable	Not Significant	Caused by: • Changing customer needs	Caused by: • Changing customer needs	Caused by: • Changing customer requirements
Competitor action	Caused by: • Many innovative competitors	Not Applicable	Not Applicable	Not Applicable	Caused by: • Internal competition - Impending group reorganisation	Caused by: • Cost pressure • Reduced lead-time by competitiors	Not Applicable
Stop making to stock	Not Applicable	Not Applicable	Caused by: • Cost avoidance	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Currency variations	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Caused by: • International operations

Table 11.2: Drivers of volume flexibility (RQ1) and their causal factors – Cross-case comparison

11.1.1 High Variability in Demand Levels

This driver refers to a situation in which there is a significant variability in demand levels on a daily, weekly or monthly basis over a year. However, the total demand over the year is relatively predictable. This driver appears to be the most common condition that drives plants to require high levels of volume flexibility in the study. It is applicable to 7 out of the 8 plants studied (Tables 11.1 and 11.2). It is not applicable to Electco due to the reasons given earlier. Hence, it can be regarded as a *generic driver* of volume flexibility for many manufacturing plants. This concurs with the results of the survey study.

The various plants experienced high levels of variability in demand for different reasons. For instance, Plastico and Foodco experience high levels of variability in demand because of the seasonal nature of their products. Over the year the plants are relatively more heavily loaded during the festive periods (e.g. Christmas). Within the busy periods they still experience high levels of demand variability as a result of changing customer requirements (e.g. small order sizes). However, the total yearly demand is relatively predictable, although Plastico has in the past experienced some high forecast errors in predicting the yearly demand (this is explained in the following sub-section). All the other plants in the study have also experienced high levels of variability in demand from period to period over a year. Lachstone and FonGoods have both experienced daily and monthly variability in demand levels due to changing customer needs. These are not seasonal variations but the total demand is relatively predictable over the year.

11.1.2 High Uncertainty of Demand Levels

This condition deals with the degree of uncertainty in forecasting customer demand levels. This condition can result from either short-term uncertainty (the overall yearly demand is relatively predictable, but there are daily, weekly or monthly uncertainties in demand levels) or long-term uncertainty (where the total demand over the planning period is highly unpredictable). All the case study plants experience short-term demand uncertainty but two of these (Teleco and Engico) experience both short and long-term demand uncertainty. Short-term demand uncertainty is generally caused by unscheduled production requirements.

Long-term demand uncertainty as a driver of volume flexibility appears to be a *specific driver* of volume flexibility in the plants studied as it is applicable to only three of the case study plants (i.e. Teleco, Engico and Plastico). In the case of Teleco and Engico the predominant causal factors for demand uncertainty is due to the nature of the plants' businesses. The two plants concerned engage in contract manufacturing carried out mostly by bidding. The likelihood of a tender being raised is highly uncertain and subject to many factors. For Engico (a defence contractor), these factors include political and legislative changes (leading to an increase or cut in the defence budget) and war. The likelihood of the plant being invited to tender for the job and subsequently winning it is also relatively unpredictable. In the case of Plastico, it is exposed to long-term demand uncertainty due to the nature of its products rather than its business. It produces materials used in packing food items such as beef and cheese. As such, the demand for Plastico's products is sometimes affected by legislation (in particular the BSE beef crisis). Although this situation tends to occur infrequently, it is highly unpredictable.

11.1.3 Supply Chain Complexity

Complexity in the supply chain drives four (Teleco, Engico, Lachstone and Plastico) of the case study plants to require high levels of volume flexibility. This driver of volume flexibility appears to be *specific* to these plants. The most common reasons for the complex supply chains are (i) the use of a high number and types of raw materials and components in production operations and (ii) having to deal with many suppliers ranging from 100 to 250 (except for Plastico). In the case of Plastico, supply chain complexity results from poor visibility of the downstream (distribution) end of the supply chain since 90% of their products are supplied as intermediate goods.

11.1.4 Short Product Life Cycle

A shortening product life cycle and new product introduction both have implications for production volume requirements (hence volume flexibility) of manufacturing plants. Goldman *et al*, (1995) argue that a shrinking product life cycle creates pressure on organisations to become flexible.

A short product life cycle drives five of the case study plants to require high levels of volume flexibility. Generally, changing market factors are responsible for the relatively shorter lives of the plants' products. Market factors render the products of some plants obsolete in a relatively shorter period of time. For example, products of plants in the Electronics sector (e.g. Teleco) tend to become obsolete relatively quicker. This sector is characterised by rapid changes in technology resulting in rapid product obsolescence. To this extent, the short product life cycle as a volume flexibility driver can be said to be *specific* to the electronics sector. However, a short product life cycle may be a *specific driver* in some plants in other sectors as well. Engico, an engineering capital sector plant uses electronic components in manufacturing. These tend to become obsolete relatively quicker. Also, products may become obsolete due to a deliberate action by the plant to shorten the life cycle of a product to ward off competition (e.g. Plastico). Products may also become obsolete as a result of changing customer tastes (e.g. FonGoods and Lachstone).

11.1.5 New Product Introduction

New product introduction drives three of the case study plants to require high levels of volume flexibility (Teleco, FonGoods and Plastico). Teleco and FonGoods constantly have to introduce new products to meet the changing customer requirements in their sectors while Plastico does so deliberately to ward off competitors.

11.1.6 Short Product Shelf Life

Having a product with a short shelf life is a condition that drives only two of the plants studied to require high levels of volume flexibility (Foodco and Proceco). The shelf lives of products actually depend on the characteristics or nature of the products themselves. For perishable products, the plant is limited to the use of volume flexibility to fill orders as it cannot afford to keep the products for a long time in stock (Oke, 1998). In the case of Foodco (which belongs to the food sector), the average shelf life of the plant's product is about 9 months. However, because the customer would not take a product with less than three-quarters of its shelf life left, the effective shelf life becomes about 2 months from the plant's point of view.

In the case of Proceco (a process sector plant) the average shelf life of its product is 6 months. This limits the plant to require volume flexibility. Generally, plants whose products have relatively short shelf lives require higher levels of volume flexibility than plants with relatively longer shelf life products, all other things being equal. Shelf life is, of course, more of a factor in the food sector.

11.1.7 High Product Mix

Having a wide range of products in their portfolio is a condition that drives four of the case study plants to require high levels of volume flexibility. With a high product mix, the plant requires the capability not only to switch between the production of different mixes of products (mix flexibility) but also to be able to handle the attendant different volume requirements. High product mix as a driver appears to be *specific* to those plants producing non-standardised products (i.e. all the case study plants except Engico and Proceco). Engico produces highly specialised capital kits for the defence industry. The contract nature of its business does not encourage many variations in product mixes once contracts for manufacture have been awarded. Proceco runs a continuous production system, which by its very nature is highly inflexible in terms of product mix and hence produces a standardised product. Market factors including changing customer needs and technology are responsible for the wide range of products being offered by the other plants in the case study.

11.1.8 Other Drivers of Volume Flexibility Needs

Competitors' actions appear to drive plants operating in fiercely competitive markets to require high levels of volume flexibility. This is not a *generic driver*, and is not applicable to, for example, the defence sector plant because of the relatively small number of competitors in that sector.

Currency variations would be expected to drive plants with international activities, either selling or buying overseas, to require some levels of volume flexibility. Although most of the plants studied are engaged in one way or the other with overseas operations, it is surprising to find that only in one plant (Plastico) is this condition deemed a highly significant driver. This may be due to the very high level of involvement in overseas operations of this plant compared to the other plants in the case study.

Company policies or business needs such as a decision to stop making to stock and market segmentation through differentiation are cost-avoidance strategies that drive some plants in the case studies to require high levels of volume flexibility. However, there are no particular characteristics to suggest why these plants took such decisions.

11.2 Enablers and Inhibitors of Volume Flexibility

This section compares the analyses of the individual cases based on Research Questions Two, Three and Four. Insights obtained from the within-case analyses are presented in four tables.

1. Table 11.3 (what are the enablers of volume flexibility in manufacturing plants? - RQ2a);
2. Table 11.4 (what are the inhibitors of volume flexibility in manufacturing plants? – RQ2b);

3. Table 11.5_{a-d} (why do some plants choose some solutions and other plants choose other solutions to achieve volume flexibility? – RQ3)
4. Table 11.6_{a-d} (how do manufacturing plants use the enablers and overcome the inhibitors to achieve high levels of volume flexibility? – RQ4).

The discussion that follows treats each enabler of volume flexibility in turn. For each enabler, the inhibitors to its implementation, the reasons for using the enabler and how the enabler has been implemented to achieve volume flexibility are discussed.

Enablers (RQ2a)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Sister plants	✔	✔	✔	✗	✗	✔	✔	✗
Multiskilling	✔	✔	✔	✔	✗	✔	✔	✗
Subcontracting	✗	✔	✔	✗	✗	✔	✔	✔
Equipment upgrade/spare capacity	✔	✗	✗	✗	✔	✔	✗	✗
Banking Hours	✔	✗	✔	✔	✗	✗	✗	✗
Annual Hours	✗	✗	✗	✗	✔	✔	✔	✗
Process Improvement	✔	✗	✔	✗	✗	✗	✔	✗
Varying lead times	✗	✔	✔	✔	✗	✗	✗	✗
Mix Flexibility	✔	✗	✗	✗	✔	✗	✔	✗
Teamworking	✗	✗	✔	✗	✔	✔	✗	✗
Supply Chain flexibility	✔	✗	✗	✗	✔	✗	✔	✗
Good Attitude	✔	✗	✗	✗	✗	✗	✗	✗
Overtime	✗	✔	✗	✗	✗	✗	✗	✗
Good Forecast measure	✗	✔	✗	✗	✗	✗	✗	✗
Temporary labour	✗	✗	✗	✗	✗	✔	✗	✗
Purchase for resale	✗	✗	✔	✗	✗	✗	✗	✗
Rejecting orders	✗	✗	✗	✗	✗	✗	✔	✗
Shut down	✗	✗	✔	✗	✗	✗	✗	✗

Table 11.3: The use of enablers of volume flexibility across case study plants. ✔ - uses; ✗ - does not use

In Table 11.4, "Not Applicable" (N/A) is used to refer to a situation when an enabler is not used in the plant concerned. "None" is used to refer to a situation when no barrier is perceived to the implementation of an enabler in the plant concerned.

Enablers (RQ2b)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Sister plants	None	Difficult to use in non-engineering operations	None	N/A	N/A	None	Adverse corporate variance	N/A
Multiskilling	None	Enlisting workers	Conflicting union membership	None	N/A	None	None	N/A
Subcontracting	N/A	None	Inconsistent quality	N/A	N/A	None	Difficult to monitor at operational level	Technical quality
Equipment upgrade	None	N/A	None	Creates tension	None	None	N/A	N/A
Banked Hours	Resistance to change	N/A	N/A	Refusal to pay back hours	N/A	N/A	N/A	N/A
Annualised Hours system	N/A	N/A	Union resistance Refusal to pay back hours	N/A	Resistance and suspicion	No team coach initially Divisive	Inaccurate forecast Resistance	N/A
Process Improvement	None	N/A	Culture	N/A	N/A	N/A	None	N/A
Varying lead times	N/A	None	Difficult with one-off purchasers	None	N/A	N/A	N/A	N/A
Mix Flexibility	Reducing set-up time	N/A	N/A	N/A	Lack of multiskilled staff	N/A	None	N/A
Teamworking	N/A	N/A	None	N/A	None	None	N/A	N/A
Supply Chain flexibility	Managing relationship with many suppliers	N/A	N/A	N/A	Managing relationship with many suppliers	N/A	Intermediate goods producer	N/A
Good Attitude	Working culture	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overtime	N/A	None	N/A	N/A	N/A	N/A	N/A	N/A
Good Forecast measure	N/A	Obtaining correct bid information	N/A	N/A	N/A	N/A	N/A	N/A
Temporary labour	N/A	N/A	N/A	N/A	N/A	Lack of required skills	N/A	N/A
Purchase for resale	N/A	N/A	Inconsistent quality	N/A	N/A	N/A	N/A	N/A
Rejecting orders	N/A	N/A	N/A	N/A	N/A	N/A	None	N/A
Shut down	N/A	N/A	Cannot be quickly turned on and off	N/A	N/A	N/A	N/A	N/A

Table 11.4: What are the inhibitors of volume flexibility in the case study plants? – RQ2b

Enablers (RQ3)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Sister plants	[*] • Provides volume flexibility to cope with demand variability and uncertainty	• Provides volume flexibility to cope with demand variability and uncertainty	• Provides volume flexibility to cope with demand variability, short-term demand uncertainty and period of equipment upgrade	N/A	N/A	• Provides volume flexibility to cope with demand variability and short-term demand uncertainty • Provides competitive advantage	• Provides volume flexibility to cope with demand variability and uncertainty	N/A
Multiskilling	• Provides mix flexibility to cope with high product mix • Aids volume flexibility indirectly	• Motivates workforce • Satisfies the high skill level requirements • Aids volume flexibility indirectly	• Gradually eliminates overtime • Aids volume flexibility indirectly	• Aids volume flexibility indirectly	N/A	• Aids effective teamworking • Provides mix flexibility to cope with high product mix • Aids volume flexibility indirectly	• Provide mix flexibility to cope with high product mix • Aids volume flexibility indirectly	N/A
Subcontracting	N/A	• Used to handle non-core activities • Provides volume flexibility	• Used to handle non-core activities • Provides volume flexibility	N/A	N/A	• Used to handle non-core activities hence reduces cycle time • Provides long-term volume flexibility	• Helps to retain segment for dying products • Avoids need for greenfield site • Aids volume flexibility	• Investment cost avoidance • Less overhead • Inability to keep up with technological change
Equipment upgrade	• Copes with changing technology • Provide long-term mix flexibility and long-term volume flexibility	N/A	• Copes with changing technology • Copes with growth in demand • Provides long-term volume flexibility	• Copes with demand growth • Aids banked hours system • Provides long-term volume flexibility	• Copes with high product mix and smaller batch sizes • Provides long-term mix and volume flexibility	• Provides long-term volume flexibility	N/A	N/A

[*] **Table 11.5a: Why do some plants use some enablers and other plants use other enablers to achieve volume flexibility – RQ3**

Enablers (RQ3)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Banked Hours system	†• Eliminates overtime cost • Provides working hours flexibility for workers • Provides volume flexibility	N/A	N/A	• Reduced overtime cost • Low absenteeism • Increased motivation and productivity • Improves relationship between management and operators • Provides volume flexibility	N/A	N/A	N/A	N/A
Annualised Hours system	N/A	N/A	• Eliminated overtime cost • Reduced absenteeism • Provides work and safety training days • Provides volume flexibility	N/A	• Eliminated overtime cost • Lowered absenteeism • Visibility of labour cost/year • Provides volume flexibility	• Reduced overtime cost • Provides volume flexibility	• Reduced overtime and labour cost • Reduced staff sickness and accidents complaints • Provides volume flexibility	N/A
Process Improvement	• Achieves reduced number of components and encourages common processes • Indirectly aids long-term volume flexibility	N/A	• Prevents equipment breakdown • Aids long-term volume flexibility indirectly	N/A	N/A	N/A	• Reduced process complexity – achieving common upstream processes • Indirectly aids long-term volume flexibility	N/A

† **Table 11.5b: Why do some plants use some enablers and other plants use other enablers to achieve *volume flexibility* – RQ3**

Enablers (RQ3)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Varying lead times	‡N/A	• To cope with high levels of demand uncertainty – political changes • Reduces the need for volume flexibility	• Reduces the need for volume flexibility	• Reduces the need for volume flexibility	N/A	N/A	N/A	N/A
Mix Flexibility	• Copes with changing customer requirements • Reduced high machine set-up time • Aids volume flexibility indirectly	N/A	N/A	N/A	• Copes with wide range of products • Aids volume flexibility directly	N/A	• Copes with wide range of products • Aids volume flexibility indirectly	N/A
Teamworking	N/A	N/A	• Complements multiskilling • Aids volume flexibility indirectly	N/A	• Increased responsibility and ownership hence motivation • Improved productivity • Encouraged better relationship across site • Facilitated annualised hours system implementation	• Aids annualised hours contract	• Aids volume flexibility indirectly	N/A
Supply Chain flexibility	• Reduced procurement lead-time • Reduced number and type of components • Reduced number of suppliers • Aids long-term volume flexibility	N/A	N/A	N/A	• Improved raw materials yield • Aids long-term volume flexibility	N/A	• Reduced components complexity • Provided better relationship with second-tier customers • Aids long-term volume flexibility	N/A

‡ **Table 11.5c: Why do some plants use some enablers and other plants use other enablers to achieve volume flexibility – RQ3**

Enablers (RQ3)	**Teleco**	**Engico**	**Proceco**	**FonGoods**	**Foodco**	**Lachstone**	**Plastico**	**Electco**
Good Attitude	• Aids implementation of banked hours system	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overtime	N/A	• Only option available to plant • Provides volume flexibility but becomes institutionalised	N/A	N/A	N/A	N/A	N/A	N/A
Good Forecast measure	N/A	• Reduced demand uncertainty • Minimised losses on planned orders • Aids volume flexibility indirectly	N/A	N/A	N/A	N/A	N/A	N/A
Temporary labour	N/A	N/A	N/A	N/A	N/A	• Provides volume flexibility	N/A	N/A
Purchase for resale	N/A	N/A	• Copes with equipment breakdown • Provides volume flexibility	N/A	N/A	N/A	N/A	N/A
Rejecting orders	N/A	N/A	N/A	N/A	N/A	N/A	• Reduced the need for volume flexibility	N/A
Shut down	N/A	N/A	• Copes with demand slump • Encourages maintenance and equipment upgrade • Aids volume flexibility	N/A	N/A	N/A	N/A	N/A

Table 11.5d: Why do some plants use some enablers and other plants use other enablers to achieve volume flexibility? – RQ3

Enablers (RQ4)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Sister plants	[§]• Good integration • Methods and process consistency across sites	• Integration • Cross-site project teams • Compatible MRPII system	• Upskill workforce and encourage mobility • Integration • Removing demarcation	N/A	N/A	• Good integration	• Integration • Common order book • Common accounting principles	N/A
Multiskilling	• Financial incentive • Education	• Financial incentive • College training Voluntary	• Consultations Right timing • Voluntary • Training need analysis • Financial incentive	• Developing dedicated floating shift team • Good training	N/A	• Good training	• Good training • Financial incentive	N/A
Subcontracting	N/A	N/A	• Subcontract non-core activities • Integration of subcontractor staff • Training for subcontractor staff	N/A	N/A	• Good audit process • Partnership relationship	• Subcontract areas where technology is easily available	• Formal selection process • Control system • Gradual implementation • Partnership
Equipment upgrade	• Good capacity and flexibility analysis	N,A	• Accurate forecast • Upskill workforce and encourage mobility • Identify production alternatives	• Education • Introduce voluntary and good redundancy package • Extensive research on available technology	• Research on available technology	• Good forecast	N/A	N/A

[§] **Table 11.6a: How do the plants implement the enablers and overcome the inhibitors to achieve high levels of volume flexibility? – RQ4**

Enablers (RQ4)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Banked Hours	**• Timing of launch • Gradual implementation • Democratic • Incentive – discounted payback hours • Managing informally	N/A	N/A	• Education and consultation • Tackle perceptions • Incentive – discounted payback hours • Gradual implementation • Good equipment and labour capacity analyses • Self managing – peer influence • Rules and regulations to discourage refusal to pay back hours	N/A	N/A	N/A	N/A
Annualised Hours system	N/A	N/A	• Communication and consultation • Understand the system • Financial incentive • Self managing – peer influence • Encourage teamwork and multiskilling	N/A	• Education and consultation • Understand the system • Gradual implementation • Financial incentive • Affordability • Capacity need analysis • Self managing – peer influence	• Gradual implementation • Introduce self managed implementation group • Appoint team coach • Educate workforce	• Communication • Timing of launch • Good forecast • Financial incentive • Develop compatible pay system • Multiskilling • Self managing – peer influence	N/A

** **Table 11.6b: How do the plants implement the enablers and overcome the inhibitors to achieve high levels of volume flexibility? – RQ4**

Enablers (RQ4)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Process Improvement	††• Frequent planning • Capacity analysis • Common processes • Rationalising number of components	N/A	• Educate workforce • Identify root causes for failures • Corrective action • Predictive and preventative maintenance • Multiskilling • Good spares	N/A	N/A	N/A	• Develop common upstream processes • Introduce good process improvement programme	N/A
Varying lead times	N/A	• Offer a fraction of requirements • Good relationship	• Good relationship with customers	• Good relationship • Volume discounts • Multilingual personnel on site for overseas customers • Reducing number of customers	N/A	N/A	N/A	N/A
Mix Flexibility	• Flexible equipment • Multiskilled workforce • Common processes	N/A	N/A	N/A	• Install flexible equipment • Programme to upskill workforce	N/A	• Install flexible lines • Develop postponement mechanism for processes • Encourage multiskilling	N/A
Teamworking	N/A	N/A	• Total autonomy • Multiskilling	N/A	• Extensive planning • Provide training • Appoint team coach • Encourage Self assessment and autonomy • Feedback system	• Encourage multiskilling • Base it on product rather than process	N/A	N/A

†† **Table 11.6c: How do the plants implement the enablers and overcome the inhibitors to achieve high levels of volume flexibility? – RQ4**

Enablers (RQ4)	Teleco	Engico	Proceco	FonGoods	Foodco	Lachstone	Plastico	Electco
Supply Chain flexibility	• Flexibility forum • Rationalising number of components • Reducing number of suppliers • Good relationship with suppliers	N/A	N/A	N/A	• Good relationship with small number of specialist suppliers	N/A	• Good relationship with first and second tier customers • Introduce electronic point of sale system	N/A
Good Attitude	• Compatible pay system • Education	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overtime	N/A	• Financial incentive	N/A	N/A	N/A	N/A	N/A	N/A
Good Forecast measure	N/A	• Effective sales information system • Use of probability theory	N/A	N/A	N/A	N/A	N/A	N/A
Temporary labour	N/A	N/A	N/A	N/A	N/A	• Use local labour pool • Attach temps to skilled company staff	N/A	N/A
Purchase for resale	N/A	N/A	• Good relationship with sellers	N/A	N/A	N/A	N/A	N/A
Rejecting orders	N/A	N/A	N/A	N/A	N/A	N/A	• Classify customers • Increase price for low-priority customers	N/A
Shut down	N/A	N/A	• Transferability of work to sister plant • Multiskilling and mobility	N/A	N/A	N/A	N/A	N/A

Table 11.6d: How do the plants implement the enablers and overcome the inhibitors to achieve high levels of volume flexibility? – RQ4

11.2.1 Sister Plants

Table 11.3 shows that 5 out of the 8 plants studied employ the strategy of moving orders to their sister plants to cope with demand level fluctuations. Using sister plants helps to manage short-term demand uncertainty and demand variability. FonGoods, Foodco and Electco do not use this strategy. In the case of FonGoods, although a continental European company owns it, it has no sister plants involved in a similar type of operation. Foodco on the other hand has sister plants within and outside the UK that it could shed load to, but because of the internal competition that exists within the group, it would not generally employ this strategy. The only strategy employed by Electco is subcontracting. Generally, the use of sister plants is *specific* to plants whose sister plants carry out similar manufacturing operations. This is a necessary but not a sufficient condition.

Inhibitors - RQ2b (Table 11.4)

Only two of the case study plants had some problems with the use of sister plants (Engico and Plastico). It was difficult for Engico to use its sister plant to cope with demand fluctuations involving non-engineering operations. This is because of the logistics problems of moving goods and materials over long distances between the two sites. Using sister plants in Plastico involves sharing loads on a European basis. From an accounting point of view, this is problematic because of the different accounting principles being used in different countries.

Why do the plants use sister plants? – RQ3 (Table 11.5)

The use of the strategy is *sector independent* as the plants that use it belong to different sectors. It appears that the most common reasons for the use of sister plants as an enabler of volume flexibility in the plants studied are (i) to cope with high variability in demand levels and (ii) short-term demand uncertainty. Therefore, the ability to move load across plants provides the plants with volume flexibility (especially from the customers' point of view). In some cases, it gives competitive advantage, especially where competitors do not possess this capability (e.g in Lachstone). Specifically, plants may shed load to their sister plants to cushion the effect of dying products in their portfolio, as is the case with Lachstone. The plant transferred the production of a particular product which was reaching its dying stages in France from the sister plant in that country to the UK plant where the product was still in the early stages of the life-cycle.

How do the plants implement 'use of sister plants'? – RQ4 (Table 11.6)

Generally, the key implementation factor for using this strategy in the plants is to have good integration in all aspects between the sister plants. Also, having a common view of the order book, having cross-site project teams, developing common accounting principles and achieving method consistency across sites have helped the plants to overcome the inhibitors discussed above and to use the strategy of sister plants successfully to achieve high levels of volume flexibility.

11.2.2 Subcontracting

Subcontracting work outside the plant is done as part of a strategy to achieve long-term volume flexibility in all the plants that use it. Subcontracting is being used by four of the case study plants (i.e. Proceco, Lachstone, Plastico and Electco). Proceco, a process plant employs the strategy in a way that is different from the other plants. It actually outsources an activity that is totally independent of its production process to a subcontractor on site. This is the provision of contract staff for such activities as scaffolding, painting and the like. These contract staff are paid by the subcontractor but supervised directly by Proceco staff. FonGoods (a household goods plant) and Foodco (a food processing plant) do not presently use the strategy and would not consider its use in the future. Teleco discontinued the use of the sub-contracting for various reasons, including the increasing cost of the strategy, the upskilling of its workers and the upgrading of its technology, leading to less need for subcontracting.

Inhibitors – RQ2b (Table 11.4)

Obtaining products of consistent quality from subcontractors appears to be the main problem for the plants that use subcontractors to achieve volume flexibility. For Plastico, due to the bespoke nature of its products, it was more difficult to manage subcontracting at the operational level where a portion of the production process was subcontracted.

Why do the plants use subcontracting? – RQ3 (Table 11.5)

For those plants that use sub-contracting it appears that the main driver for its use is high variability in demand levels (apart from Electco). Subcontracting is used mainly to handle non-core activities when there is an increase in demand levels, although the plant may actually possess the capability internally. It can also be used as an exit and entry strategy into a market segment, as is the case with Plastico. Electco subcontracts its main manufacturing operation for cost avoidance and inability to keep up with rapid technological change. Although relatively costly for some plants, subcontracting generally provides the needed volume flexibility for most of the plants that use it. Lachstone will increase its level of outsourcing in the future in order to further reduce the production cycle time.

How do the plants implement subcontracting? – RQ4 (Table 11.6)

Having a good relationship with the subcontractor and good audit and control systems are the main factors for the successful implementation of the strategy. These factors have helped the plants to overcome the major problem of inconsistent quality. Additionally, subcontracting can be less problematic where the technology required for the outsourced activity is easily available. Proceco trained and fully integrated the subcontractor staff it uses into its operations. This helped in reducing minor accidents on site which were previously attributed to the subcontractor's staff.

11.2.3 Multiskilling

Multiskilling as an enabler of volume flexibility is being used by all but two of the case study plants. Electco, as explained before, are wholly involved in subcontracting. Although Foodco has some multiskilled staff in its workforce, it has not employed the strategy consciously as an enabler of volume flexibility. Quite recently the need for highly multiskilled staff as an aid to the successful use of teamworking has become apparent to the plant, and a plan is now underway to implement multiskilling. Multiskilling appears to be a *generic enabler* of volume flexibility in the case studies but its effect on the achievement of volume flexibility in the plants is indirect.

Inhibitors – RQ2b (Table 11.4)

Implementing the strategy has generally not been problematic for most of the plants but in some cases there were problems of getting people to enlist for training programmes (e.g. in Engico) and some union membership problems in heavily unionised plants (e.g. in Proceco).

Why do the plants use multiskilling? – RQ3 (Table 11.5)

The *generic drivers* for the use of multiskilling are high variability in demand levels, short-term demand uncertainty and high product mix. Thus, workers can be moved from a quiet area of the plant to the busy area quite easily, irrespective of the skill level requirements. Where there is a high product mix or component complexity such as in Teleco (an Electronics sector plant), the need for workers to be multiskilled cannot be over-emphasised. Generally, multiskilling has provided many of the plants studied with the required levels of volume flexibility because of its compatibility with other enablers of volume flexibility such as mix flexibility, team working and the use of annualised hours systems. In Electco, multiskilling has been used to gradually eliminate overtime as paid training hours were initially used to replace overtime hours.

How do the plants implement multiskilling? – RQ4 (Table 11.6)

The key generic factors, which have helped in successfully implementing the strategy in the plants, are the provision of good and relevant training, financial incentives for the upskilled workers and making participation in the programme voluntary. Where union problems and other resistance to change were encountered (Proceco and Engico), the plants carried out extensive consultations and thoroughly educated the parties involved about the reasons for the implementation of the strategy.

11.2.4 Banked Hours System/Annualised Hours System

The underlying principles behind the use of two the strategies above to achieve high levels of volume flexibility are similar, the only difference being that the annualised hours system is based on a yearly contract. The banked hours system is based on a flexible (usually weekly) time horizon depending on needs. An individual is committed to work a certain number of hours over the relevant period in line with scheduled or known demand pattern, which may vary from time to time within the period. Each individual has additional reserved hours which are paid for but only used to cover short-term demand uncertainty, such as an increase in demand levels over and above forecasts. Because they directly provide a plant with the ability to vary labour hours to cope with either demand variability or short-term demand uncertainty the banked hours and annualised hours systems are direct enablers of volume flexibility in the case studies. The details of how each is used are explained in the case analyses of the individual plants in Chapter 10.

All but one of the plants use either the banked hours system or the annualised hours system to cope with demand level fluctuations (Electco is not included). Engico, the only plant that does not use either of the strategies, had actually used an annualised hours system unsuccessfully before. The failure of the system, however, was due to its poor management (Chapter 9) and not the unsuitability of the strategy to the plant's operations. So the fact that most of the plants use these strategies confirms the result of the survey research, that the use of an annualised hours system and/or banked hours system does not depend on the sector of the plant. It is pertinent to note that the survey did not differentiate between banked hours and annualised hours systems.

Inhibitors – RQ2b (Table 11.4)

The most common or *generic inhibitor* to the implementation of the strategies across the plants is *resistance to change*. This is more pronounced in heavily unionised plants (e.g. Proceco). One of the reasons from the plants' perspective is that the philosophies underpinning the strategies go against the commonly accepted paradigm of working. Refusing to pay back banked or reserved hours when required is also a common problem, which the plants encountered (Proceco and FonGoods). In Lachstone, the gradual implementation of an annualised hours system resulted in division and conflict as a section of the plant where the strategy was first implemented was seen as different and better by the other sections of the plant. The success of the use of the annualised hours system depends very much on having a relatively predictable total demand over the planning period (usually one year). High forecast errors (over 1 year) in Plastico therefore resulted in too many committed and reserved hours, which were paid for but never used.

Why do the plants use banked hours/annualised hours systems – RQ3 (Table 11.5)

The generic drivers for the adoption of the two strategies are high variability in demand levels, short-term demand uncertainty and the need to reduce or eliminate excessive overtime costs. Other reasons given by some plants include low productivity, the need to have better visibility of labour costs and high absenteeism. The analysis reveals that the adoption of these strategies has been fruitful for the plants. Generally, all the plants have achieved high levels of volume flexibility and have either reduced or totally eliminated overtime costs, experienced reduced a absenteeism rate and increased productivity. The adoption of an annualised hours system enables Foodco to have a better visibility of impending labour costs. Hence, there is a desire to use banked hours and annualised hours' systems more in the future by all the case study plants that presently use them. This was a trend observed in the survey analyses.

How do plants implement banked hours/annualised hours systems? – RQ4 (Table 11.6)

Overcoming the inhibitors and implementing the strategies to achieve high levels of volume flexibility in all the plants is all about the management of change. The cross-case analyses reveal that the generic key factors for the successful implementation of the two strategies are:

- Effective communication and consultation
- Gradual implementation of the strategy
- Provision of incentives (financial or otherwise)
- Correct timing of launch
- Allowing the system to be self managed.

Self-management means that operators formulate their own rosters, hence it is relatively more difficult to exploit the system due to peer pressure (e.g. illegal accidents' complaints to stay off work).

It is interesting to note from the analyses that the incentives offered by the plants that implemented the banked hours system are non financial (Teleco and FonGoods) while the plants that used the annualised hours system offered financial incentives (Proceco, Foodco and Plastico). This might be due to the differences in the way the implementation of the strategy affects or impacts on the workforce. The annualised hours system is perceived to be more of a big change than the banked hours system. Thus, the former may require more persuasion to get it implemented.

Generally, the analyses reveal that an annualised hours system is more suitable for coping with *demand variability* (i.e. significant variation within the year but relatively predictable total yearly demand) and *short-term demand uncertainty* (i.e. uncertainty in the short-term but fairly predictable total yearly demand levels). Hence, it is being used in Foodco and Plastico, plants that experience highly seasonal demand profiles. The banked hours system on the other hand appears to be suitable for coping with both *demand variability* (including non-seasonal demand profile – Teleco and FonGoods) and *demand uncertainty*.

11.2.5 Process Improvement

Improving the production process is a method of changing the volume flexibility characteristics of a plant, although the effect of this method on volume flexibility may be indirect. It is important to note that, unlike some of the other enablers of volume flexibility, carrying out process improvement is not a strategy that was implemented for instance in a given period 'N' to solve the demand level fluctuations experienced in that given period 'N'. Rather, it is a long term and a gradual process, which, for example, is implemented, in a given period 'N' to cope with the demand level fluctuations in a subsequent period 'N+1'. Three of the case study plants (Teleco, Proceco and Plastico) consciously improved their processes to achieve some levels of long-term volume flexibility, albeit indirectly.

Inhibitors – RQ2b (Table 11.4)

Proceco had to deal with the issue of lack of a maintenance culture. The other two plants had no real problems carrying out process improvements.

Why do plants improve their processes to achieve volume flexibility? –RQ3 (Table 11.5)

One of the generic reasons for improving processes in the plants appears to be the need to achieve long-term volume flexibility, albeit indirectly. In the case of Proceco, process improvement takes the form of implementing a manufacturing reliability programme to prevent equipment breakdown. Focusing the process improvement on equipment breakdown is more significant to this plant because of the nature of its operation (heavily capital intensive and a continuous process). For Teleco and Plastico, process improvement is undertaken to rationalise the number of components required for production and to achieve common upstream processes in order to be able to handle a wide range of products using a smaller number of components.

How do plants implement process improvement? – RQ4 (Table 11.6)

The implementation process in Proceco focuses on a manufacturing reliability programme. This is done by performing a historical analysis of breakdowns and failures. The future analysis of potential problems is also undertaken and corrective actions are formulated in the form of a preventative and predictive maintenance programme. With proper education, training and ownership of equipment transferred to teams, Proceco was able to change the attitudes towards maintenance.

Teleco put together a process improvement group whose main task was to find ways of achieving common processes upstream and reducing the number of components required in production.

11.2.6 Equipment Upgrade/Investment in Technology

Four of the case study plants have carried out equipment upgrade either as a strategy to provide additional capacity (long-term volume flexibility) or the ability to handle a wide range of products (long-term mix flexibility) or both (as in Foodco). The analyses reveal that the adoption of this strategy is *sector independent* and as a matter of fact does not appear to depend on any other special plant's characteristics.

Inhibitors – RQ2b (Table 11.4)

Upgrading equipment and investing in new technology is perceived generally not to be problematic to implement, although it created tension amongst workers in FonGoods. This was due to fear of job losses and to the alienation of workers. It appears, though, that for many of the plants, it has been a costly exercise. This may be because of the relatively long recovery period of the fixed cost of investment and in some cases because of idle capacity when demand falls.

Why do plants upgrade their equipment or invest in new technology – RQ3 (Table 11.5)

The generic reason for the use of this strategy appears to be growth in demand levels. In some cases, it was due to changing technology and an increase in product mix. Equipment upgrade at Foodco provided the plant with the ability to handle smaller batch sizes and at the same time with the ability to handle a wider range of products effectively. At FonGoods, an equipment upgrade provided spare machine capacity which aided the implementation of the banked hours system.

How do the plants go about upgrading their equipment to achieve long-term volume flexibility? – RQ4 (Table 11.6)

Generally, the plants carried out good capacity analyses and extensive research on available technology that best met their needs prior to embarking on the process of equipment upgrading. In the case of Proceco, equipment upgrading meant plant shutdown, so the existence of a nearby sister plant was vital to the successful implementation of the strategy, as was the availability of a multiskilled and mobile workforce. FonGoods employed effective change management techniques through education and introduction of a lucrative voluntary redundancy package to overcome the problem of fear and tension which investment in new technology created in the plant. Lachstone improved on their demand forecasting to gain a better view of potential demand growth in the market place. Like process improvement, equipment upgrade is a strategy that is implemented in 'period N' to solve the problems of 'period N+1'. In other words, it is a long-term solution to providing volume flexibility.

11.2.7 Varying Lead Times

This is a mechanism used to cope with demand variability and uncertainty, which reduces the need for internal volume flexibility. Consider a plant that has two customers A and B. The plant may be able to meet the volume requirements of customer A if it succeeds in varying the lead-time for customer B's orders. From customer A's perspective, the plant has some degree of volume flexibility. So, varying lead-time can be said to have an indirect effect on the achievement of volume flexibility.

Three of the case study plants employ 'varying lead-times' to cope with high levels of demand fluctuation (Engico, Proceco and FonGoods).

Inhibitors – RQ2b (Table 11.4)

The use of variation in lead-time is generally not perceived to be problematic for the plants studied. For Proceco, it was difficult to vary the lead times for customers who make one-off purchases. Clearly, this is because of the lack of a good relationship with such customers.

Why do the plants use 'variation in lead-times' to cope with demand variability? – RQ3 (Table 11.5)

As explained above, the plants use this strategy to reduce the need for volume flexibility, hence providing indirectly some degree of volume flexibility from some customers' points of view. Engico uses it mainly because of the nature of its business – contracting, which involves winning orders on the basis of bids that have highly uncertain success rates and depend on political changes. The contract nature of the business and the characteristics of the sector in which it operates (defence industry - dependent on political changes) make 'varying lead-times' a viable strategy for Engico to employ. It is mostly used when the customer makes changes to a signed contract that already has a fixed completion and delivery date. Proceco has a continuous production system. Its output capacity is constrained by the plant capacity, which is rather inflexible in the short term, rather than people capacity, and hence will be more likely to use this option to cope with high variability in demand levels. FonGoods operates in a market that is not very competitive and can afford to negotiate its lead times to cope with demand fluctuations. Generally, the use of 'varying lead-times' to cope with demand variability and uncertainty appears to depend on the nature of the business, the production process and the competitive nature of the market in which the plants operate.

How do the plants implement 'varying lead-times' to cope with demand variability? – RQ4 (Table 11.6)

All the plants were able to use this strategy because they developed and maintained good relationships with their customers. Engico offers its customers a fraction of demand requirements when it asks for the lead-time to be varied. FonGoods gives volume discounts to customers and employs friendly multilingual personnel on site for their overseas customers. This enhances the plant's relationship with its customers. FonGoods is able to maintain these relationships because it classified its customers, and subsequently reduced the number of customers it has very close relationships with.

11.2.8 Mix Flexibility

By implementing mix flexibility strategies three of the case study plants were able to achieve indirectly high levels of volume flexibility (Teleco, Foodco and Plastico). This is because having mix flexibility gives the plant the ability to adjust quickly to relative volume changes within mix. Mix flexibility strategies implemented in these plants include multiskilling and the installation of flexible machines and lines that can handle a wide range of products in a prompt manner. As discussed previously, multiskilling provides the plant with the ability to move operators around the factory, depending on the loading requirements. Flexible machines, as defined here, have low set-up and changeover times and can handle a wide range of products. These lead to reduced lead-times and increased volume flexibility, provided the plant is able to vary its capacity (in terms of labour and machine hours) in line with demand requirements. Thus, a plant that produces a wide range of products would require high levels of mix flexibility in order to have high levels of volume flexibility, provided that the plant has the capability to alter its capacity in line with the demand requirements. However, it is possible for a plant to have high levels of mix flexibility but no volume flexibility.

Inhibitors – RQ2b (Table 11.4)

Inhibitors to implementing mix flexibility appear to be dependent on the particular plant. Reducing set-up time is problematic for Teleco because extra care is required when setting up the surface mount machines to avoid heavy losses due to wrong placements. Lack of sufficient multiskilled staff restricts the ability of Foodco to achieve high levels of mix flexibility. It is not problematic to achieve mix flexibility in Plastico.

Why do the plants implement mix flexibility strategies to achieve volume flexibility? – RQ3 (Table 11.5)

Generally, the plants need mix flexibility because of the wide range of products which they are required to produce. Prior to implementing a mix flexibility strategy (installing flexible lines), Foodco was restricted to weekly batches of production in spite of the many SKUs, which the plant carries. This was due to the inflexible nature of the machines that it was using. Teleco needed to reduce the set-up time on its surface mount machines as this leads to increased lead-time, which restricts the volume flexibility of the plant. It also needed to break the bottleneck in its production process. The PCB manual-testing operation is the bottleneck in Teleco as the process involves manual handling and checking for defects and testing, which tend to be slower compared to the other processes in the PCB manufacture in the plant. This operation effectively determined the throughput of the system. By implementing suitable strategies (discussed below) to achieve mix flexibility the plants were able to reduce the lead-time of their manufacturing operations and achieve increased levels of volume flexibility.

How do the plants achieve mix flexibility? – (RQ4) (Table 11.6)

Three generic factors consistently appear in the cases studied for the successful implementation of mix flexibility. These are, multiskilled workforce, having flexible equipment or lines (which provides the ability to chop and change), and common processes (or postponement mechanisms).

It was important for Teleco to focus on multiskilling to achieve mix flexibility. The plant embarked on an extensive training scheme for its operators with particular focus on training for manual testing of PCBs. With multiskilling, the plant is able to beef up the capacity of the manual testing operation when it is overloaded as it becomes possible to move operators to this section of the production process.

Foodco's focus was on installing flexible lines, which gave the plant the ability to move from production of weekly batches (at a small number of SKU per week) to daily production of many SKUs per week. This reduced the lead-times for production and increased the level of volume flexibility for the plant (as long as the plant was able to vary its labour capacity).

Teleco and Plastico focused on achieving common upstream processes (or postponement mechanisms). These give the plants the ability to handle a wide range of products in shorter lead-times and hence can lead to mix flexibility.

Consider a plant that requires high levels of volume flexibility, but is required to produce a wide range of products. It is proposed that the plant needs high levels of mix flexibility (in addition to other volume flexibility strategies), as shown in the model below in order to achieve high levels of volume flexibility.

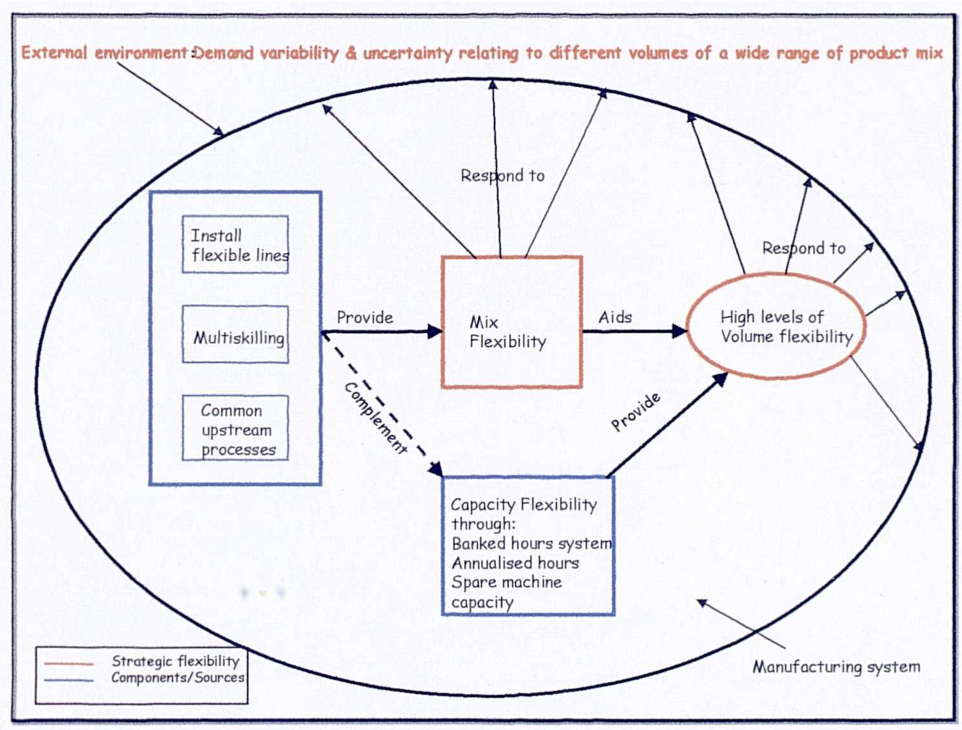

Figure 11.0: Relationship between mix and volume flexibility in an environment relating to high demand variability and uncertainty in product mix and volume requirements.

Due to the nature of the factors required to achieve mix flexibility, it is important to note that having mix flexibility to achieve volume flexibility must be done as part of a strategy to provide long-term volume flexibility rather than a short-term solution to achieve volume flexibility.

11.2.9 Teamworking

Three of the case study plants use teams in ways that provide the plants with volume flexibility (Proceco, Foodco and Lachstone). The use of teamworking has aided the achievement of volume flexibility in the plants by facilitating the implementation of an annualised hours system. It is interesting to note that the three plants that use teams also use annualised hours systems to achieve volume flexibility. One of the key factors in the successful implementation of an annualised hours contract as evidenced in the cases studied is the encouragement of self and informal management of the system. Self-management works best in a group context (i.e. teamworking). Engico was unsuccessful in its implementation of annualised hours contracts because it tried to manage the system from the top. This exposed the system to exploitation by the operators who felt distanced and removed from such important decisions as organising and scheduling rosters, which are better handled by teams. Within the teams, informal arrangements can be made for cover and the like. Hence, teamworking and the use of an annualised hours system to achieve volume flexibility can be said to be *complementary*.

Inhibitors – RQ2b (Table 11.4)

Evidence from the case studies reveals that none of the plants had problems implementing teamworking.

Why do the plants use teamworking? – RQ3 (Table 11.5)

Foodco has used teamworking to foster integration and to increase job responsibility and ownership. These resulted in better relationships amongst the operators, improved motivation and productivity. In Teleco, teams provided the right atmosphere for the implementation of multiskilling. Teamworking also provided the right medium for the implementation of annualised hours systems in the three plants.

How do the plants implement teamworking? – RQ4 (Table 11.6)

Forming teams that consist of multiskilled operators and giving the teams total autonomy in the way they choose their leaders, and organise and schedule activities appear to be the generic factors for the successful implementation of teamworking in the plants. The move to a teamwork system in Foodco took about 12 months of planning. The planning was conducted by a steering group which met regularly to define the modality of the system. The appointment of a team coach and provision of adequate training for team coaches and other team members relating to the workability of the teams are also important in the successful implementation of the teamwork system in Foodco.

11.2.10 Supply Chain Flexibility

A flexible supply network has been regarded as an important source of flexibility (Slack, 1991). Having supply chain flexibility is significant for three of the case study plants to achieve high levels of volume flexibility (Teleco, Foodco and Plastico). Effective or flexible supply chains would increase the responsiveness of manufacturing plants where materials could be delivered by suppliers in a prompt and efficient manner and finished products are also delivered to customers in an efficient and prompt manner.

Inhibitors – RQ2b (Table 11.4)

For Teleco and Foodco, it was difficult to achieve flexibility in the supply chain because of the difficulties involved in managing a large number of suppliers. The difficulty is further compounded in the case of Teleco because of the wide range of different components involved. Plastico did not have direct links with the major players in its supply chain (second tier customers - the retailers) because it supplies intermediate products that require further conversion before reaching the point of retail. The implication is that Plastico has a poor visibility of the end customer requirements. This restricted Plastico's ability to achieve total supply chain flexibility.

Why do the plants choose to have supply chain flexibility? – RQ3 (Table 11.5)

Supply chains have been recognised by the plants as sources of competitive advantage in that competition is increasingly shifting from organisations competing against organisations to supply chains competing against supply chains (Christopher, 1992). The plants deal with a large number of suppliers (Teleco and Foodco) and equally high variety and number of components (Teleco and Plastico). These factors create complexity in the supply chains and drive the plants to require supply chain flexibility.

How do the plants achieve supply chain flexibility? – RQ4 (Table 11.6)

The objectives for the plants were clear: to achieve supply chain flexibility by improving the relationship with their suppliers and second tier customers (in the case of Plastico) and to reduce component complexity by reducing the number and type of components that they had to deal with. Teleco launched a project with a number of their suppliers. This project was named the Teleco flexibility forum. The forum met regularly and developed together some interesting improvements in order to enhance flexibility. Combined with the work of another group formed within Teleco, the forum came up with an improvement programme that helped to rationalise the number of components required for PCB manufacture and reduce the large supplier base. Better relationships can be developed and maintained with a relatively small number of suppliers.

Installation of an electronic point of sale system and working directly with end customers (grocery retailers) has helped Plastico to achieve supply chain flexibility and to overcome the supply chain visibility problem.

11.2.11 Other Enablers of Volume Flexibility

Tables 11.4, 11.5 and 11.6 present the other strategies used by the case study plants to achieve high levels of volume flexibility. A good cross-case analysis cannot be carried out because each of the strategies is used by only one plant to cope with demand level fluctuations. Thus, it is sufficient to refer to the individual case analyses (Chapters 9 and 10) for issues relating to how the enablers have been used, what the inhibitors are, why the plants choose to use some enablers and how the plants have actually implemented the enablers.

It is pertinent to note that the use of a 'shut down' strategy to cope with demand fluctuations is limited to a plant that has a sister plant with spare capacity. The fact that only one of the plants in the case study is using overtime suggests a general switch from the use of overtime hours due to the drawbacks of its use, as highlighted in the Engico case analysis (Engico had previously tried unsuccessfully to implement an annualised hours system). The use of overtime hours by full time staff to cope with demand fluctuations is not seen by Engico as the best solution but the only option that is open to it. There is no reason in the analyses to suggest that this is due to certain distinguishing characteristics of the plant in question. So, overtime hours could have been used by any of the case studies plants if they had chosen to, irrespective of sector and other plant characteristics.

Engico, an engineering capital sector plant also uses probability theory to carry out forecasts to reduce demand uncertainty. The plant is involved in the contract manufacturing business. Although customer demand is highly uncertain in this type of business, using probability theory to predict the likelihood of getting a tender and eventually winning it can actually reduce the uncertainty in the demand as long as the parameters have been correctly determined. This reduces the need for volume flexibility in the plant.

11.3 Further Analyses

Figure 11.1 shows the characteristics of the enablers identified and the nature of their effects on volume flexibility. The classification has been done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels, short-term demand uncertainty, absenteeism and equipment breakdown.

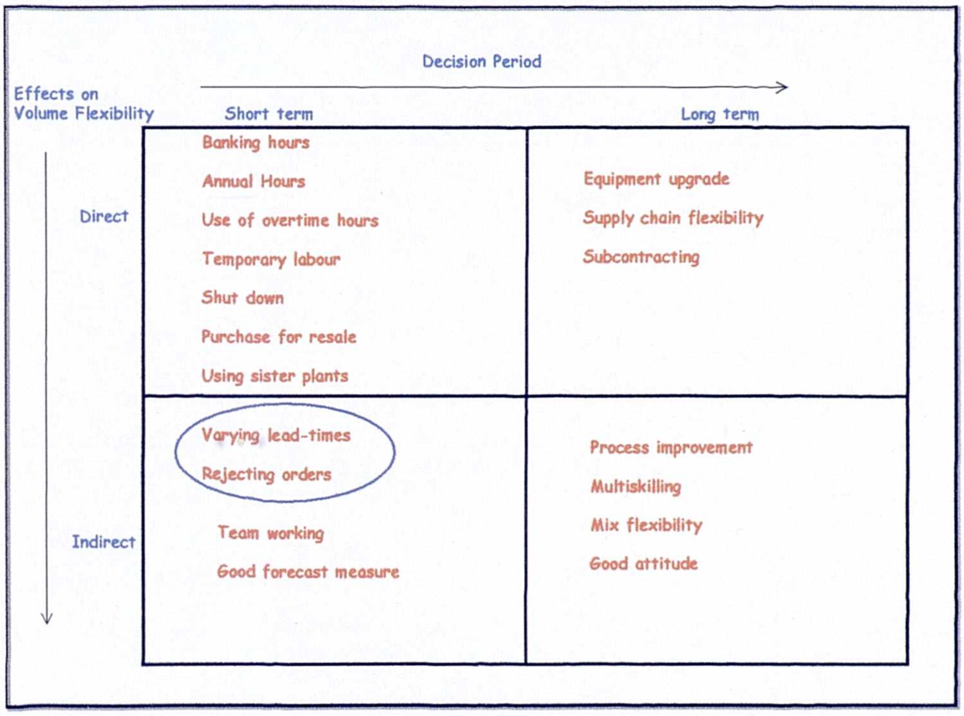

Figure 11.1: Decision hierarchy view and the effects of enablers on volume flexibility

The circled enablers are those solutions, which reduce the need for internal volume flexibility. From the customer's point of view, a plant that employs any of these solutions to cope with demand variability and uncertainty is perceived to have some degree of volume flexibility. Hence, it is proposed that the effects of these solutions on the achievement of volume flexibility are indirect.

Figure 11.2 shows a further classification of the enablers of volume flexibility identified from the case study analyses. **Generic enablers* are those that can be used by all the

* Note that the terms *Generic* and *Specific* have been used here in reference only to the case study plants.

plants studied as far as achieving volume flexibility is concerned. In other words, their use by the case study plants is not in any way peculiar to the plants, either in terms of sector or any other plant characteristics observable in the case analyses. *Specific enablers* are those for which their use by the case study plants to achieve volume flexibility are specific to the plants, either because of the sectors to which the plants belong or other peculiar plant, product or market characteristics. It is interesting to note that all the enablers identified from the case studies are *sector independent*.

The figure also summarises the relationships between the enablers. Thus, enablers are classified as *substitutes* (where one enabler can be used to replace another) and *complements* (where the use of one enabler aids the use of another) in achieving volume flexibility.

Volume Flexibility Solutions ↓	Generic	Specific	Substitutes	Complements
Labour	Multiskilling Banking hours Teamworking Good attitude of workers Overtime	Annualised hours system Temporary labour	Annual hours & Overtime Banking hours & Overtime	Multiskilling/Annual hours Multiskilling/Banking hours Multiskilling/Mix flexibility Multiskilling/Sister plants Teamworking/Annual hours Teamworking/Banking hours Teamworking/Multiskilling
Material		Supply chain flexibility		
Equipment	Process improvement	Shut down Equipment upgrade		Equipment Upgrade & Process improvement
Others	Process improvement	Using sister plants Subcontracting Varying lead times Mix Flexibility Purchase for resale Good forecast measure Rejecting orders		

Figure 11.2: Classification of enablers based on case studies evidence only

11.4 Quality of the Case Study Design

Yin (1994) identifies four tests, which can be used to judge the quality of any empirical research. These have been applied to the case study research in this study as follows:

Construct Validity: The operational measures used for the main concepts in this research were established and initially tested in the pilot study. These were refined and used in the survey research for which statistical validity tests were carried out to confirm the adequacy of the measures. The construct validity is further improved upon by collecting data from multiple sources of evidence in the case study (i.e. both qualitative and quantitative evidence).

Internal Validity: The causal relationships established between the variables in the case study research are found to be valid as these relationships hold in all the cases studied (where variables are applicable). The evidence obtained in respect of these relationships appears to be convergent. Also, the relationships observed are compared and found to match with the predicted ones from the literature (pattern matching, Yin, 1994). This confirms that relationships are free from the effects of spurious factors.

External Validity: The cases have been selected from the Best Factory Award database which consists of UK manufacturing plants that have entered for the competition between 1995 and 1998. Replication logic, rather than a sampling logic, has been used to select the cases. This gives room for differences (theoretical replication) and similarities (literal replication) to emerge from the cross-case analyses. The findings of each case are tested and confirmed in subsequent cases using the same research instruments, thus confirming the external validity of the research. Although the replications are limited to eight cases, Yin (1994) argues that the results might be accepted for a much larger sample of similar cases even though further replications have not been performed. The larger sample in the case of this project consists of plants that have entered for the BFA competition. These plants generally employ more than 100 employees, are run by management teams with the awareness of, and motivation and ability to complete the BFA questionnaire. However, it is pertinent to note that the resulting generalisations of case study research are analytical rather than statistical and should be generalised to theory (Yin, 1994).

Reliability: A single procedure was used to carry out the case study research and analyses. Testing out the research methods in a pilot case study also improved the reliability of the research. The same research instruments have been used for different case analyses to increase the reliability of the research. Hence, it should be possible to use the same instruments to repeat the research and obtain similar results.

11.5 Chapter Summary

The objectives of the case study analyses have been to:

1. Identify the conditions under which plants will require high levels of volume flexibility (Research Question One)
2. Explore and explain the reasons behind the applicability of these drivers to certain manufacturing plants.
3. Identify the factors that enable and inhibit the achievement of volume flexibility in manufacturing plants (Research Question Two)
4. Provide explanations as to why some plants use some enablers and other plants use other enablers (Research Question Three).
5. Provide explanations as to how plants actually use the enablers and overcome the inhibitors to achieve high levels of volume flexibility (Research Question Four).

The table below has been used to summarise the outcome of the case study analyses regarding point 1 above. It is important to note that all the drivers of volume flexibility identified are *sector independent* (i.e. they appear to be applicable to all sectors).

Drivers of Volume Flexibility (RQ1)	**Generic?**	**Specific?**	**†Applicability**
High variability in demand levels	Yes	No	Generally applicable to all the plants studied
Short term demand uncertainty	Yes	No	Applicable to all the plants studied
Long term demand uncertainty	No	Yes	Applicable to plants engaged in contract manufacturing
Supply chain complexity	No	Yes	Applicable to plants with high number of components in production and plants dealing with many suppliers.
Short Product Life Cycle	No	Yes	Applicable to plants whose products become obsolete quickly as a result of rapid technology changes, changing customer tastes and competition.
New Product Introduction	No	Yes	As above
High Product Mix	No	Yes	Applicable to plants producing non-standardised products
Short Product Shelf Life	No	Yes	Applicable to plants whose products are perishable
Competitors' actions	No	Yes	Applicable to plants operating in fiercely competitive environment
Currency Variations	No	Yes	Applicable to UK plants with high level of overseas business involvement
Business needs and company policies including 'stop making to stock', and differentiation	No	Yes	Inconclusive
Communication with customers	No	Yes	Applicable to intermediate goods producer.

Table 11.7: Summary of drivers of volume flexibility and their applicability in the case study plants.

† This refers only to the case study plants

The table below summarises the analyses in respect of Research Question 2a (i.e. what are the enablers of volume flexibility in manufacturing plants?). The enablers are classified as either *generic* (i.e. generally applicable in the case study plants) or *specific* (i.e. only applicable in specific plants in the case studies).

Enablers of Volume Flexibility	Effect on Volume Flexibility	Time horizon	Generic?	Specific?	‡Applicability
Using sister Plant	Direct	Short term	No	Yes	Plants having sister plants with spare capacity and similar manufacturing processes
Sub-contracting	Direct	Long term	No	Yes	Plants having easily available and transferable technology and some non core processes
Multiskilling	Indirect	Long term	Yes	No	Most plants
Banked Hours	Direct	Short term	Yes	No	Most plants
Annualised hours system	Direct	Short term	No	Yes	Plants with seasonal demand and/or relatively good yearly demand level forecast (demand variability + short term demand uncertainty)
Process improvement	Indirect	Long term	Yes	No	Most plants
Equipment upgrade	Direct	Long term	No	Yes	Plants having significant demand growth, inflexible machines, high product mix and/or smaller batch sizes.
Varying lead times	Indirect	Short term	No	Yes	Plants engaged in contract manufacture, continuous production system and/or less competitive markets
Mix Flexibility	Indirect	Long term	No	Yes	Plants having high product mix, flexible lines and/or multiskilled workforce
Team working	Indirect	Short term	Yes	No	Most plants
Supply Chain Flexibility	Direct	Long term	No	Yes	Plants having high number of components and raw materials, many suppliers and poor visibility of supply chain
Good attitude	Indirect	Long term	Yes	No	Most plants
Purchase for resale	Direct	Short term	No	Yes	Plants having co-operative competitors and/or plants in a horizontal form of network
Overtime	Direct	Short term	Yes	No	Plants having willing workforce and are able to bear the cost
Good forecast measure	Indirect	Long term	No	Yes	Plants having high uncertainty in demand levels
Temporary labour	Direct	Short term	No	Yes	Plants with relatively low skilled jobs and/or operating where labour pool is available
Shut down	Direct	Short term	No	Yes	Continuous process plants which cannot be easily turned on and off. Must have production alternatives
Rejecting orders	Indirect	Short term	No	Yes	Plants with great clout, having classified customer base and being assured of orders from priority customers.

Table 11.8: Classification of volume flexibility enablers relating to the case studies

‡ Again, this refers only to the case study plants.

The cross-case analyses further reveal the inhibitors of volume flexibility (RQ2b), why plants choose to use particular enablers (RQ3) and how the case study plants actually implement the enablers and overcome the inhibitors to achieve volume flexibility (RQ4). The results of analyses for some selected enablers are summarised in Table 11.9.

Enablers (RQ2a)	**Inhibitors (RQ2b)**	**Why do some plants use some enablers and other plants use other enablers? (RQ3)**	**How do plants implement the enablers and overcome the inhibitors to achieve volume flexibility? (RQ4)**
Banked hours system	• Resistance to change • Refusal to pay back hours	• Copes with demand variability and uncertainty • Eliminates overtime • Reduces absenteeism rate • Increases motivation and productivity	• Correct timing of launch • Gradual implementation • Education and consultation • Incentive – discounted payback hours • Self managing • Good capacity needs analyses
Annualised hours system	• Resistance to change • Refusal to pay back hours • Divisive if implemented gradually • Inaccurate forecast	• Copes with demand variability and short-term demand uncertainty • Eliminates overtime • Reduces absenteeism rate • Improves labour cost visibility • Provides work and safety training days • Suitable for seasonal demand	• Communication and consultation • Financial incentive • Capacity need analysis • Implement through teams • Self managed • Correct timing of launch • Appoint team coach • Good forecast
Use of overtime hours	• None	• Copes with demand variability and uncertainty • Only option available to the plant that uses it	• Financial incentive
Use of temporary labour	• Lack of required skills	• Copes with demand variability and uncertainty	• Use local labour pool • Attach temps to skilled company staff

Table 11.9: Summary of analyses: Insights into RQ2, RQ3 and RQ4.

The next chapter will discuss the methodological triangulation for the study. It will compare the results from the survey analyses (presented in Chapters 7 and 8) with the results of the case studies analyses discussed in this chapter.

Chapter 12 – Methodological Triangulation: Comparing the Survey and Case Studies Results

12.0 Introduction

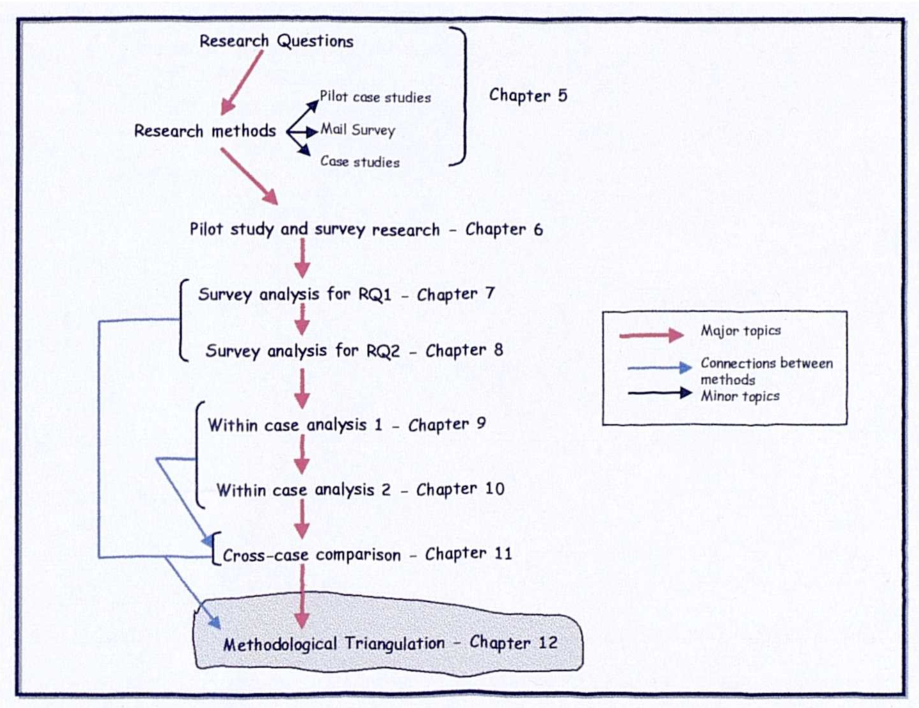

Figure 12.0: Empirical research road map. Chapter coverage shaded

This chapter presents, summarises and compares the results of the survey research and case studies. This process is known as methodological triangulation. The most important advantage of using multiple sources of evidence is the development of converging lines of inquiry (Yin, 1994). The qualitative study (case studies in this case) attempts to overcome the limitations of the quantitative approach (survey) and vice versa. Multiple and independent measures, if they reach the same conclusions, provide a more certain portrayal of the phenomenon under investigation (Jick, 1979). By examining the issue under investigation from different perspectives, we could also enrich our understanding by allowing new and deeper dimensions to emerge (Jick, 1979). The case studies have been used to explain the emerging trends from the survey research.

The chapter has been divided into five sections. Sections One and Two present and compare the insights provided to answer the first and second Research Questions, using the survey and case study research respectively. Sections Three and Four present and summarise the insights provided to answer Research Questions Three and Four respectively, based on the case studies only. Section Five summarises the chapter.

12.1 Drivers of Volume Flexibility

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

Figure 12.1 below summarises the insights from the survey in respect of the first Research Question.

Evidence from Survey

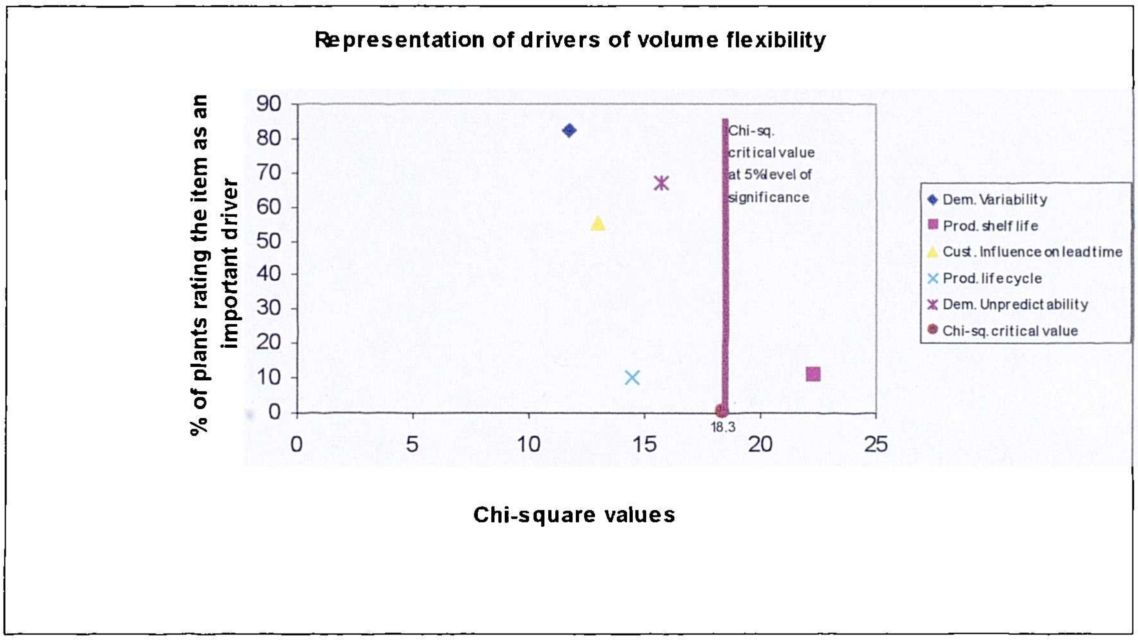

Figure 12.1: Representation of the conditions that drive plants to require high levels of volume flexibility.

The conditions that drive manufacturing plants to require high levels of volume flexibility are identified from the survey and summarised in Figure 12.1 above. Descriptive statistical analyses were carried out to determine the level of applicability of the drivers in the plants surveyed. A relatively higher proportion of the plants surveyed perceived *high variability in demand levels* as a significant driver of volume flexibility in their plants. A relatively smaller proportion of plants perceived *short product life cycle* as a significant driver of volume flexibility in their plants. In an attempt to investigate the disparity in the applicability of the conditions, chi-square tests were performed to check for the effect of sectoral differences on the applicability of the drivers. Out of all the drivers of volume flexibility identified from the survey analyses, only *short product shelf life* was found to be dependent on the sector to which the plants belong. This driver was found to be predominantly applicable in the food sector. Other drivers (see Table 7.3, Chapter 7) were also identified by responding plants but were not classified as above due to lack of sufficient data for meaningful statistical analysis.

Evidence from Case Study Analyses

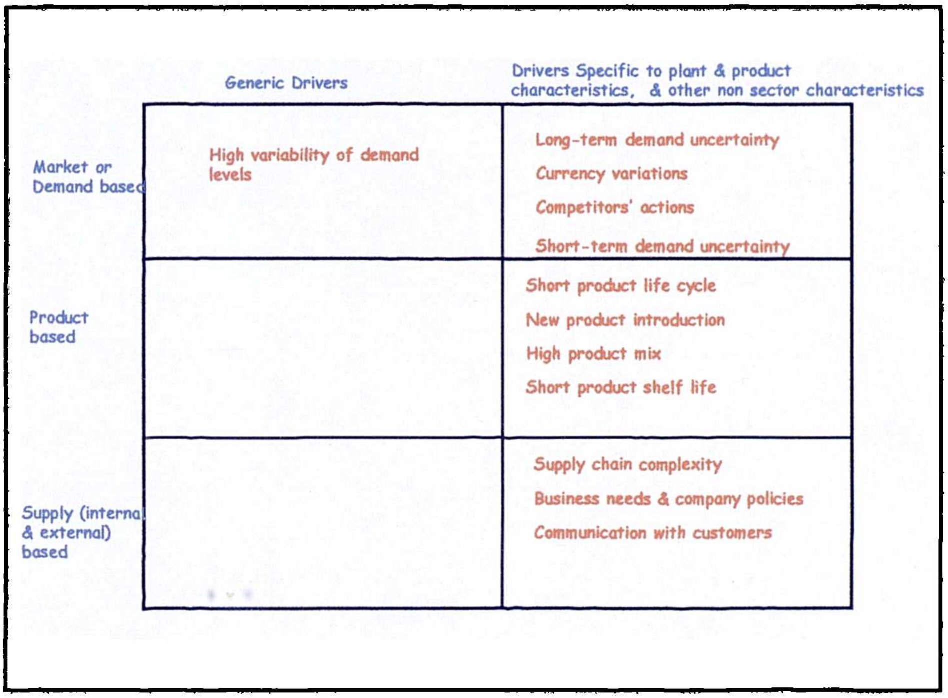

Figure 12.2: *Drivers of volume flexibility: Evidence from case study

The figure above summarises the result of the case study analyses for drivers of volume flexibility. A 2 by 3 matrix has been used to classify the drivers of volume flexibility identified in the case study. Unlike the survey analyses, the relative strength of the applicability of the drivers could not be determined in the case studies analyses. However, the analyses reveal more in-depth explanations for the differences observed in the applicability of the market drivers in driving manufacturing plants to require volume flexibility. The analyses identify generic and specific drivers of volume flexibility. *Generic drivers* are those that are applicable to all the case study plants regardless of sector differences, plant and product characteristics and all other characteristics identified with individual plants. The *specific drivers* identified are dependent on some characteristics of

* All the drivers identified in the case study research are found to be sector independent

the plant or product and characteristics other than sectoral differences. The analyses also reveal that all the drivers identified are *sector independent.*

Triangulation

Comparing the results of the two methodologies above reveals some interesting correlation. The survey analyses reveal that *high variability in demand levels* is the strongest driver of volume flexibility in manufacturing plants. The case study analyses also reveal that *high variability in demand levels* is a major driver of volume flexibility, but the relative strength of this driver compared to other market drivers of volume flexibility could not be determined. The survey analyses reveal that *high variability of demand levels* is *sector independent*. The case study analyses concur with this. In addition, the case studies reveal that *high variability in demand levels* is also independent of other plant characteristics observable in the case studies. Hence, this driver is referred to as a *generic driver* of volume flexibility as far as the case study research is concerned.

The survey analyses reveal that *high unpredictability of demand levels* (or demand uncertainty) is a *sector independent* driver of volume flexibility in the plants surveyed. The case study analyses concur with this. In addition, the case studies reveal that the applicability of this driver differs with time scales. The case studies provided the opportunity of differentiating between long-term and short-term demand uncertainty. This reflects the strength of the case study research and the advantage of using multiple methods to investigate a phenomenon.

Long-term demand uncertainty is experienced when the total demand over the whole planning period is highly unpredictable. Short-term demand uncertainty refers to a situation where the overall total demand is fairly predictable but there are immediate uncertainties due to unscheduled production requirements.

Some of the plants in the case studies experience only short-term demand uncertainty. Plants that engage primarily in contract manufacture operating predominantly in the Electronics and the Engineering capital sectors experience long-term demand uncertainty. However, one plant in the Household goods sector also experienced long-term demand uncertainty as a result of political and legislative changes.

Short product life cycle was found to be a *sector independent* driver of volume flexibility in both the survey and the case study research analyses. Additionally, the case studies reveal that the driver was *specific* to plants operating in markets characterised by fierce competition, changing customer tastes and, rapid changes in technology – leading to rapid product obsolescence. *Customers' influence in lead-time determination,* a driver found to be *sector independent* in the survey research, was found not to be applicable at all to the case study plants. Other drivers identified in the survey analyses but not classified due to insufficient data for statistical analysis were all found to be *sector independent* in the case study research. The case studies reveal that many of these drivers are *specific* to some other characteristics of the plants or product (e.g. *Supply chain complexity* – appears to be specific to plants that deal with many suppliers and require a wide range of components for manufacture).

Short product shelf life was classified as being *sector dependent* (mainly applicable to the food sector) in the survey analyses. This is because, evidence of the applicability of this driver from the survey analyses (based on the statistical distribution across the sectors) was heavily biased towards the food sector. It is, however, interesting to observe that *short product shelf life* was found to be *sector independent* in the case studies. The reason for this discrepancy is that the case studies provided an opportunity to carry out an in-depth investigation into the applicability of *short product shelf life* in sectors other than the food sector. The case study analyses reveal that *short product shelf life* as a driver of volume flexibility is not only applicable to the food sector but to any plant having perishable products, products with relatively short 'use-by' date periods and in some make-to-order businesses.

Two conclusions are drawn from the insights provided for the first Research Question.

1. The condition of *high variability in demand levels* is the major driver of volume flexibility requirements in manufacturing plants regardless of differences in sector, product and other plant characteristics. This is because demand variability is a characteristic shared by most markets.

2. Apart from *high variability in demand levels,* there are other drivers of volume flexibility such as *short product life cycle, short product shelf life, demand uncertainty, supply chain complexity and high product mix* (see Table 11.7). The applicability of these drivers in manufacturing plants does not necessarily depend on the sector to which the plants belong but on other characteristics specific to the plants in question. For instance, *short product shelf life* is applicable to plants having products that are perishable or deteriorate quickly and in some make-to-order businesses. *Short product life cycle* is applicable to plants operating in markets

characterised by fierce competition, changing customer tastes and, rapid changes in technology – that lead to rapid product obsolescence.

12.2 Enablers and Inhibitors of Volume Flexibility

RQ2: Given the required capacity of equipment and an effective supply of materials into, through and out of the production process, what are the other factors that enable and inhibit the achievement of volume flexibility in manufacturing plants?

Enablers: Evidence from Survey Analyses

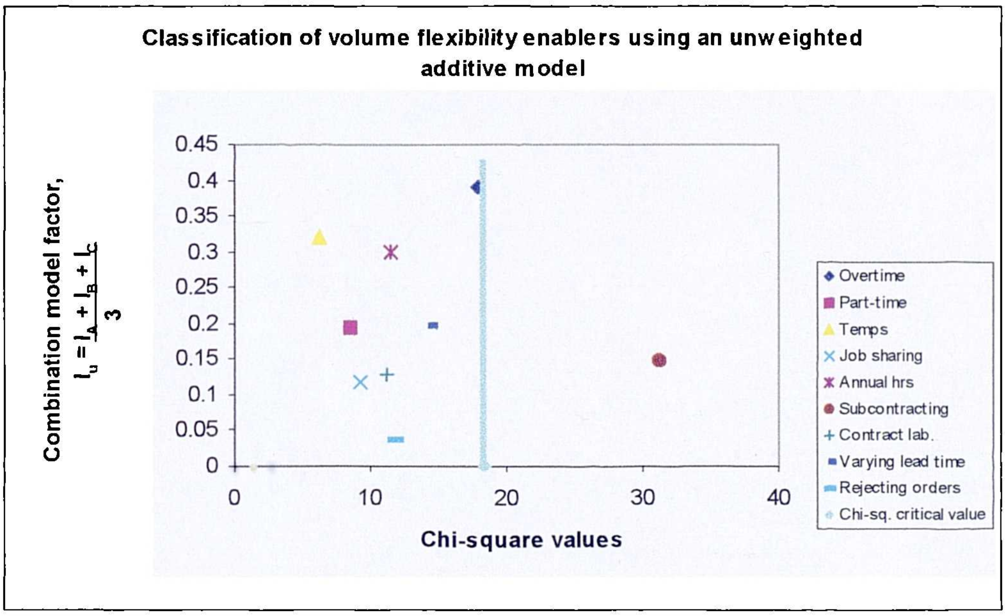

Figure 12.3: Enablers of volume flexibility: Evidence from survey analyses.

Using an unweighted additive combination model, the identified enablers of volume flexibility are classified as shown in Figure 12.3 above. The survey analyses suggest that the use of *overtime hours* appears to be the strongest enabler of volume flexibility, and is closely followed by *temporary labour* and *annualised hours contracts* respectively. As one might expect, *rejecting orders* appears to be the weakest enabler of volume flexibility (y-axis, Figure 12.3). The survey analyses also reveal that only the use of *sub-contracting* (when used as an enabler of volume flexibility) depends on the sector to which the plants belong. The use of the other strategies is found to be *sector independent*. Respondents to the survey identified other enablers, which could not be classified as above due to insufficient data for reasonable statistical analysis. The use of these enablers was, however, investigated in the case studies.

Enablers of Volume Flexibility: Substitutes and Complements

Substitutes	Where significant	Complements	Where significant
Annual hours and Overtime	Process Household and General goods	Overtime and Temporary staff	Food
Contract staff and Overtime	Process	Overtime and Varying lead time	Engineering capital
Overtime and Rejecting orders	Food	Subcontracting and Contract staff	Electronics
		Subcontracting and Varying lead times	Engineering consumer
		Job sharing and Part-time	Engineering consumer

Table 12.0: Substitute and complementary enablers of volume flexibility: Survey analyses

The table above shows the *substitute* and *complementary* enablers identified from the survey analyses. For instance, an annualised labour hours contract can be used to replace overtime hours to provide volume flexibility in manufacturing plants. This is what one would expect, since one of the objectives of an annualised labour hours contract is to eliminate the need for using overtime hours to provide volume flexibility. Employees on an annualised hours contract are required to work a varying number of hours within a given period in the year, as long as the hours worked do not exceed the annually contracted hours.

Inhibitors of Volume Flexibility: Evidence from Survey Analyses

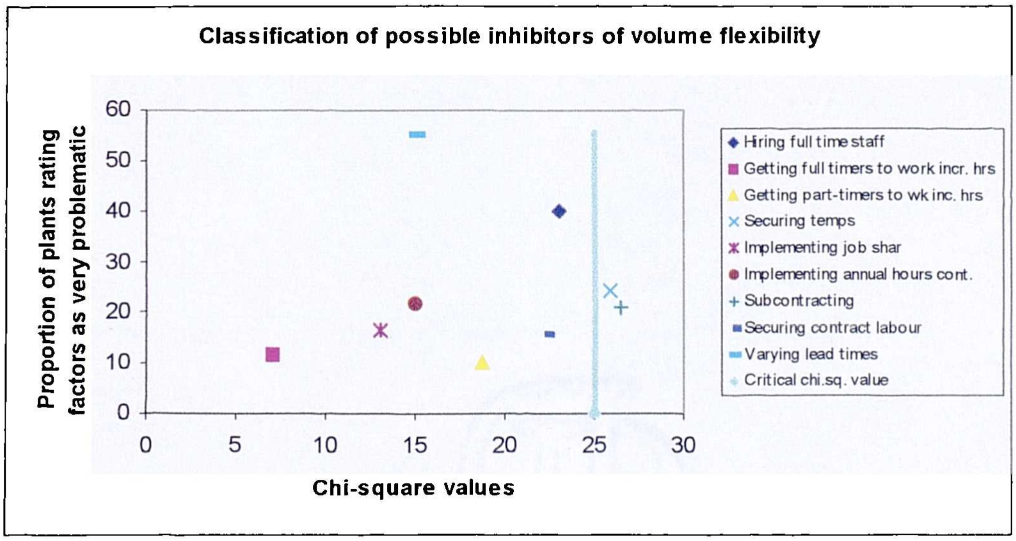

Figure 12.4: Inhibitors to volume flexibility implementation: Survey analyses

Figure 12.4 above shows a classification of the identified inhibitors from the survey analyses. The analyses reveal that *getting customers to agree to lead time variation* appears to be problematic for most of the responding plants, hence this is the strongest inhibitor. Both *subcontracting* and *securing temporary labour* appear to be *sector dependent* inhibitors of volume flexibility.

Enablers: Evidence from Case Study Analyses

Volume Flexibility Solutions	Generic	Specific	Substitutes	Complements
Labour	Multiskilling Banked hours Teamworking Good attitude of workers Overtime	Annualised hours system Temporary labour	Annualised hours & Overtime Banked hours & Overtime	Multiskilling/Annual hours Multiskilling/Banking hours Multiskilling/Mix flexibility Multiskilling/Sister plants Teamworking/Annual hours Teamworking/Banking hours Teamworking/Multiskilling
Material		Supply chain flexibility		
Equipment	Process improvement	Shut down Equipment upgrade		Equipment Upgrade & Process improvement
Others	Process improvement	Using sister plants Subcontracting Varying lead times Mix Flexibility Purchase for resale Good forecast measure Rejecting orders		

†Figure 12.5: Enablers of volume flexibility: Evidence from case studies

Figure 12.5 above summarises the enablers of volume flexibility identified from the case study analyses. Unlike the survey analyses, it was not possible to classify the enablers by their absolute strengths. However, generic and specific enablers are identified. *Generic enablers* here refer to those strategies that are employable in any of the case study plants. Although they could be used in different ways, their use does not depend on differences in sectors, plant characteristics or any other observable characteristics in the case studies. *Specific enablers* are those that are specifically employable in plants that have some unique characteristics in terms of the nature of their business, nature of demand and the like. For example *multiskilling* (classified as a *Generic enabler*) could be used by any of

† The *Generic* and *Specific enablers* referred to here are sector independent. They are either common or specific to the case study plants based on observable characteristics in the case studies.

the case study plants. On the other hand, an *annualised hours system* is most suitable in plants that have relatively low levels of long-term demand uncertainty (hence an annualised hours system is classified as a *Specific enabler*).

Figure 12.5 also displays substitute enablers and complementary enablers identified from the analyses of the cases.

Inhibitors: Evidence from Case Study

Enablers of Volume Flexibility	**Inhibitors**	
	‡Generic Inhibitors	**Inhibitors specific to plants**
Using sister plants	None	• Physical constraints
Subcontracting	None	• Inconsistent quality • Monitoring at operational level
Multiskilling	None	• Conflicting union membership
Equipment upgrade	None	• Creates tension amongst operators
Banked Hours system	Resistance to change	• Refusal to pay back hours
Annualised Hours system	Resistance to change	• Refusal to pay back hours • Divisive if implemented gradually • Inaccurate forecasts • No team coach • Union resistance
Process Improvement	None	• None
Equipment upgrade	None	• Creates tension amongst workers
Varying lead times	None	• Difficult with one-off purchasers
Mix flexibility	None	• Lack of multiskillied workforce
Good attitude	None	• Working culture
Team working	None	• None
Temporary labour	None	• Lack of required skills
Purchase for resale	None	• Inconsistent quality
Supply chain flexibility	None	• Distorted customer requirements • Managing relationships with many suppliers

Table 12.1: Inhibitors to volume flexibility achievement: Case study evidence

Triangulation

Enablers

The use of *overtime hours* which was found to be a major enabler in the survey analyses is not popular in the case study plants. The reason for this is probably due to the selection criteria of the case studies. However, it also reflects a trend as most of the case

‡ Generic and Specific inhibitors are common and specific only as far as the case studies are concerned.

study plants had replaced using *overtime hours* to achieve volume flexibility with other policies such as *annualised hours contracts*. It is interesting to note that the use of *overtime hours by full time employees, annualised hours system, temporary labour and rejecting orders* which were all found to be *sector independent* in the survey research were also found to be *sector independent* in the case studies. However, the case studies reveal that the use of an *annualised hours system* depends on the nature of the demand characteristics of the plant (e.g. it is most suitable where there are *short-term demand uncertainty* and *demand variability* within the year and the overall total yearly demand is relatively predictable).

Other enablers of volume flexibility which were identified in the survey, such as *multiskilling, the use of sister plants, equipment upgrade* etc. are also confirmed as enablers of volume flexibility in the case studies. Evidence from the case studies reveals that plants use these strategies for different reasons. The reasons are explored under the third Research Question. However, it is interesting to note that sector differences do not significantly affect the use of most of these enablers. For instance, the case study analyses reveal that these enablers are all *sector independent*. The use of *subcontracting* was found to be *sector dependent* in the survey research but found to be *sector independent* in the case study research. The case studies, however, reveal that using *subcontracting* actually depends on an individual plant's policy such as, the *need to retain a particular segment for a dying product, and sub-contracting non-core activities to reduce manufacturing lead-time.*

Substitutes and Complements

In terms of substitutes and complements, some of the results of the survey analyses concur with those of the case study analyses. For instance, the analyses using both survey and case studies reveal that plants implement an *annualised hours system* as a substitute for the *use of overtime hours* to achieve volume flexibility. By its very nature an *annualised hours system* has no provision for additional overtime hours within the relevant planning period (usually one year). For instance, an individual may be committed to work a minimum of 1700 hours and be paid for 1900 hours over the year (200 reserved hours). The 1700 hours are spread over the year to cope with predictable variability in demand. The reserved 200 hours are only used to cover demand uncertainty over and above forecasts. As long as the long-term demand uncertainty is relatively low, the use of an *annualised hours system* completely discourages the *use of overtime hours* to achieve volume flexibility.

Inhibitors

The survey analyses reveal that *getting customers to agree to variation in lead times* is the strongest inhibitor. Interestingly, the case study plants that employ the strategy of varying lead times do not find it particularly problematic. It was not possible to check for the strength of the inhibitors identified in the case study analyses. The survey analyses further reveal that *securing temporary labour* and *subcontracting* are both *sector dependent*. All the inhibitors identified in the case studies are *sector independent*. However, many of the inhibitors identified in the case studies are found to be dependent on some other non-sector characteristics. For instance, it was more difficult to implement *multiskilling* and an *annualised hours system* in a unionised plant than it was in a non-unionised plant in the case study research.

The third, fourth, fifth and sixth conclusions are drawn from the triangulation of results relating to the second Research Question.

3. Strategies chosen by plants to achieve high levels of volume flexibility include *annualised hours contracts, banked hours system, subcontracting, overtime hours, sister plants and temporary labour* (see Figure 12.3 and Table 12.1). Problems inherent in the use of *annualised hours contracts, subcontracting and temporary labour* to achieve volume flexibility include *resistance to change, inconsistent quality and lack of required skills* respectively.

4. The strategies chosen by plants to achieve high levels of volume flexibility depend on specific characteristics of the plants that are mostly not sectoral in nature. For instance, *annualised hours contracts* can be successfully adopted by *any* manufacturing plant experiencing *high demand variability and short-term demand uncertainty* to achieve volume flexibility. It should be noted, however, that both conditions refer to a situation in which the total demand over the planning period is relatively predictable.

5. Although *overtime hours by full time employees* is currently the most widely used strategy to achieve volume flexibility, this strategy is becoming less favoured in the future by manufacturing plants. There is a growing preference for the use of variable hours strategies such as *annualised hours contracts* to achieve volume flexibility by manufacturing plants.

6. Substitute enablers of volume flexibility exist. For instance, a variable hours strategy such as an *annualised hours contract* and/or a *banked-hours system* can be used by manufacturing plants to substitute *overtime hours by full time employees* to achieve volume flexibility. Also, complementary enablers exist. For instance, the strategies of *multiskilling* and *teamworking* can be used to *complement annualised hours contracts* and *banked hours system* to achieve volume flexibility in manufacturing plants.

12.3 Enablers and Reasons for Choice

RQ3: Why do some plants choose some enablers and other plants choose other enablers to achieve high levels of volume flexibility?

The third Research Question evolved from the survey analyses and seeks to provide an explanation into why certain enablers are preferred to others by manufacturing plants that use them and why these enablers are desirable in future. Hence, the only evidence that provides insights relating to this Research Question is obtained from the case studies.

Evidence from the case study analyses

The reasons for using various enablers to achieve volume flexibility have been classified as *generic* (i.e. common reasons given by plants) and *specific* reasons that are not common to all the plants studied.

Enablers of Volume Flexibility	Reasons for using enablers	
	Generic reasons	**Specific reasons**
Using sister plants	• High variability in demand levels • Demand uncertainty	• Equipment upgrade
Subcontracting	• High variability in demand levels • To handle non core activities	• Exit/Entry strategy • Reduction of cycle time
Multiskilling	• High variability in demand levels	• High product mix • High skill level requirements • Aids teamworking
Banked Hours system	• Copes with high variability in demand levels • Eliminates overtime costs • Copes with demand uncertainty	• Increases productivity • Increases motivation • Improves relationship between management and operators
Annualised Hours system	• High variability in demand levels • Eliminates overtime costs • Short-term demand uncertainty • Reduces absenteeism	• Unavailable labour for peak demand periods • Provide work & safety training days • Visibility of labour cost/year
Process Improvement	• High variability in demand levels	• Competition • Equipment breakdown • Reduces component complexity • Achieves common upstream processes
Equipment upgrade	• Growth in demand levels • Changing technology	• Inflexible lines or machines
Varying lead times	• High variability in demand levels • Reduces the need for volume flexibility	• Short and long-term demand uncertainty (Political changes) • Nature of production process (i.e. continuous)
Mix flexibility	• High product mix • High variability in demand levels	• High set up time
Overtime	• None	• Only option available to plant
Team working	• High variability in demand levels • Complements multiskilling	• Increases responsibility and ownership • Encourages better relationship amongst workers on site
Supply chain flexibility	• None	• Yield factor • Many suppliers • Component complexity

Table 12.2: Reasons for using enablers by the case study plants only.

The table above suggests that there are many different factors that influence the choice of some solutions to achieve volume flexibility in manufacturing plants. The table also suggests why some solutions may be more desirable than others to some plants in future (a trend observed in the survey analyses). For instance, the use of a *banked hours system* is preferred to an *annualised hours system* by Teleco, an Electronics sector contract manufacturer. The plant wins orders that are based on bids, which have highly uncertain success rates. *Annualised hours system* contracts do not work well in conditions of *long-term demand uncertainty* over the normal planning period as they depend on a reasonably good forecast of overall total demand. According to the General Manager Operations of Teleco:

"The annualised hours system was a little bit too structured for us. We needed something that was a little bit more flexible and not quite as deliberate, and we came up with a thing called banked hours".

The survey analyses reveal a general increase in the perceived desirability of using an *annualised hours system* and a *banked hours system* to achieve volume flexibility. This is partly due to the perception which plants have of the relative costs of the different solutions in achieving volume flexibility. For instance, the survey analyses reveal that *annualised hours systems* are seen to be relatively cheap by most of the responding plants when compared to other solutions like *overtime* and *sub-contracting*. However, as Table 12.4 above suggests, the *annualised/banked hours systems* additionally provide the case study plants with the ability to adequately cope with demand variability, lower the rate of absenteeism, achieve improved motivation and productivity and have better visibility of labour cost/year.

The insights provided into the third Research Question led to the development of the seventh conclusion for the project.

7. Plants choose some solutions in preference to others to achieve volume flexibility because of the perceived cost and other advantages, which the preferred solutions offer and the capability of the solutions to cope effectively with internal and external conditions that the plant is faced with. For instance, an *annualised hours system* is preferred to *overtime hours* for the achievement of volume flexibility because the former is perceived to be relatively cheaper to implement, reduces absenteeism and copes effectively with demand variability (seasonality) and short-term demand uncertainty.

12.4 Implementing Enablers and Overcoming Inhibitors

RQ4: How do plants actually use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?

The fourth Research Question also evolved as a follow up to the survey results. It is required to partly fill the gap in the literature concerning the lack of studies on volume flexibility implementation in manufacturing plants. Because it asks the "how" question, the case study methodology is most appropriate for answering the Research Question (Yin, 1994). Hence, the only evidence that provides insights relating to this Research Question is obtained from the case studies. The table below summarises the ways in which the plants studied have implemented enablers and overcome the inhibitors to achieve high levels of volume flexibility. These are defined as key implementation factors and have been classified as *generic implementation factors* (common to all the plants in the case study) and *specific implementation factors* (peculiar to some plants in the case study).

Enablers of Volume Flexibility	Key Factors for Implementing enablers and overcoming inhibitors	
	Generic implementation factors	Specific implementation factors
Using sister plants	• Good integration • Compatible planning system & methods consistency	• Common accounting principles • Multiskilled workforce
Subcontracting	• Good relationship with subcontractors • Good audit, selection & control systems • Easily available technology	• Provide training for subcontractor staff
Multiskilling	• Good training • Financial incentive • Voluntary enlistment	• Consultations & education
Banked Hours System	• Incentive – discounting hours • Gradual implementation • Managing informally/Self-managing (Peer influence) • Education & consultation • Good capacity analysis • Tackle perceptions • Correct timing of launch	• Rules & regulations concerning refusal to pay back hours • Democratic
Annualised Hours System	• As above for banked hours system + • Carry out good forecasts • Financial incentive • Understand the system	• Multiskilling • Implement through teams • Team coach • Resource analysis – affordability • Use implementation group
Process Improvement	• Implement common processes or postponement mechanism	• Predictive & preventative maintenance
Equipment upgrade	• Good research on available technology • Good capacity analysis	• Multiskilling • Educate workers • Introduce voluntary and good redundancy package • Identify production alternatives – sister plants
Varying lead times	• Good relationship with customers	• Volume discounts – better relationship • Reduce customer base • Multi-lingual personnel for overseas customers • Offer a fraction of requirements
Mix flexibility	• Install flexible lines • Multiskilling • Postponement mechanism	• None
Team working	• Total autonomy • Multiskilling • Self managing	• Team coach
Supply chain flexibility	• Good relationship with customers and suppliers	• Rationalise number of components and suppliers • Proactive relationship with indirect customers • Electronic point of sale • Flexibility forum

Table 12.3: Enablers of volume flexibility and the key factors for their implementation

Table 12.3 above suggests that manufacturing plants go about implementing the enablers of volume flexibility in various ways. For instance, the case studies reveal that to implement *multiskilling*, many of the plants provide very *good training* and *financial incentives* to encourage the workers. Also, workers in most cases are allowed to *volunteer* for the training schemes. In some plants (e.g. a unionised plant), implementing *multiskilling* involves *extensive consultations* with the unions because of the potential problem of conflicting union membership when workers are trained in areas that require different skills.

The eighth conclusion is drawn from the discussion of the fourth Research Question.

8. Effective management of change through good education, consultation, gradual implementation, correct timing of launch, informal management and offering of incentives (financial or non-financial) is important for the successful implementation of variable hours strategies such as an *annualised hours contract* and *banked hours system* in the achievement of high levels of labour capacity flexibility in manufacturing plants.

12.5 Chapter Summary

This chapter has reviewed and compared the results of the analyses carried out using the survey and the case study research methods. This has been done based on the Research Questions developed for the project. For the first two Research Questions, many of the results obtained in the survey research are confirmed in the case studies. However, the case studies shed more light on some unresolved issues from the survey research. For instance, the survey found that the drivers of volume flexibility in manufacturing plants are largely *sector independent* (except for *short product shelf life*). The case studies found that all the drivers of volume flexibility are sector independent (including short product shelf life) but that these drivers actually depend on some other characteristics of the plant, product or the market in which the plants operate. Only *demand variability* was found to be common to all the plants studied.

The third and fourth Research Questions were analysed using the case studies and the results are summarised in this chapter. For instance, a plant would use the *banked hours system* to achieve volume flexibility because with the system the plant is able to *eliminate overtime cost, to lower the absenteeism rate, to cope with demand variability and uncertainty and to improve workers' motivation and productivity*. To implement a *banked hours system* requires *extensive consultation, providing incentives, correct timing of launch and allowing the system to be self-managed.*

The next and final chapter will summarise and conclude the project. It will discuss the limitations of the study, highlight the contribution to knowledge of the study and suggest future areas for research.

Chapter 13 - Summary and Conclusions

13.0 Introduction

This chapter has been divided into four main sections. Section One gives a summary of the research project, including the literature review and Research Questions. Section Two presents the research strategy. Section Three presents the main findings, and the conclusions drawn from the research study and the limitations of the research. Section Four concludes the chapter by evaluating the contribution to knowledge and highlighting future areas for research.

13.1 Summary of the Research Project

The figure below summarises the areas covered in the literature review to identify the Research Questions.

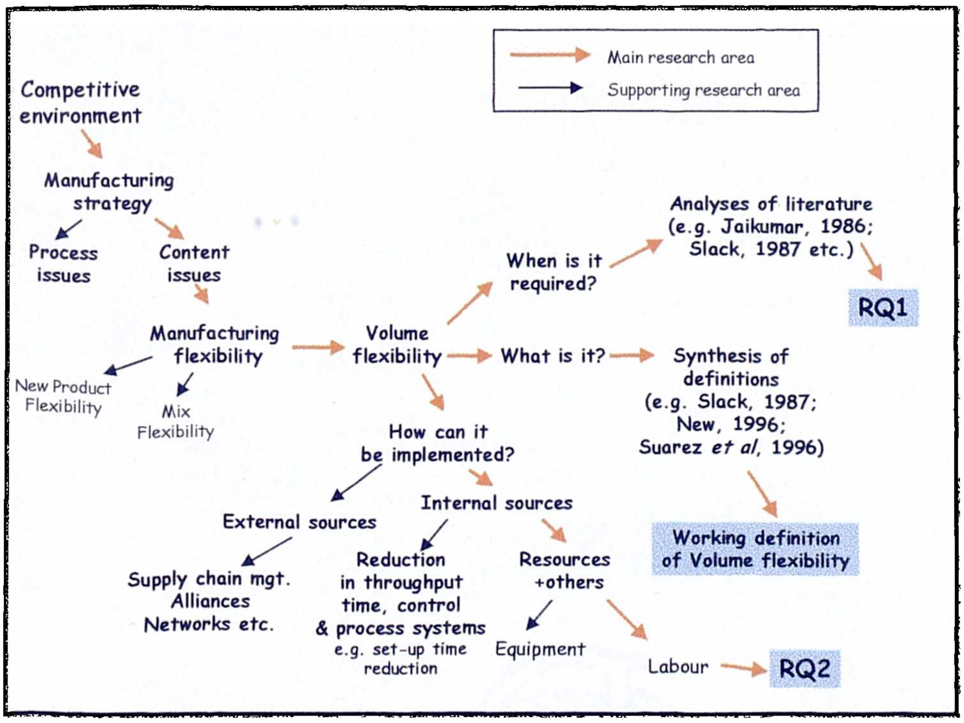

Figure 13.0: Summary of literature review coverage

Today, manufacturing organisations operate in demanding markets and are subject to intense and often global competition. Customers and markets demand increased product customisation, more extensive product ranges and configurations, shorter delivery lead times with the expectation of significantly improved delivery reliability. When these pressures are coupled with the inherent complexity of many manufacturing organisations and their supply chains and delivery networks, then the challenges facing manufacturing businesses become apparent. On the other hand the opportunities and rewards are very great in most sectors for those businesses that are able to respond to the competitive challenges successfully. This research project has focused on the issue of flexibility which according to many authors provides manufacturing organisations with the capabilities of adapting to the requirements of a fast changing environment (e.g. Garett, 1986; Swamidass and Newell, 1987; Tombak, 1988, De Meyer *et al*, 1989 and Correa and Slack, 1996).

While much has been written on the subject of manufacturing flexibility, the review of the literature reveals that many of the studies have focused on developing the typologies of the concept. This research project was carried out to expand the knowledge on the issue of flexibility in manufacturing plants. In order to develop a framework for investigating the issue of flexibility, this research adopted the broad classification of manufacturing flexibility proposed by Slack (1987) and Suarez *et al* (1996):

(1) Strategic or first order manufacturing flexibility (e.g. volume, mix, new-product flexibility and delivery time flexibility)
(2) Resource or lower-order flexibility types (e.g. routing, component, material flexibility etc.).

The literature review reveals that, of the two broad classifications defined above, more studies have been carried out on the lower order flexibility types. This research has argued that the strategic types of manufacturing flexibility should consist of volume, mix and new product flexibility (excluding delivery time flexibility). It has been argued that delivery time flexibility should not be seen as separate but as falling under the umbrella of volume flexibility. In other words, a plant which is truly volume flexible is by definition, capable of having delivery time flexibility.

Within the first-order flexibility types, volume flexibility has attracted the least attention in the literature compared to mix and new product flexibility (Suarez *et al,* 1996). The concept of manufacturing flexibility as a whole remains a conundrum, a paradoxical concept where authors cannot agree on the answers to even the most basic questions. What is it? When should a company strive for it? and how can it be implemented in manufacturing organisations? These issues were addressed in this research project within the context of volume flexibility.

13.1.1 What is Volume Flexibility?

A synthesis of the definitions of volume flexibility resulted in the working definition of volume flexibility for the research as: ***the extent to which a manufacturing system can vary its output level for a given mix, within a given time period without any unacceptable effect on cost and other competitive criteria of the plant.***

13.1.2 Research Questions

The need to clarify why flexibility is needed has been emphasised by Slack (1991). In a comparative study of flexible manufacturing systems in the US and Japan, Jaikumar (1986) found that *"...with few exceptions, the flexible manufacturing systems in the United States show an astonishing lack of flexibility..."*. Jaikumar (1986) argued that this might have been due to the wrong assessment of flexibility needs by manufacturing management. Although a number of volume flexibility drivers have been identified in the literature, many of these lack empirical research evidence. The first Research Question was developed to partly fill this gap in the literature.

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

Traditional research studies in operations management have focused on issues relating to design and planning, and the control of process systems in manufacturing organisations. Studies into how to achieve labour capacity flexibility have not received much attention in the operations management literature. Most of the studies on this issue come from the human resources management literature (Kossoris and Kohler, 1974; Atkinson, 1985; Hunter and Maclnnes, 1992; Brewster *et al*, 1993). These studies do not provide the needed link between the labour strategies and technical aspects of production flexibility. The second Research Question was developed to partly fill yet another gap in the literature.

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable or inhibit the achievement of volume flexibility in manufacturing plants?

13.2 Research Strategy

The Figure 13.1 below summarises the empirical research process for the project.

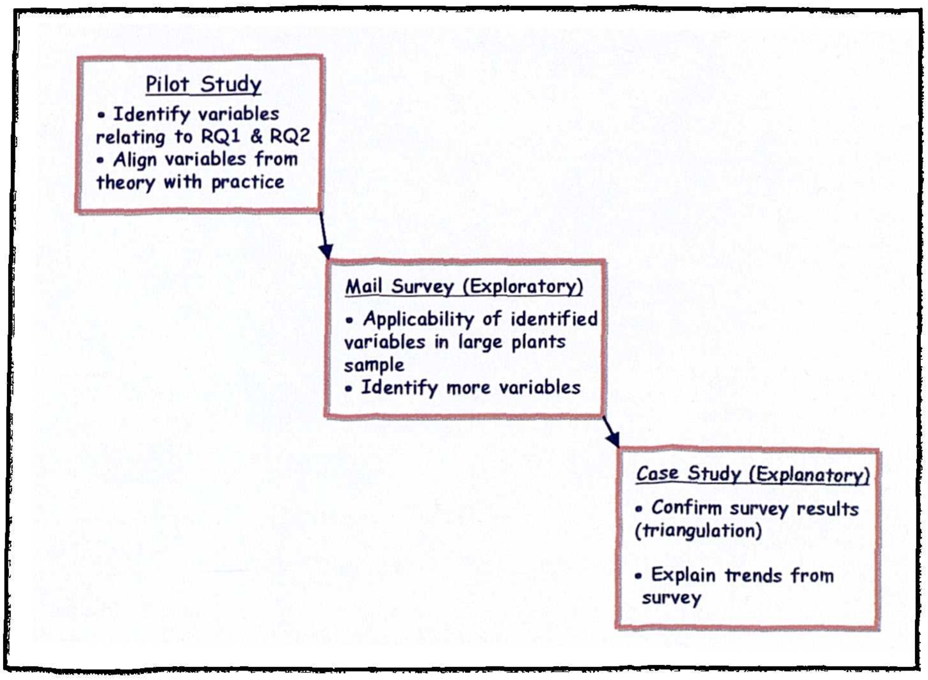

Figure 13.1: The empirical study process

The research strategy consists of the use of a pilot study, survey and case study. The choice of the research methods was based on Yin's (1994) criteria for choosing a research strategy. Due to the nature of the Research Questions (i.e. "what"), the survey and case study methods were found to be suitable and thus chosen for exploring the Research Questions. The process is displayed in the figure above.

13.2.1 Survey Research

A pilot study was undertaken to provide an insight into the basic issues of volume flexibility. In view of the novel nature of the research project, it was necessary to carry out further exploratory research using a mail survey to investigate the applicability of the variables identified from the pilot study and literature review. It was also necessary to actually identify other drivers and enablers of volume flexibility in different operations contexts. Thus, a structured mail survey questionnaire was designed and administered to 529 UK manufacturing plants that had entered for the Best Factory Award competition between 1995 and 1998. A response rate of 23% (or 120 plants) was obtained. The analysis of the survey confirms that most of the identified drivers and enablers from the pilot study are indeed drivers and enablers of volume flexibility. Also, other variables are identified. The survey analyses also raised some other issues, which culminated in two further Research Questions for the project.

RQ3: Why do some plants choose some enablers and other plants choose other enablers to achieve high levels of volume flexibility?
RQ4: How do plants actually use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?

13.2.2 Case Study Research

The case studies were used to address the first and the second Research Questions for the project in order to provide methodological triangulation for the survey research. Additionally, the case studies were used to provide explanations of the trends observed and the new questions raised from the survey analyses. The use of the case studies to explore these new questions is supported by Yin (1994). He argues that "how" and "why" questions are best tackled using case studies.

Selection of the case studies was based on the analysis of the survey. One plant each that provided the richest data set on the survey questionnaire was chosen from across the six industrial sectors (i.e. Process, Engineering Capital, Engineering Consumer, Electronics, Houeshold/General goods and Food). Two other plants (Electronics and Household goods sector) that used other interesting strategies were chosen to add to the richness of the case study research. A total of eight manufacturing plants were used as case studies. The field study involved visiting the manufacturing sites, interviewing the manufacturing managers or top production personnel, walking through the production process and collecting relevant archival and quantitative data.

Analyses of the individual cases were carried out qualitatively and quantitatively, relying on various analytic techniques suggested by researchers, notably Eisenhardt (1989), Miles and Huberman (1994) and Yin (1994). This was followed by cross-case analyses to bring together the key features of the various cases to compare them. This helped to answer questions relating to the effects that contextual factors have on the concepts being studied.

13.3 Summary of Findings

This section presents the overview of the research findings from the survey and case studies analyses. The section is organised into sub-sections based on the Research Questions and the results obtained in the analyses in respect of each Research Question.

13.3.1 Drivers of Volume Flexibility

RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?

The summary of the results relating to the first Research Question is presented within the conceptual framework developed for the Research Question as shown below.

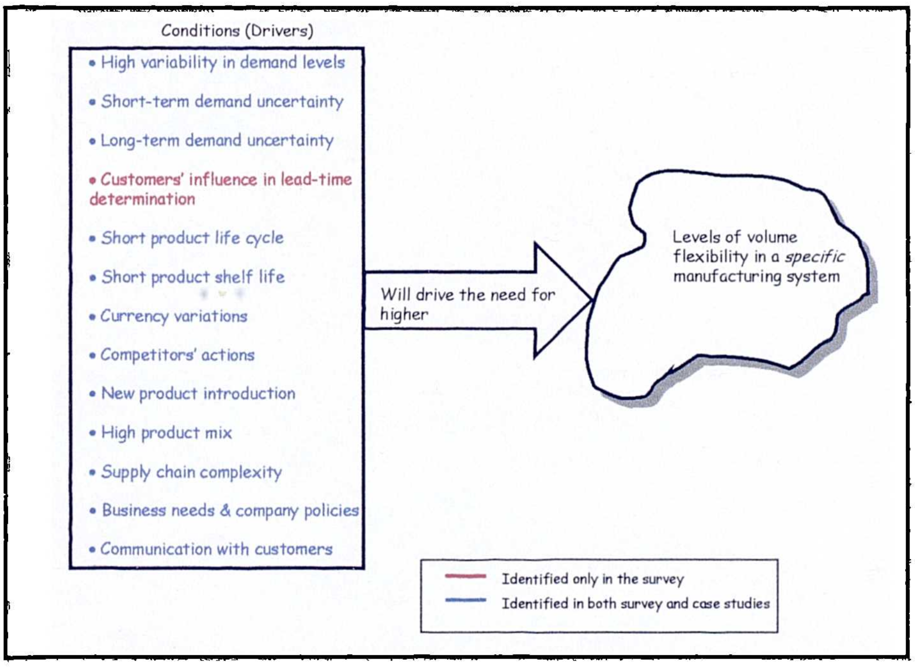

Figure 13.2: Drivers of volume flexibility in manufacturing plants

From the figure above, it is interesting to note that all the drivers of volume flexibility identified from the survey analyses were also identified in the case studies (except *customers' influence in lead time determination*). This is hardly surprising since the case study plants are a subset of the survey respondents. What is, however, more interesting to note is that, of all the drivers identified, only *high variability in demand levels* appears to be a *generic driver* of volume flexibility in the plants studied. In other words, this driver is applicable to many of the plants studied regardless of the sectors to which they belong, the nature of their processes and all other observable characteristics tested for in the empirical research. Demand variability is rated highly by virtually all responding plants because it is a characteristic shared by most markets. The y-axis in Figure 13.3 shows the proportion of plants that rated the drivers as highly significant.

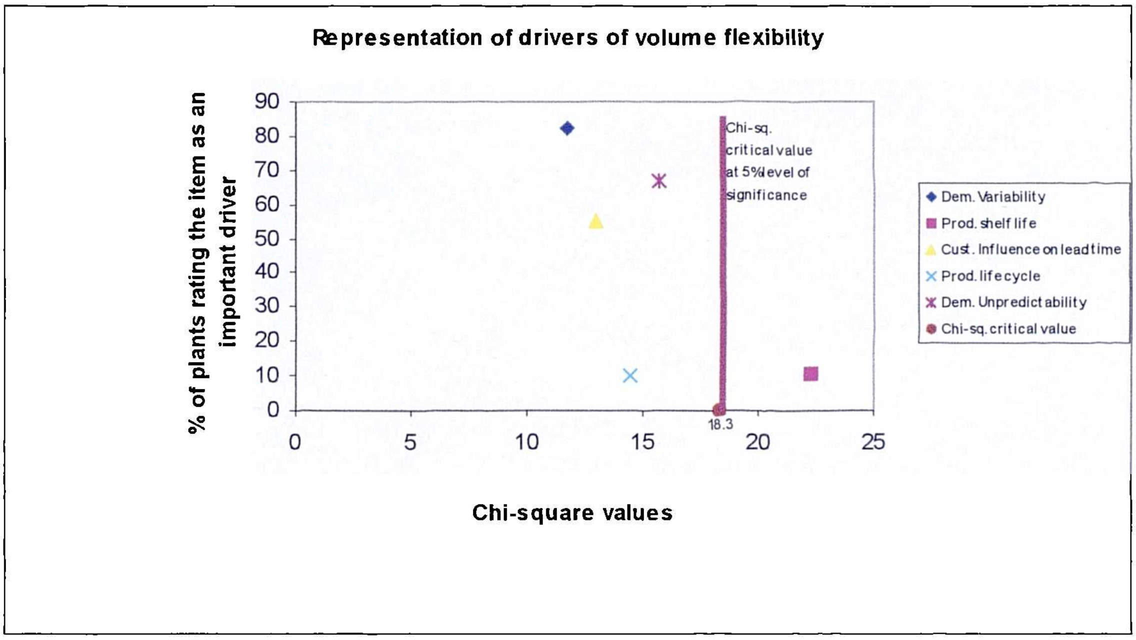

Figure 13.3: Representation of volume flexibility drivers

As Figure 13.3 above shows, the applicability of these drivers to plants varies. For instance, *short product life cycle* was highly rated by a few plants. This driver was found to be a *sector independent* driver of volume flexibility in both the survey and the case studies. Additionally, the case studies reveal that plants that rated this driver as highly significant operate in markets characterised by *fierce competition, changing customer tastes and, rapid changes in technology that lead to rapid product obsolescence*.

Table 13.0 has been used to summarise the drivers of volume flexibility and their applicability to manufacturing plants based on the empirical evidence provided by the case studies.

Drivers of Volume Flexibility (RQ1)	Generic?	Specific?	*Applicability
High variability in demand levels	Yes	No	Generally applicable to all the plants studied
Short term demand uncertainty	Yes	No	Applicable to all the plants studied
Long term demand uncertainty	No	Yes	Applicable to plants engaged in contract manufacturing
Supply chain complexity	No	Yes	Applicable to plants with high number of components in production and plants dealing with many suppliers.
Short Product Life Cycle	No	Yes	Applicable to plants whose products become obsolete quickly as a result of rapid technology changes, changing customer tastes and competition.
New Product Introduction	No	Yes	As above
High Product Mix	No	Yes	Applicable to plants producing non-standardised products
Short Product Shelf Life	No	Yes	Applicable to plants whose products are perishable or deteriorate quickly e.g. Food sector.
Competitors' actions	No	Yes	Applicable to plants operating in fiercely competitive environment
Currency Variations	No	Yes	Applicable to UK plants with high level of overseas business involvement
Business needs and company policies including 'stop making to stock', and differentiation	No	Yes	Inconclusive
Communication with customers	No	Yes	Applicable to intermediate goods producer.

Table 13.0: Summary of volume flexibility drivers and their applicability

The first two conclusions of the study are derived from the above discussion.

1. The condition of *high variability in demand levels* is the major driver of volume flexibility requirements in manufacturing plants regardless of differences in sector, product and other plant characteristics. This is because demand variability is a characteristic shared by most markets (see Figure 13.3).

2. Apart from *high variability in demand levels*, there are other drivers of volume flexibility such as *short product life cycle, short product shelf life, demand uncertainty, supply chain complexity and high product mix* (see Table 13.0). The applicability of these drivers in manufacturing plants does not necessarily depend on the sector to which the plants belong but on other characteristics specific to the plants in question. For instance, *short product shelf life* is applicable to plants having products that are perishable or deteriorate quickly and in some make-to-order businesses. *Short product life cycle* is applicable to plants operating in markets characterised by fierce competition, changing customer tastes and, rapid changes in technology – that lead to rapid product obsolescence.

* This refers only to the case study plants

13.3.2 Enablers and Inhibitors of Volume Flexibility

RQ2: Given the required capacity of equipment and an effective supply of materials into and out of the production process, what are the other factors that enable and inhibit the achievement of volume flexibility in manufacturing plants?

The summary of the results relating to the second Research Question is presented within the conceptual framework developed for the Research Question as shown below.

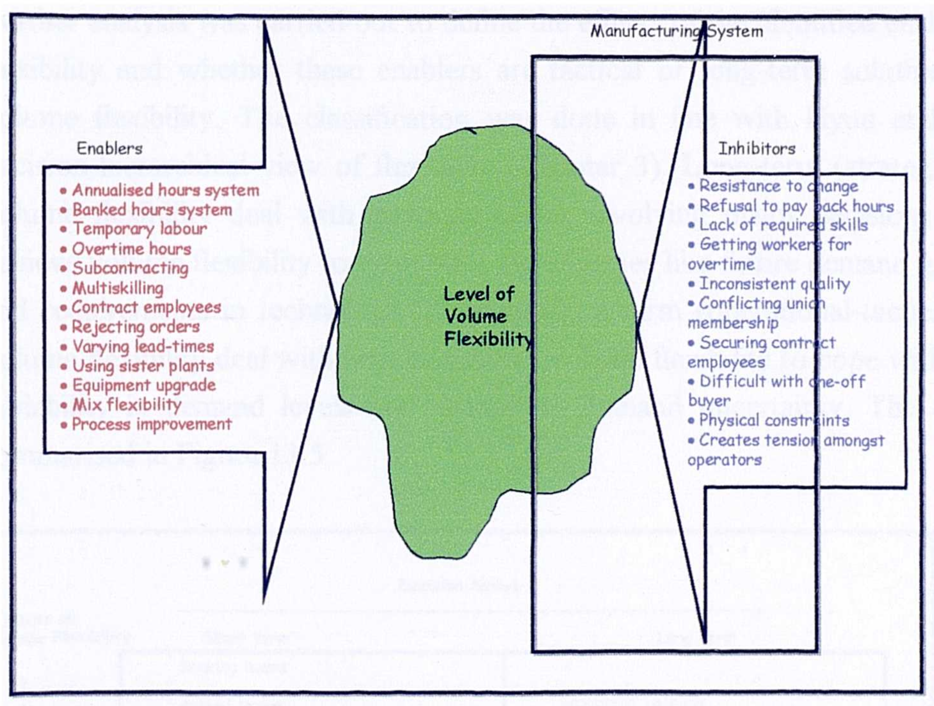

Figure 13.4: Selected enablers and inhibitors of volume flexibility in manufacturing plants

The figure above shows the enablers and the corresponding inhibitors that were identified from both the survey and the case studies. For instance, the use of an *annualised hours system* was found to be an effective enabler of volume flexibility. The survey analyses reveal a general increase in the perceived desirability of using an *annualised hours system* to deliver volume flexibility (the reasons for this are explored under the third Research Question).

The case studies reveal that *annualised hours systems* work reasonably well for coping with specific conditions such as *demand variability* over the planning period (usually one year) and *short-term demand uncertainty*, within a predictable overall total demand.

Hence, the *annualised hours contract* is classified as a *specific enabler* of volume flexibility.

Resistance to change is the main inhibitor to the implementation of the *annualised labour hours* contract in manufacturing plants. This is more pronounced in unionised plants. Other problems encountered specifically in some plants include *refusal to pay back hours* and mismanagement due to *lack of a team coach*. The mechanisms by which the plants overcome these inhibitors are covered under the fourth Research Question.

Further analysis was carried out to define the effects of the identified enablers on volume flexibility and whether these enablers are tactical or long-term solutions to achieving volume flexibility. The classification was done in line with Hyun and Ahn's (1992) decision-hierarchical view of flexibility (Chapter 3). Long-term (strategic) solutions of volume flexibility deal with strategic issues involving major decisions about how to achieve volume flexibility to cope with major issues like future demand growth or slump and requirements in technology. Short-medium term (operational-tactical) solutions of volume flexibility deal with how to achieve volume flexibility to cope with issues such as variability in demand levels and short-term demand uncertainty. The classification is summarised in Figure 13.5.

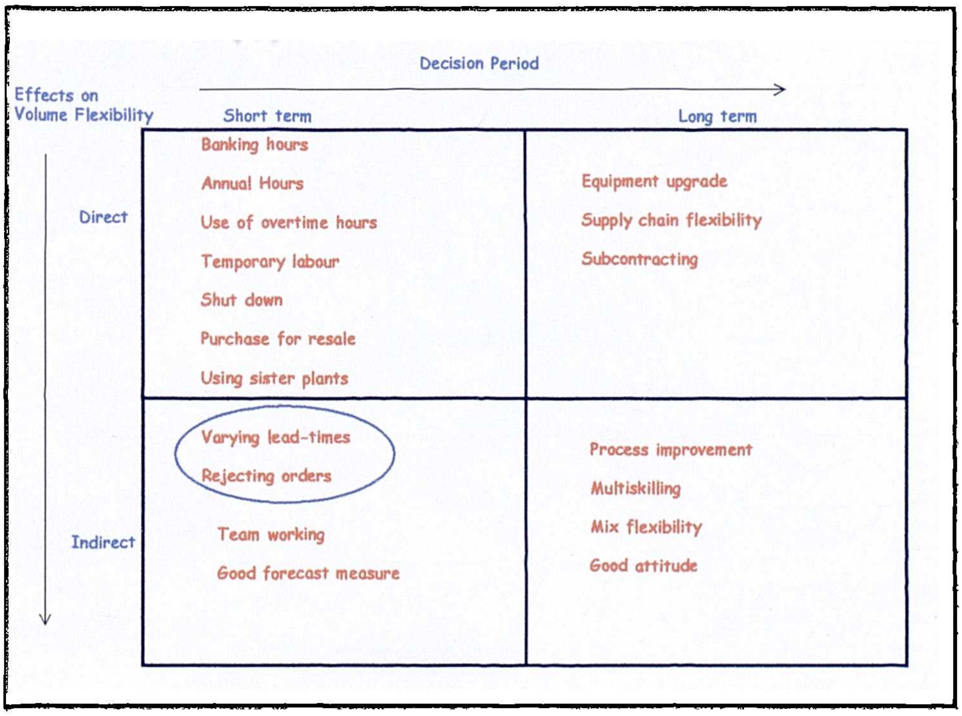

Figure 13.5: Decision hierarchy view and the effects of enablers on volume flexibility

The circled enablers are those solutions which reduce the need for internal volume flexibility. For instance, a plant may reject the orders of customer A in order to be more responsive to a more valued customer B. From customer B's point of view, the plant is perceived to have some degree of volume flexibility. Hence, it is proposed that the effects of these solutions on the achievement of volume flexibility are indirect.

The empirical research reveals that some enablers can be used to replace other enablers and other enablers complement each other in achieving volume flexibility. These are classified as *substitute enablers* and *complementary enablers* respectively. For instance, the analyses reveal that an *annualised hours contract* is being used to replace *overtime hours* to provide volume flexibility. This is not surprising because one of the reasons for the introduction of an *annualised hours contract* in manufacturing plants is to eliminate the need for *overtime hours*. Employees on *annualised hours contracts* are required to work a varying number of hours within a given period in the year. As long as the hours worked do not exceed the annually contracted hours, there is no need for *overtime hours*. The use of teams (*teamworking*) and *multiskilling* are found to complement the implementation of both the *banked hours* and of *annualised hours contracts*. Encouraging self-management and informal management are found to be important in the implementation of the *banked hours* and *annualised hours systems*. These management styles work best within the contexts of teams. The teams are given autonomy to set their schedules and rosters. Working in teams also means that the influence of peer pressure could be significant. Peer influence was found to be significant, helping to discourage exploitation of the *banked hours* and *annualised hours systems* by operators.

The third, fourth, fifth and sixth conclusions are drawn from the above insights provided into the second Research Question.

3. Strategies chosen by plants to achieve high levels of volume flexibility include *annualised hours contracts, banked hours system, subcontracting, overtime hours, sister plants and temporary labour*. Problems inherent in the use of *annualised hours contracts, subcontracting and temporary labour* to achieve volume flexibility include *resistance to change, inconsistent quality and lack of required skills* respectively (see Figure 13.4).

4. The strategies chosen by plants to achieve high levels of volume flexibility depend on specific characteristics of the plants that are mostly not sectoral in nature. For instance, annualised hours contracts can be successfully adopted by any manufacturing plant experiencing *high demand variability* and *short-term demand uncertainty* to achieve volume flexibility. It should be noted, however, that both conditions refer to a situation in which the total demand over the planning period is relatively predictable.

5. Although *overtime hours by full time employees* is currently the most widely used strategy to achieve volume flexibility, this strategy is becoming less favoured in the future by manufacturing plants. There is a growing preference for the use of variable hours strategies such as *annualised hours contracts* to achieve volume flexibility by manufacturing plants.

6. Substitute enablers of volume flexibility exist. For instance, a variable hours strategy such as an *annualised hours contract and/or a banked hours system* can be used to substitute *overtime hours by full time employees* to achieve volume flexibility. Also, complementary enablers exist. For instance, the strategies of *multiskilling* and *teamworking* can be used to complement *annualised hours contracts and banked hours system* to achieve volume flexibility.

13.3.3 Enablers and Reasons for Choice

RQ3: Why do some plants choose some solutions and other plants choose other solutions to achieve high levels of volume flexibility?

The third Research Question, which evolved from the survey analyses, was formulated to provide answers to why certain enablers are preferred to others by manufacturing plants that use them and why these enablers are desirable in future. The trend observed in the survey analyses is displayed in Figure 13.6 below.

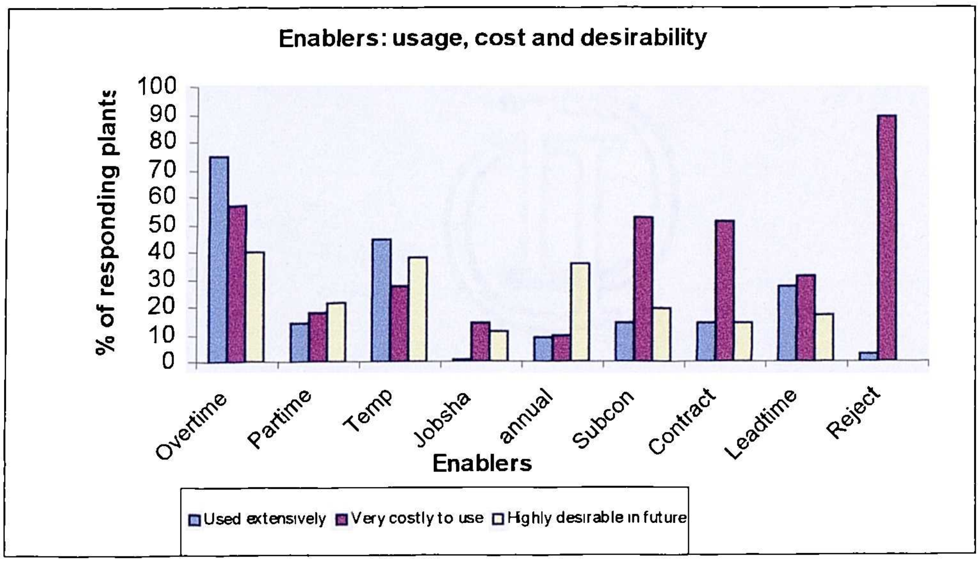

Figure 13.6: Enablers of volume flexibility: present usage vs. cost vs. future desirability

As the figure above shows, there are reductions in the use of *overtime, temporary labour* and *varying lead times* to achieve volume flexibility. There are increases in the use of *annualised hours contracts, increased hours worked by part-time employees* and *job sharing* to achieve volume flexibility. The reasons for the trends observed can be partly explained by the perception of relative cost of using these strategies as shown in the above figure. For instance, about 58% of responding plants perceived the use of *overtime hours* to be very costly while only 10% perceived the use of *annualised hours contracts* to be very costly, hence the decreasing adoption of *overtime hours* and increasing use of *annualised hours contracts* to achieve volume flexibility. Other reasons underpinning the decreasing or increasing adoption of each enabler relate to the market drivers of volume flexibility and other perceived benefits, which these solutions offer. These are summarised in Table 13.1 below.

Enablers of Volume Flexibility	Reasons for using enablers	
	Generic reasons	**Specific reasons**
Using sister plants	• High variability in demand levels • Demand uncertainty	• Equipment upgrade
Subcontracting	• High variability in demand levels • To handle non core activities	• Exit/Entry strategy • Reduction of cycle time
Multiskilling	• High variability in demand levels	• High product mix • High skill level requirements • Aids teamworking
Banked Hours system	• Copes with high variability in demand levels • Excessive overtime cost • Copes with demand uncertainty	• Increases productivity • Increases motivation • Improves relationship between management and operators
Annualised Hours system	• High variability in demand levels • Eliminates overtime cost • Short-term demand uncertainty • Lowered absenteeism	• Unavailable labour for peak demand periods • Provide work and safety training days • Visibility of labour cost/year
Process Improvement	• High variability in demand levels	• Competition • Equipment breakdown • Reduces component complexity • Achieves common upstream processes
Equipment upgrade	• Growth in demand levels • Changing technology	• Inflexible lines or machines
Varying lead-times	• High variability in demand levels • Reduces the need for volume flexibility	• Short and long-term demand uncertainty (Political changes) • Nature (i.e. continuous) of production process
Mix flexibility	• High product mix • High variability in demand levels	• High set up time
Overtime	• None	• Only option available to plant
Team working	• High variability in demand levels • Complements multiskilling	• Increases responsibility and ownership • Encourages better relationship amongst workers on site
Supply chain flexibility	• None	• Yield factor • Many suppliers • Component complexity

Table 13.1: Reasons for using and choosing enablers

The table above suggests that there are many different factors that influence the choice of some solutions (or enablers) to achieve volume flexibility in manufacturing plants. For instance, the use of the *banked hours system* is preferred to an *annualised hours system* by Teleco (an Electronics sector contract manufacturer). The plant wins orders that are based on bids which have highly uncertain success rates. Compared to the *banked hours system, annualised hours contracts* do not work well in conditions of *long-term demand uncertainty* over the normal planning period as they depend on a reasonably good forecasts of overall total demand.

As discussed earlier, it was also important to seek explanations to why some solutions are more desirable than others to some plants in the future. For instance, *an annualised* *hours contract* is more desirable in future because it is seen to be relatively cheap by most of the responding plants when compared to other solutions like *overtime and sub-contracting*. However, as Table 13.1 above suggests, the *annualised/banked hours systems* also provided the case study plants with the ability to adequately cope with *demand variability, lower the rate of absenteeism, achieve improved motivation and productivity and have better visibility of labour costs per year*.

The insights provided to answer the third Research Question lead to the seventh conclusion for the research

7. Plants choose some solutions in preference to others to achieve volume flexibility because of the perceived cost and other advantages which the preferred solutions offer and the capability of the solutions to cope effectively with internal and external conditions that the plant is faced with. For instance, an *annualised hours system* is preferred to *overtime hours* for the achievement of volume flexibility because the former is perceived to be relatively cheaper to implement, reduces absenteeism and copes effectively with demand variability (seasonality) and short-term demand uncertainty (see Table 13.1).

13.3.4 Implementing enablers and overcoming inhibitors

RQ4: How do manufacturing plants actually use the enablers and overcome the inhibitors to achieve high levels of volume flexibility?

The fourth Research Question also evolved from the survey analyses. The question was addressed in the case studies. The conceptual framework developed for the second Research Question has been used to summarise the insights provided for the fourth Research Question. Only one enabler (using an *annualised hours contract*) has been considered in this summary. Details of other enablers can be found in Chapters 11 and 12.

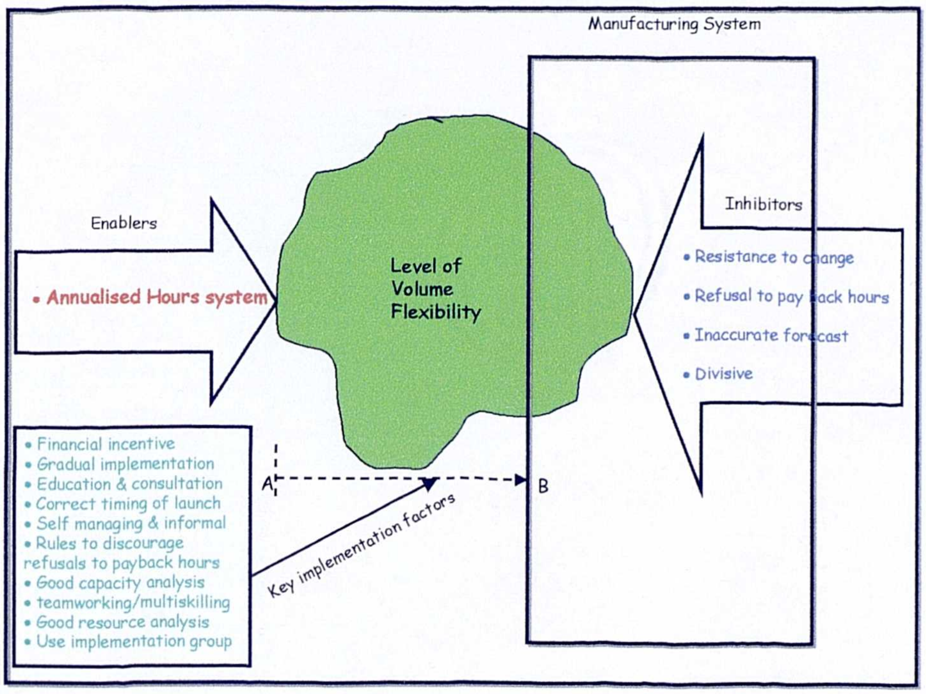

Figure 13.7: Conceptual framework to summarise insights into RQ4

The implication of the framework above is that in order to increase the level of volume flexibility in its manufacturing system, a manufacturing plant has to implement an enabler such as an *annualised hours system* (if it finds it suitable!). In other words, the "mass" (level of volume flexibility) has to be pushed from point 'A' to point 'B'. However, there are some frictional forces that have to be overcome in order for the mass to get to point 'B'. These frictional forces are the inhibitors such as *resistance to change*. Overcoming the inhibitors and implementing the enablers are achieved through some factors referred to as the *key implementation factors*. For instance, the problem of *resistance to change* can be overcome through effective management of change. This involves *good education, communication and consultations with the operators and unions, providing financial incentives, implementing the system gradually and correct timing of launch.*

The insights provided to answer the fourth Research Question lead to the eighth conclusion.

8. Effective management of change through good education, consultation, gradual implementation, correct timing of launch, informal management and offering of incentives (financial or non-financial) is important for the successful implementation of variable hours strategies such as an *annualised hours contract* and *banked hours system* in the achievement of high levels of volume flexibility in manufacturing plants (see Table 12.3).

Table 13.2 below summarises the Research Questions and the major conclusions of this project.

Research Questions	Conclusions
RQ1: Under what conditions does a manufacturing plant require high levels of volume flexibility?	**1.** The condition of high variability in demand levels is the major driver of volume flexibility requirements in manufacturing plants regardless of differences in sector, product and other plant characteristics. This is because demand variability is a characteristic shared by most markets (see Figure 13.3). **2.** Apart from *high variability in demand levels*, there are other drivers of volume flexibility such as *short product life cycle, short product shelf life, demand uncertainty, supply chain complexity and high product mix* (see Table 13.0). The applicability of these drivers in manufacturing plants does not necessarily depend on the sector to which the plants belong but on other characteristics specific to the plants in question. For instance, *short product shelf life* is applicable to plants having products that are perishable or deteriorate quickly and in some make-to-order businesses. *Short product life cycle* is applicable to plants operating in markets characterised by fierce competition, changing customer tastes and, rapid changes in technology – that lead to rapid product obsolescence.
RQ2: Given the required capacity of equipment and an effective supply of materials into, through and out of the production process, what are the other factors that enable and inhibit the achievement of volume flexibility in manufacturing plants?	**3.** Strategies chosen by plants to achieve high levels of volume flexibility include *annualised hours contracts, banked hours system, subcontracting, overtime hours, sister plants and temporary labour.* Problems inherent in the use of *annualised hours contracts, subcontracting and temporary labour* to achieve volume flexibility include, *resistance to change, inconsistent quality and lack of required skills* respectively (see Figure 13.4). **4.** The strategy chosen by plants to achieve high levels of volume flexibility depends on specific characteristics of the plants that are mostly not sectoral in nature. For instance, *annualised hours contracts* can be successfully adopted by *any* manufacturing plant experiencing *high demand variability and short-term demand uncertainty* to achieve volume flexibility. It should be noted, however, that both conditions refer to a situation in which the total demand over the planning period is relatively predictable. **5.** Although *overtime hours by full time employees* is currently the most widely used strategy to achieve volume flexibility, this strategy is becoming less favoured in the future by manufacturing plants. There is a growing preference for the use of variable hours strategies such as *annualised hours contracts* to achieve volume flexibility by manufacturing plants (see Figure 13.6). **6.** Substitute enablers of volume flexibility exist. For instance, a variable hours strategy such as an *annualised hours contract and/or a banked-hours system* can be used to substitute *overtime hours by full time employees* to achieve high levels of volume flexibility. Also, complementary enablers exist. For instance, the strategies of *multiskilling* and *teamworking* can be used to complement *annualised hours contracts* and *banked hours system* to achieve volume flexibility in manufacturing plants.
RQ3: Why do some plants choose some enablers and other plants choose other enablers to achieve high levels of volume flexibility?	**7.** Plants choose some solutions in preference to others to achieve volume flexibility because of the perceived cost and other advantages, which the preferred solutions offer and the capability of the solutions to cope effectively with internal and external conditions that the plant is faced with. For instance, an *annualised hours system* is preferred to *overtime hours* for the achievement of volume flexibility because the former is perceived to be relatively cheaper to implement, reduces absenteeism and copes effectively with demand variability (seasonality) and short-term demand uncertainty (see Table 13.1).
RQ4: How do manufacturing plants implement the enablers and overcome the inhibitors to achieve high levels of volume flexibility?	**8.** Effective management of change through good education, consultation, gradual implementation, correct timing of launch, informal management and offering of incentives (financial or non financial) is important for the successful implementation of variable hours strategies such as an annualised hours contract and banked hours system in the achievement of high levels of labour capacity flexibility in manufacturing plants (see Table 12.3).

Table 13.2: Research Questions and Conclusions

13.3.5 Limitations of the Study

It is worth mentioning the weaknesses of this research work. This evaluation can be of some help for the advancement of research in the area of manufacturing flexibility.

Narrow focus of the research – The literature review reveals that flexibility is a multi-dimensional concept. As such, many of the studies (Slack, 1987; Cox, 1989, Hyun and Ahn, 1992, Suraez *et al,* 1996 and Thomke and Reinertsen, 1998) on flexibility have evaluated the core identified dimensions of flexibility in an attempt to advance knowledge in the area. Due to the relatively little attention given to the issue of volume flexibility by researchers in the area, this research focuses on volume flexibility, although it recognises that volume flexibility is just one aspect of manufacturing flexibility. This focus is a limitation in the sense that the study does not provide empirical evidence that gives a complete picture of the analysis and the implementation of flexibility as a whole in manufacturing plants. However, by focusing on and carrying out an in-depth study on volume flexibility, this study has improved on previous studies that tended to only 'scratch' the surface of the issues in an attempt to cover all the components of manufacturing flexibility.

The second Research Question was focused on labour-based enablers or sources of volume flexibility. Hence, the mail survey concentrated on exploring the labour-based enablers of volume flexibility. This limited the scope of the survey, although respondents were given the opportunity to identify other sources of volume flexibility that were applicable to their respective plants. The subsequent case studies were used to correct this limitation and the case studies reveal other sources of volume flexibility that were not considered in the design of the survey research.

Difficulty in securing "hard data" about volume flexibility – Much of the evidence obtained in relation to the analysis and implementation of volume flexibility in manufacturing plants was based on managers' perceptions and less on objective measures. There are two main reasons for this.

1. As the literature review has revealed, the research on measurement of flexibility as a whole and in particular volume flexibility is still inconclusive. Authors have not reached a consensus on how to measure volume flexibility in manufacturing plants. Similarly, flexibility is a concept that is scarcely measured by managers. Although the measurement of volume flexibility was not one of the empirical objectives of this study, it was necessary to be able to assess the degree of volume flexibility of the

plants studied. This is because *enablers* of volume flexibility (which the second Research Question seeks to identify) are only enablers in so far as they provide a system with the required volume flexibility. Most of the managers interviewed saw the need to measure the volume flexibility of their manufacturing operations, but none of them had systems or procedures in place that could assess it. Hence, the assessment of the degree of volume flexibility was based on the perception of these managers and not on objective measures.

2. In order to mitigate the above limitation, an attempt was made to carry out an assessment of volume flexibility based on some models developed in the literature (e.g. Slack, 1987 and Suarez *et al*, 1996). Using these models requires a combination of some sensitive quantitative data (i.e. historical production volume and data on production cost of achieving flexibility) and some qualitative data. In most cases, the managers were not willing to divulge this information, especially the production cost information. In other cases the information was just not available. According to the GMO of Teleco. *"Unfortunately I have to decline this request. Forward production planning is carried out daily/weekly such that the most recent plan is meaningful and therefore retained. Retention of numerous iterations of plans which are months/years out of date is not our policy"*. The lack of historical data on actual production volume and forecast as well as other attributes of the physical environments also limited the ability to determine objectively the level and type of demand uncertainty and in some cases demand variability that the plants experience. Much of the evidence used to provide answers to the first Research Question (i.e. drivers of volume flexibility) is therefore largely based on managers' perceptions. Although some authors (e.g. Downey *et al*, 1975) have proposed objective measures for factors like demand uncertainty, there have also been arguments in support of the use of managers' perceptions. Correa (1992) argues that depending on the previous level of knowledge of the manager and his cognitive process, the same set of stimuli from the environment can foster different levels of perceived uncertainty in different managers. Thus, what is certain to one person is uncertain to another, even when decisions are based on similar quantitative data (Huff, 1978). Therefore, the use of managers' perceptions in this research is well justified.

13.4 Contribution of the Research

This research has contributed to the manufacturing flexibility literature and practice and the human resources literature.

Contributions to the Concept of Manufacturing Flexibility

Many authors have proposed factors that drive organisations to require flexibility (e.g. Zelenovic, 1982; Garrett, 1986; Slack, 1991; Guptal and Goyal, 1992 and Hyun and Ahn, 1992). However, very few have carried out empirical studies to investigate the relationship between these factors and flexibility (e.g. Swamidass and Newell, 1987, Correa, 1992 and Correa and Slack, 1996). Flexibility is a multi-dimensional concept. The components of flexibility are characterised by the types of interactions they have with environmental or internal factors. A major gap in the manufacturing flexibility literature has been that many of the studies have treated flexibility as a uni-dimensional concept in spite of the huge number of contributions towards the development of various taxonomies of manufacturing flexibility. For instance, a manufacturing plant that experiences *high variability in the demand levels* of a standard product that it produces would require volume flexibility rather than mix flexibility. By carrying out an in-depth study on one component of manufacturing flexibility (i.e. volume flexibility), this project has partly filled a gap in the manufacturing flexibility literature, particularly in terms of providing quantitative and qualitative empirical evidence.

1. It has identified various conditions (product, market and supply based) that would drive a manufacturing plant to require high levels of volume flexibility. This project shows that the applicability of these drivers is, however, contingent on a number of factors identified, such as product and plant characteristics. By identifying the drivers of volume flexibility and most importantly where these drivers are applicable, this research project has contributed significantly to the manufacturing flexibility literature as it shows that volume flexibility is not an attribute that is universally advantageous to all manufacturing plants. Also, practising managers are able to do a proper assessment of volume flexibility needs prior to implementing volume flexibility. For instance, most manufacturing plants should be concerned with, and seek for strategies that can cope with demand variability as it appears to be a characteristic shared by most markets. Additionally, plants operating in markets characterised by fierce competition, changing customer tastes and rapid technological changes – that lead to rapid product obsolescence should be concerned with, and seek for solutions to cope with short product life cycle.

2. This study expands the understanding of the classification of manufacturing flexibility as it proposes three dimensions of strategic manufacturing flexibility (i.e. mix, volume and new product flexibility types). This project also advances the understanding of the measurement of volume flexibility. Although the dimensions and measures of flexibility proposed are based purely on theoretical frameworks, this project contributes to areas of manufacturing flexibility literature (developing taxonomies of flexibility and measuring flexibility) which have attracted many studies, many of which are lacking in consensus.
3. This project has identified various mechanisms through which manufacturing plants can achieve volume flexibility (this is explained in the next section). By providing explanations based on empirical evidence as to why some mechanisms are preferred to others, the project has contributed to an area of manufacturing flexibility literature, that is, flexibility implementation that has been neglected. The insights also have important policy implications for practising managers seeking to introduce flexibility strategies into their operations.
4. By combining the use of quantitative (survey research) and qualitative (case studies) methods to investigate a common phenomenon, this project has proved that the two methods can be used to complement each other in the field of operations management, thus making a methodological contribution to knowledge.

Implications to Practitioners

Managers need to do a proper assessment of volume flexibility needs prior to implementing solutions to achieve volume flexibility. Some volume flexibility enablers identified in this research and their characteristics in terms of when to use them, how to implement them, problems in implementation and their perceived benefits are summarised in Table 13.3 below to provide pointers for managers hoping to achieve volume flexibility.

Volume flexibility enablers	Characteristics
Annualised hours contracts	A tactical solution for achieving volume flexibility. Good for handling high levels of demand variability over the planning period provided overall total demand is reasonably predictable. Involves a major structural change for implementation, hence may be resisted by workforce. Most effective if implemented gradually and allowed to be self-managed using multiskilled teams. May be necessary to educate workforce and provide financial incentive for workers to buy into it. Can eliminate overtime and reduce absenteeism if managed properly. Can generally be implemented in most sectors.
Use of temporary labour	A tactical solution for achieving volume flexibility. Good for handling demand variability and long term demand uncertainty. Can handle short-term demand uncertainty where required skill level is low and there is local labour availability. Can be implemented in most sectors.
Use of overtime hours by full time employees	A tactical solution for achieving volume flexibility. Good for handling short-term demand uncertainty and low levels of demand variability. Otherwise, could be costly and become institutionalised. Hence, may be difficult to get workforce off the scheme. It may also be subject to the problem of labour availability if used over a longer period of time. Can be implemented in most sectors.
Banked hours system	A tactical solution for achieving volume flexibility. Similar to annualised hours contracts. Good for handling high levels of demand variability and demand uncertainty. Can be resisted by the workforce since it involves a major structural change. Most effective if implemented gradually and allowed to be self-managed using multiskilled teams. May be necessary to educate workforce and provide incentive (financial or non-financial) for workers to buy into it. Can eliminate overtime and reduce absenteeism if managed properly. Can generally be implemented in most sectors.
Subcontracting	A relatively long-term solution for achieving volume flexibility. Good for handling high levels of demand uncertainty. Suitable for handling non-core activities otherwise will increase costs and waste capacity in conditions of high demand variability and low long-term demand uncertainty. Implementation may involve formal selection process for subcontractors, having a good control system and developing a good relationship with subcontractors. Can be implemented in sectors where technology is easily transferable.
Use of contract employees	A tactical solution for achieving volume flexibility. Similar to the use of temporary labour but focus is on handling demand variability over the medium to long term at a professional level.
Increased hours by part-time employees	A tactical solution for achieving volume flexibility. Good for handling demand uncertainty provided plant utilisation allows for additional hours in suitable time slots.
Varying lead times	Reduces the need for volume flexibility. Can be used to handle low levels of demand variability and demand uncertainty. May lead to loss of customers. Works well in low competitive markets, or where product is unique or protected by patents. Requires good relationship with customers and good planning system for effective implementation.
Rejecting orders	Reduces the need for volume flexibility. Mostly used where supplier has more clout. May be necessary to classify customers and be selective about which customers' orders to reject. Costly but may be better than promising what cannot be delivered.
Sister plants	A tactical solution for achieving volume flexibility. Good for handling overload due to demand uncertainty and demand variability. May be costly due to internal transfer pricing. May involve complicated logistic problems if it involves physical movements of goods across great distances. Will be most effective where there are methods and process consistency and good integration across sites.
Supply chain flexibility	A long-term solution for achieving volume flexibility. Necessary where the flow of materials, goods or information from suppliers to end users is complex due to a large number of players involved, a large number of components etc. May be required to re-engineer the process and reduce the number of components and therefore number of suppliers needed, and developing and maintaining a network of relationship and information flow with the players in the supply chain.
Equipment upgrade	A long-term solution for achieving volume flexibility. Can be implemented when existing machinery is seen to be incapable of handling future demand variability. Long-term demand uncertainty must be low otherwise will be very costly and waste capacity. May be necessary to have accurate forecasts, good capacity and flexibility analysis and an extensive research on available technology for implementation.
Multiskilling/ Teamworking	Have an indirect effect on the achievement of volume flexibility. Complement other enablers such as annualised hours contracts and banked hours system. Require providing good training for the workforce. May be necessary to educate workforce, provide financial incentives and encourage voluntary participation for effective implementation. Total autonomy is also required in the case of teamworking.
Process improvement	A long-term solution for which volume flexibility is only a by-product. May be required to focus on ways of increasing throughput. These may include achieving common upstream processes, rationalising number of components, predictive and preventative maintenance, teamworking and introduction of continuous improvement programmes.
Mix flexibility	Indirectly aids the achievement of long-term volume flexibility since it provides the ability to adjust quickly to relative volume changes within mix. Can be used to handle demand variability and uncertainty relating to different volumes of a wide range of product mix, in addition to other volume flexibility solutions such as annualised hours contracts. May be necessary to have multiskilled workforce, flexible equipment or lines and common processes for effective implementation.

Table 13.3: Practical Prescriptions: Volume flexibility enablers and characteristics

Contributions to Human Resources Flexibility

Voss (1995) proposes that because of the applied nature of the operations management field, many of the new developments in the field come from the interface between operations management and other disciplines. This project has partly filled the gap between labour flexibility issues in the human resources management literature and technical aspects of production flexibility. The study has identified various mechanisms through which a manufacturing plant can achieve volume flexibility and the potential problems of implementation. These mechanisms are labelled enablers and inhibitors respectively and are mostly labour-based. This project has also offered explanations of how these enablers are used to achieve volume flexibility in manufacturing plants. These contributions have important policy implications in terms of how to achieve volume flexibility for practising managers involved in managing in highly turbulent and uncertain environments. They also have implications for management of change in a production environment. The following model has been developed to show the relationship between human resources flexibility literature (e.g. Atkinson, 1985) and the outcome of this project in relation to the enablers of volume flexibility.

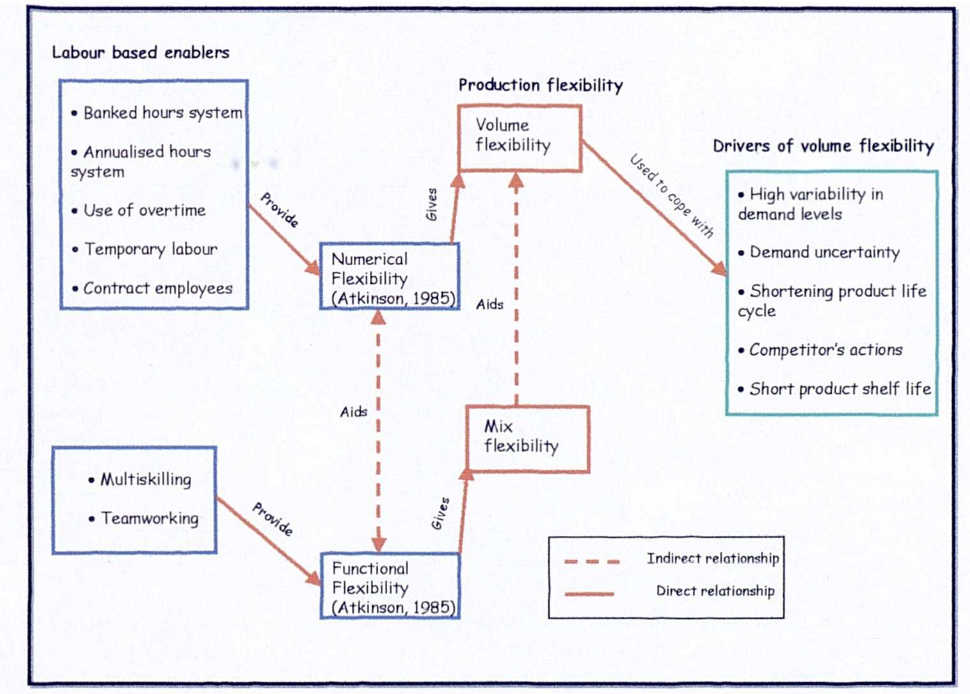

Figure 13.8: Linking human resources flexibility with production flexibility

Atkinson (1985) defined functional flexibility as the type of flexibility, which enables employees to be re-deployed quickly and smoothly between activities and tasks. He defined numerical flexibility as the ease with which the number of workers employed (or hours worked) can be adjusted to meet fluctuations in the level of demand. Using the flexible firm model (Chapter 4), Atkinson (1985) argued that employees who provide functional flexibility form the core group of the workforce since their skills cannot easily be brought in. He posited that employees who provide numerical flexibility are the peripheral workers who can easily be brought in and released in line with demand requirements (e.g. temporary labour). The Atkinson model has come under many attacks. Pollert (1987) argued that the concept of core and periphery workers does not help understand the relationships between labour flexibility and the production system as a whole. The fact that the model ignores the issue of motivation and commitment of the peripheral workforce shows the bias of the model towards cost control rather than to the achievement of labour flexibility (Pollert, 1987).

With the model developed in Figure 13.8 above, this research has contributed to the resolution of the above debate. The implication of Atkinson's (1985) model is that a firm can only achieve numerical flexibility (or volume flexibility) by using peripheral workers who can easily be brought in and released in line with demand fluctuations. These peripheral workers are usually not as motivated and committed as the core workers are, therefore achieving numerical flexibility in this way may lead to other problems such as an increase in reject rates (quality problems) or low productivity. This research has confirmed the view that peripheral workers can be used to achieve numerical flexibility (e.g. using temporary labour and contract employees). It has, however, also provided empirical evidence to show that an organisation's core group of workers (who would normally only provide functional flexibility in Atkinson's model) can also be used to provide numerical flexibility without the organisation having to resort to the use of peripheral workers. This is achieved through the use of variable hours strategies like an *annualised hours system, banked hours system, job sharing contracts* and in some cases the use of *overtime hours*. Using these strategies affords an organisation the advantage of using its motivated and committed workforce to achieve volume flexibility.

To summarise the above argument this research has found that an organisation can achieve flexibility (both numerical and functional) by:

1. Using its core group of workers and peripheral workers to achieve both functional and numerical flexibility respectively (Atkinson's 1985 model)
2. Using only its core group to achieve both numerical and functional flexibility.

The choice of which option to adopt depends on the characteristics of the plant or the conditions which it faces. However, choosing option 2 has the added advantage of ensuring the commitment and motivation of the workforce. Workers' commitment and motivation have been found to be important for operational success in manufacturing organisations (Deming, 1986; Hayes *et al*, 1988 and Womack *et al*, 1990).

New Areas for Research

Measurement of volume flexibility - As the literature review in this project has revealed, the studies on the measurement of volume flexibility and in fact the flexibility concept itself as a whole are still inconclusive. A number of models have been proposed in the literature for the measurement of flexibility. However, there has been a lack of empirical studies to support the theoretical models. This project has proposed that future measures of flexibility need to be based on a combination of objective measures that utilise historical data and perceptual measures that measure the potential or ability of the manufacturing system to cope with future changes. This combination model should consist of, for example, Suarez *et al*'s (1996) objective flexibility measure and Slack's (1987) perceptual measure of the range and response dimension of flexibility. There is a need to further develop this combination model and test the model using a suitable empirical investigation to check the model's validity and applicability.

Studies on other dimensions of flexibility – This project has carried out an in-depth study on volume flexibility, defined as one of the strategic components of manufacturing flexibility. Many studies in the literature have treated manufacturing flexibility as a uni-dimensional concept. Interestingly, many of these studies have also revealed various dimensions of manufacturing flexibility. By treating the issue of flexibility in the broad sense, it is impossible to reach into the depths of the concept and to be able to address specific questions such as those addressed in this research project. It is proposed that future studies on manufacturing flexibility be focused on the other strategic components of flexibility such as mix flexibility and new product flexibility. This should give a better picture and understanding of the make up of the concept of manufacturing flexibility, which to this day is still not well understood either by practising managers or by academics.

Flexibility in inter-organisational networks – In recent years there has been an increase in the coming together of firms to harness the benefits of contributing their core or relative competencies through collaboration, while maintaining their independent identities. If these relationships exist in a vertical sense, they are referred to as vertical inter-organisational networks (where the core firm collaborates with its distributors and suppliers – Achrol, 1997). Vertical networks are being captured in the supply chain management literature. If the relationships are between similar firms or firms operating in similar markets, the network type is referred to as a horizontal network (Hinterhuber and Levin, 1994 and Oliver and Ebers, 1998).

One of the reasons for the formation of these network types is for organisations to be able to achieve flexibility either collectively or individually and be responsive to the fast changing market environment. Thus, the study on flexibility needs to move beyond the boundaries of individual organisations to explore the issues within different types of network structures. It will be interesting to explore:

1. Whether flexibility is an issue in inter-organisational networks
2. Whether drivers of flexibility differ with different types of inter-organisational networks
3. The enablers and inhibitors of flexibility in different inter-organisational networks
4. Differences and similarities in the manner in which different types of inter-organisational networks seek to address the issue of or achieve flexibility.

As the new millennium approaches, it is clear that the market requirement will be an extension of the existing ones. Manufacturing organisations will face more challenges, more competition and highly uncertain environment. These will lead to the search for different ways to reduce risks and compete in the market place. It is suggested that flexibility should not be regarded as a thing of the past or as another passing "fad". As this research project has shown, many of the new frontiers of competition are based on flexibility. Thus, practitioners need to understand and implement flexibility where appropriate before embarking on new frontiers of competition. Successful companies in the new millennium will be those who can effectively manage the transition process faster than their competitors.

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APPENDIX 1

The questionnaire design before pre-testing is presented in this appendix. This questionnaire was pre-tested internally within the Cranfield school of Management and externally with the pilot case study plants using a *'declared or participating'* pre-test method. After pre-testing, the questionnaire was modified and the final questionnaire that was administered to Uk manufacturing plants is displayed in Appendix 2. The cover page of the questionnaire presented in this appendix also serves as the cover page for the final questionnaire.

Cranfield UNIVERSITY
School of Management

ANALYSIS AND IMPLEMENTATION OF VOLUME FLEXIBILITY: A SURVEY OF UK MANUFACTURING PLANTS

CRANFIELD SCHOOL OF MANAGEMENT

The Operations Management Research Centre

About The Survey

The study is attempting to :

(1) Investigate the conditions under which high levels of volume flexibility (i.e. the ability to respond effectively to fluctuations in production requirements) will be required by manufacturing plants, and

(2) Identify the enablers and inhibitors of volume flexibility in manufacturing plants.

Please answer all questions by either checking the appropriate box, circling the appropriate number, or by writing in the blank space provided. While you are free to leave any question unanswered, we urge you to give us your best estimate in cases where you do not have an exact answer.

Plant Profile and Instructions

Company name ______________________________

Product/Service ______________________________

Parent company name
if different from above ______________________________

Plant address ______________________________
____
____
____
____

Name of company contact
to whom feedback report will
be sent and to whom queries
can be directed ______________________________

Position ______________________________

Telephone ______________________________

Fax number ______________________________

Pledge of Confidentiality
Information will not be presented in any way that would identify any individual plant or firm.

1. What percentage of the plant's total output (at manufacturing cost) is supplied to customers :

Off the shelf (ex-finished goods stock)	%
On a quoted lead time shorter than the actual manufacturing lead time (i.e. assemble-to-order, pack-to-order)	%
On a quoted lead time equal to or longer than the actual manufacturing lead time (through engineering design work or backlog for example)	%
Total output of plant	100%

2. Which of the following characteristics drive your plant to require high levels of volume flexibility? (please circle one for each item)

Volume flexibility *is the ability of the plant to vary its production output in a timely and cost efficient manner*

Demand level variability *refers to the magnitude of variation in the absolute quantities of actual customer demand levels.*

Shelf-life *refers to the perceived limited elapsed time period between the date the product manufacture is completed and the 'use-by' date of the product.*

Customer lead time *is the elapsed time from the time an order is placed to delivery to the customer.*

Product life cycle *is the perceived elapsed time period that the product is in use for before it becomes obsolete or modified.*

	Insignificant				Highly Significant
High customer demand level variability	1	2	3	4	5
Short product shelf-life	1	2	3	4	5
Customer has more power in the determination of customer lead time	1	2	3	4	5
Short product life cycle	1	2	3	4	5
High unpredictability of customer demand level	1	2	3	4	5
Others (please list)					
______________	1	2	3	4	5
______________	1	2	3	4	5
______________	1	2	3	4	5
______________	1	2	3	4	5

Please answer questions 3-9 relating to information about the employees directly involved in production operations in your plant during low, normal and peak demand conditions on average in the past year.

3. What is the total number of employees involved in production operations in the plant?

Period	Low demand	Normal demand	Peak demand
Number			

4a. How many of these are full-time employees?

b. How many hours on average does each full-time employee work in a week?

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

5a. How many are part-time employees?

b. On average, how many hours does each part-time employee work in a week?

• ***Part-time employees*** : employees who only work a restricted number of hours each week which would normally be less than the standard working week.

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

6. Of the part-timers in Q5a above, how many are on job-sharing contracts?

• ***Job Sharing*** : the equivalent full time job is shared between employees in a certain proportion, say two employees sharing 50% each. The job sharers are expected to vary hours of work in a flexible way and are free to exchange each others rota.

Period	Low demand	Normal demand	Peak demand
Number			

7a. How many temporary workers do you have?

b. On average, how many hours does each temporary worker work in a week?

• ***Temporary Labour*** : includes casual, freelance, short-term cover or fixed-term employment.

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

8a. How many contract employees do you have?

b. How many hours on average does each contract employee work in a week?

• ***Contract employees*** : Usually skilled and employed for a fixed-term, work full hours as company staff within the contractual period but may not be entitled to full company benefits.

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

9a. How many workers are on annual hours contracts or equivalent?

b. What is the average annual total hours for each employee on this contract?

Hours

• ***Annual Hours Contract***: a contract, which enables the employer to vary the number of hours, worked in a defined period within a context of the agreed total working hours for the year.

If you employ other variants of annual hours contract, please specify :

____

10. How did you cope with the actual fluctuations in demand levels in the past year? Please circle one number for each strategy. • ***Overtime***: provides for longer hours of work than the standard week worked normally by employees. • ***Sub-contracting*** : Out-sourcing all or part of the production process to absorb some of the fluctuations faced by the company		Never Used				Used Extensively
	Overtime by full time employees	1	2	3	4	5
	Increased hours worked by part-time employees	1	2	3	4	5
	Temporary Labour	1	2	3	4	5
	Job Sharing	1	2	3	4	5
	Annual Hours contracts	1	2	3	4	5
	Sub-contracting	1	2	3	4	5
	Contract employees	1	2	3	4	5
	Rejecting orders	1	2	3	4	5
	Others (please list)					
	______________	1	2	3	4	5
	______________	1	2	3	4	5
	______________	1	2	3	4	5

11. In coping with actual demand level fluctuations in your plant, how would you assess the relative economics of the use of each of these strategies? (where applicable, please circle one number for each)		Not Costly				Very Costly
	Overtime by full time employees	1	2	3	4	5
	Increased hours worked by part-time employees	1	2	3	4	5
	Temporary Labour	1	2	3	4	5
	Job Sharing	1	2	3	4	5
	Annual Hours contracts	1	2	3	4	5
	Sub-contracting	1	2	3	4	5
	Contract employees	1	2	3	4	5
	Rejecting orders	1	2	3	4	5
	Others (please list)					
	______________	1	2	3	4	5
	______________	1	2	3	4	5
	______________	1	2	3	4	5

12. Which of the above strategies do you think was the most successful in your plant and why?	______________________________ ______________________________ ______________________________ ______________________________

13. In your opinion, what is the desirability of each of the listed strategies (in terms of suitability and relative economics) in coping with demand fluctuations in your plant **in the future**? (please circle one for each).	Not Desirable				Highly Desirable
Overtime by full time employees	1	2	3	4	5
Increased hours worked by part-time employees	1	2	3	4	5
Temporary Labour	1	2	3	4	5
Job Sharing	1	2	3	4	5
Annual Hours contracts	1	2	3	4	5
Sub-contracting	1	2	3	4	5
Contract employees	1	2	3	4	5
Rejecting orders	1	2	3	4	5
Others (please list)					
____________	1	2	3	4	5
____________	1	2	3	4	5
____________	1	2	3	4	5

14. How problematic has each of the listed factors been to your plant's ability to cope with demand fluctuations in the past two years? (please circle one for each item used. Ignore strategies 'not used')	Not Problematic				Very Problematic
Getting full-time employees to work overtime hours	1	2	3	4	5
Getting part-time employees to work increased hours	1	2	3	4	5
Securing temporary Labour	1	2	3	4	5
Implementing job sharing	1	2	3	4	5
Implementing annual hours contracts	1	2	3	4	5
Sub-contracting	1	2	3	4	5
Securing contract employees	1	2	3	4	5
Others problems(please list)					
____________	1	2	3	4	5
____________	1	2	3	4	5
____________	1	2	3	4	5

15. How problematic do you think each of the listed factors will be to the ability of your plant to cope with demand fluctuations **in the future**? (please circle one for each item)		Not Problematic				Very Problematic
	Getting full-time employees to work overtime hours	1	2	3	4	5
	Getting part-time employees to work increased hours.	1	2	3	4	5
	Securing temporary Labour	1	2	3	4	5
	Implementing job sharing contract	1	2	3	4	5
	Implementing annual hours contract	1	2	3	4	5
	Sub-contracting	1	2	3	4	5
	Securing contract employees	1	2	3	4	5
	Rejecting orders	1	2	3	4	5
	Others problems(please list)					
	______________	1	2	3	4	5
	______________	1	2	3	4	5
	______________	1	2	3	4	5

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

Please write your comments below regarding the completion of this questionnaire in terms of clarity of the questions, ease of obtaining the required information, time spent on the questionnaire and your feelings in general.

PLEASE SEND THE COMPLETED QUESTIONNAIRE TO CRANFIELD SCHOOL OF MANAGEMENT IN THE PRE-PAID ENVELOPE OR BY FAX TO 01234 754488.

Should you have any questions about this survey, please contact:

Goke Oke
Doctoral Researcher
Operations Management Research Centre
Cranfield School of Management
Cranfield, Bedfordshire, MK43 0AL.
Tel. 01234 754380
Fax: 01234 754488
Email: a.oke@cranfield.ac.uk

APPENDIX 2

The questionnaire shown in Appendix 1 was pre-tested. The revised questionnaire design and the covering letter are, therefore, presented in this appendix. The questionnaire was administered by mail survey to a total of 529 UK manufacturing plants.

20 October, 1998

Mr -------------

Dear Mr -----------

Based on your past participation in the Management Today/Cranfield School of Management Best Factory Awards, I would like to ask for your co-operation in a research programme which we are now undertaking. This part of the research study is being carried out by my research student, Mr. Goke Oke, as part of his doctoral studies.

The study is attempting to investigate the conditions under which high levels of volume flexibility (i.e. the ability to respond effectively to fluctuations in production requirements) will be required by manufacturing plants and how it can be implemented. Much has been written lately about the importance of volume flexibility in today's markets, but no study to date has proposed a comprehensive framework to identify the enablers and inhibitors to its implementation through rigorous empirical analysis. We believe the results of the study will have direct application to business practice and will contribute to filling existing gaps in knowledge about this critical issue in manufacturing strategy.

The findings of the study will be fed back to the participating plants as the research progresses, and there will be at least a 1-2 year delay before significant public dissemination of any results. We hope therefore that this study might be of mutual benefit.

We would sincerely appreciate your participation in this survey which we are sure will be of mutual benefit. The survey is being distributed to more than 500 manufacturing plants in the UK representing various industrial classifications. In trials, the questionnaire took approximately 15 minutes to complete.

As for the Best Factory Award, you are assured of full confidentiality in this survey. Your completed questionnaire will be assigned a code number and handled exclusively by the researcher. No individual response will ever be identifiable. Only aggregate data will be used for analysis and interpretation, and in summary reports. I do hope you will feel able to participate.

Yours Sincerely,

Professor Colin New
Head, Operations Management Research Center.
Cranfield School of Management.

About The Survey

The study is attempting to:

(1) Investigate the conditions under which high levels of volume flexibility (i.e. the ability to respond effectively to fluctuations in production requirements) will be required by manufacturing plants, and

(2) Identify the enablers and inhibitors of volume flexibility in manufacturing plants.

Please answer all questions by either checking the appropriate box, circling the appropriate number or by writing in the blank space provided. While you are free to leave any question unanswered, we urge you to give us your best estimate in cases where you do not have an exact answer.

Plant Profile and Instructions

Company name ______________________________

Product/Service ______________________________

Parent company name
if different from above ______________________________

Plant address ______________________________
____
____
____
____

Name of Company contact
to whom feedback report will
be sent and to whom queries
can be directed ______________________________

Position ______________________________

Telephone ______________________________

Fax number ______________________________

Pledge of Confidentiality

Information will not be presented in any way that would identify any individual plant or firm.

1. Which of the following characteristics drive your plant to require high levels of volume flexibility? (please circle one for each item)

***Demand level variability** refers to the magnitude of variation (i.e. highs & lows) in the absolute quantities of actual customer demand levels*

***Shelf-life** refers to the perceived limited elapsed time period between the date the product manufacture is completed and the 'use-by' date of the product.*

***Customer lead time** is the elapsed time from the time an order is placed to delivery to the customer.*

***Product life cycle** is the perceived elapsed time period that the product is in use for before it becomes obsolete or modified*

***Demand level unpredictability** refers to the degree of uncertainty in determining customer demand levels.*

***Volume flexibility** is the ability of the plant to vary its production output in a timely and cost efficient manner*

	Insignificant				Highly Significant
High customer demand level variability	1	2	3	4	5
Short product shelf-life	1	2	3	4	5
Customer has more power in the determination of customer lead time	1	2	3	4	5
Short product life cycle	1	2	3	4	5
High unpredictability of customer demand level	1	2	3	4	5
Others (please list) ____________	1	2	3	4	5
____________	1	2	3	4	5
____________	1	2	3	4	5
____________	1	2	3	4	5

Questions 2-8 relate to information about the employees (full time, part-time, temporary and contract) directly involved in production operations in your plant during low, normal and peak demand conditions, over a time period.

2. Over what time period did you (or do you) experience fluctuations in demand levels? (i.e. low, normal & peak demand). Please circle one.

Within 1 year	Over 2 years	Over or longer than 3 years

3. What was (is) the average total number (head count) of employees (including full-time, part-time etc.) involved in production operations in the plant over this time period?

Period	Low demand	Normal demand	Peak demand
Number			

4a. How many of these were (are) full-time employees?

b. How many hours on average did (does) each full-time employee work in a week?

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

5a. How many were (are) part-time employees?

b. On average, how many hours did (does) each part-time employee work in a week?

• ***Part-time employees*** : employees who only work a restricted number of hours each week which would normally be less than the standard working week.

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

6. Of the part-timers in Q5a, how many were (are) on job-sharing contracts?

Period	Low demand	Normal demand	Peak demand
Number			

• ***Job Sharing*** : the equivalent full time job is shared between employees in a certain proportion, say two employees sharing 50% each. The job sharers are expected to vary hours of work in a flexible way and are free to exchange each others rota.

7a. How many temporary workers did (do) you have?

b. On average, how many hours did (does) each temporary worker work in a week?

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

• ***Temporary Labour*** : includes casual, freelance, short-term cover or fixed-term employment.

8a. How many contract employees did (or do) you have?

b. How many hours on average did (or does) each contract employee work in a week?

Period	Low demand	Normal demand	Peak demand
Number			
Hours			

• ***Contract employees*** : Usually skilled and employed for a fixed-term, work full hours as company staff within the contractual period but may not be entitled to full company benefits.

9a. How many workers are on annual hours contracts or equivalent?

b. What is the average annual total hours for each employee on this contract?

Hours

• ***Annual Hours Contract*** : a contract which enables the employer to vary the number of hours worked in a defined period within a context of the agreed total working hours for the year.

For example an employee may be contracted for and is paid to work 1900hrs yearly. The actual number of hours worked on daily/weekly/monthly bases may vary depending on the requirements as long as the annual total is within the 1900hrs. Hence overtime is discouraged.

If you employ other variants of annual hours contract, please specify :

____

____

____

____

____

____

10. How did your plant cope over the period when you experienced fluctuations in actual demand levels? Please circle one number for each strategy.

- ***Overtime***: provides for longer hours of work than the standard week worked normally by employees.
- ***Job Sharing*** : the equivalent full time job is shared between employees in a certain proportion, say two employees sharing 50% each. The job sharers are expected to vary hours of work in a flexible way and are free to exchange each others rota
- ***Annual Hours Contract*** : a contract which enables the employer to vary the number of hours worked in a defined period within a context of the agreed total working hours for the year
- ***Sub-contracting*** : Out-sourcing all or part of the production process to absorb some of the fluctuations faced by the company

	Not Used				Used Extensively
Overtime by full time employees	1	2	3	4	5
Increased hours worked by part-time employees	1	2	3	4	5
Temporary Labour	1	2	3	4	5
Job Sharing	1	2	3	4	5
Annual Hours contracts	1	2	3	4	5
Sub-contracting	1	2	3	4	5
Contract employees	1	2	3	4	5
Varying lead times	1	2	3	4	5
Rejecting orders	1	2	3	4	5
Others (please list)					
____________	1	2	3	4	5
____________	1	2	3	4	5
____________	1	2	3	4	5

11. In coping with actual demand level fluctuations in your plant, how would you assess the relative economics of the use of each of these strategies? (please circle one number for each). Your perceptions for strategies 'not used' is also sought.

	Not Costly				Very Costly
Overtime by full time employees	1	2	3	4	5
Increased hours worked by part-time employees	1	2	3	4	5
Temporary Labour	1	2	3	4	5
Job Sharing	1	2	3	4	5
Annual Hours contracts	1	2	3	4	5
Sub-contracting	1	2	3	4	5
Contract employees	1	2	3	4	5
Varying lead times	1	2	3	4	5
Rejecting orders	1	2	3	4	5
Others (please list)					
____________	1	2	3	4	5
____________	1	2	3	4	5
____________	1	2	3	4	5

12. Which of the above strategies (in Q10) do you think was the most successful in your plant and why?	______________ ______________ ______________					
13. In your opinion, what will the desirability of each of the listed strategies (in terms of suitability and relative economics) be in coping with demand fluctuations in your plant **<u>in the future</u>**? (please circle one for each).		Not Desirable				Highly Desirable
	Overtime by full time employees	1	2	3	4	5
	Increased hours worked by part-time employees	1	2	3	4	5
	Temporary Labour	1	2	3	4	5
	Job Sharing	1	2	3	4	5
	Annual Hours contracts	1	2	3	4	5
	Sub-contracting	1	2	3	4	5
	Contract employees	1	2	3	4	5
	Varying lead times	1	2	3	4	5
	Rejecting orders	1	2	3	4	5
	Others (please list)					
	______________	1	2	3	4	5
	______________	1	2	3	4	5
	______________	1	2	3	4	5
14. How problematic has each of the listed factors been to your plant's ability to meet production output requirements during the period of demand fluctuations? (please circle one for each item used. Ignore strategies 'not used')		Not Problematic				Very Problematic
	Hiring full-time employees	1	2	3	4	5
	Getting full-time employees to work overtime hours	1	2	3	4	5
	Getting part-time employees to work increased hours	1	2	3	4	5
	Securing temporary Labour	1	2	3	4	5
	Implementing job sharing	1	2	3	4	5
Continued.........						

Question 14 continued:		Not Problematic				Very Problematic
	Implementing annual hours contracts	1	2	3	4	5
	Sub-contracting	1	2	3	4	5
	Securing contract employees	1	2	3	4	5
	Getting customers to agree to variations in lead time.	1	2	3	4	5
	Others problems(please list)					
	______________	1	2	3	4	5
	______________	1	2	3	4	5
	______________	1	2	3	4	5

15. If you were to use them **in future**, how problematic do you think each of the listed factors will be to the ability of your plant to cope with demand fluctuations? (please circle one for each item). Ignore strategies that you will not consider at all to cope with demand level fluctuations in the future.		Not Problematic				Very Problematic
	Hiring full-time employees	1	2	3	4	5
	Getting full-time employees to work overtime hours	1	2	3	4	5
	Getting part-time employees to work increased hours.	1	2	3	4	5
	Securing temporary Labour	1	2	3	4	5
	Implementing job sharing contract	1	2	3	4	5
	Implementing annual hours contract	1	2	3	4	5
	Sub-contracting	1	2	3	4	5
	Securing contract employees	1	2	3	4	5
	Getting customers to agree to variations in lead time	1	2	3	4	5
	Rejecting orders	1	2	3	4	5
	Others problems(please list)					
	______________	1	2	3	4	5
	______________	1	2	3	4	5
	______________	1	2	3	4	5

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

Please write any comments you may have below:

PLEASE SEND THE COMPLETED QUESTIONNAIRE WITHIN THE NEXT 15 DAYS TO CRANFIELD SCHOOL OF MANAGEMENT IN THE PRE-PAID ENVELOPE. THANK YOU.

Should you have any questions about this survey, please contact:

Goke Oke
Doctoral Researcher
Operations Management Research Centre
Cranfield School of Management
Cranfield, Bedfordshire, MK43 0AL.
Tel. 01234 754380
Fax: 01234 754488
Email : a.oke@cranfield.ac.uk

APPENDIX 3

The results of the reliability test carried out for the questionnaire are presented in this appendix. The questionnaire was given to different managers working in the same plant within the production department. Collusion amongst respondents was highly discouraged. The rule of thumb for a reliable question using this method is that the Cronbach's alpha must be equal to or greater than 0.7.

Plant A – 2 respondents

****** Method 1 (space saver) will be used for this analysis ******

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases =   44.0   N of Items = 2

Alpha =   .9278

Plant B – 3 respondents

****** Method 1 (space saver) will be used for this analysis ******

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases =   44.0   N of Items = 3

Alpha =   .8023

Plant C – 3 respondents

****** Method 1 (space saver) will be used for this analysis ******

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases = 44.0 N of Items = 3

Alpha = .8630

Plant D – 3 respondents

****** Method 1 (space saver) will be used for this analysis ******

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases = 44.0 N of Items = 3

Alpha = .8533

Plant E – 2 respondents

****** Method 1 (space saver) will be used for this analysis ******

_

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases = 44.0 N of Items = 2

Alpha = .8741

APPENDIX 4

The results of the analysis of Research Question One (i.e. Drivers of volume flexibility) based on an uncollapsed scale are presented in this appendix. These are:

1. The percentage of responding plants rating the drivers on a 5-point significance rating scale across sectors.
2. Chi-square tests to determine whether differences in ratings are sector dependent.

An example of the SPSS Syntax programme used to execute the analysis is given below:

```
CROSSTABS
 /TABLES=demvar  BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT ROW COLUMN .
```

demvar is the variable that represents high variability in demand levels

High demand level variability * Sector Crosstabulation

			Sector						Total
			Process	Eng. Consumer goods	Eng. Capital kits	Electronics	Household products	Food	
High demand level variability	Insignificant	Count	1						1
		% within High demand level variability	100.0%						100.0%
		% within Sector	4.2%						.8%
	Less Significant	Count	1		3	1		1	6
		% within High demand level variability	16.7%		50.0%	16.7%		16.7%	100.0%
		% within Sector	4.2%		25.0%	4.5%		6.7%	5.0%
	Significant	Count	1	3	2	5	2	1	14
		% within High demand level variability	7.1%	21.4%	14.3%	35.7%	14.3%	7.1%	100.0%
		% within Sector	4.2%	11.5%	16.7%	22.7%	9.5%	6.7%	11.7%
	More Significant	Count	12	12	4	8	9	4	49
		% within High demand level variability	24.5%	24.5%	8.2%	16.3%	18.4%	8.2%	100.0%
		% within Sector	50.0%	46.2%	33.3%	36.4%	42.9%	26.7%	40.8%
	Highly significant	Count	9	11	3	8	10	9	50
		% within High demand level variability	18.0%	22.0%	6.0%	16.0%	20.0%	18.0%	100.0%
		% within Sector	37.5%	42.3%	25.0%	36.4%	47.6%	60.0%	41.7%
Total		Count	24	26	12	22	21	15	120
		% within High demand level variability	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.346[a]	20	.228
Likelihood Ratio	21.148	20	.388
Linear-by-Linear Association	1.528	1	.216
N of Valid Cases	120		

a - 19 cells (63.3%) have expected count less than 5. The minimum expected count is .10.

Short Product Shelf Life * Sector Crosstabulation

			Sector						Total
			Process	Eng. Consumer goods	Eng. Capital kits	Electronics	Household	Food	
Short Product Shelf Life	Insignificant	Count	15	18	11	14	14	3	75
		% within Short Product Shelf Life	20.0%	24.0%	14.7%	18.7%	18.7%	4.0%	100.0%
		% within Sector	62.5%	69.2%	91.7%	63.6%	66.7%	20.0%	62.5%
	Less significant	Count	7	5	1	5	4	4	26
		% within Short Product Shelf Life	26.9%	19.2%	3.8%	19.2%	15.4%	15.4%	100.0%
		% within Sector	29.2%	19.2%	8.3%	22.7%	19.0%	26.7%	21.7%
	Significant	Count	1	1		1	1	2	6
		% within Short Product Shelf Life	16.7%	16.7%		16.7%	16.7%	33.3%	100.0%
		% within Sector	4.2%	3.8%		4.5%	4.8%	13.3%	5.0%
	More Significant	Count	1	1		2	2	5	11
		% within Short Product Shelf Life	9.1%	9.1%		18.2%	18.2%	45.5%	100.0%
		% within Sector	4.2%	3.8%		9.1%	9.5%	33.3%	9.2%
	Highly significant	Count		1				1	2
		% within Short Product Shelf Life		50.0%				50.0%	100.0%
		% within Sector		3.8%				6.7%	1.7%
Total		Count	24	26	12	22	21	15	120
		% within Short Product Shelf Life	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0 %	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.372[a]	20	.125
Likelihood Ratio	26.656	20	.145
Linear-by-Linear Association	6.915	1	.009
N of Valid Cases	120		

a - 22 cells (73.3%) have expected count less than 5. The minimum expected count is .20.

Lead time determined by customers * Sector Crosstabulation

			Sector						Total
			Process	Eng. Consumer goods	Eng. Capital kits	Electronics	Household	Food	
Lead time determined by customers	Insignificant	Count	2	1		2		1	6
		% within Lead time determined by customers	33.3%	16.7%		33.3%		16.7%	100.0%
		% within Sector	8.3%	3.8%		9.1%		6.7%	5.0%
	Less significant	Count	2	1	2	1	2	1	9
		% within Lead time determined by customers	22.2%	11.1%	22.2%	11.1%	22.2%	11.1%	100.0%
		% within Sector	8.3%	3.8%	16.7%	4.5%	9.5%	6.7%	7.5%
	Significant	Count	8	9	7	7	6	2	39
		% within Lead time determined by customers	20.5%	23.1%	17.9%	17.9%	15.4%	5.1%	100.0%
		% within Sector	33.3%	34.6%	58.3%	31.8%	28.6%	13.3%	32.5%
	More Significant	Count	10	11	1	8	7	5	42
		% within Lead time determined by customers	23.8%	26.2%	2.4%	19.0%	16.7%	11.9%	100.0%
		% within Sector	41.7%	42.3%	8.3%	36.4%	33.3%	33.3%	35.0%
	Highly Significant	Count	2	4	2	4	6	6	24
		% within Lead time determined by customers	8.3%	16.7%	8.3%	16.7%	25.0%	25.0%	100.0%
		% within Sector	8.3%	15.4%	16.7%	18.2%	28.6%	40.0%	20.0%
Total		Count	24	26	12	22	21	15	120
		% within Lead time determined by customers	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0 %	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.554[a]	20	.551
Likelihood Ratio	20.540	20	.425
Linear-by-Linear Association	3.760	1	.053
N of Valid Cases	120		

a - 20 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

Short Product Life Cycle * Sector Crosstabulation

			Sector						Total
			Process	Eng. Consumer goods	Eng. Capital kits	Electronics	Household	Food	
Short Product Life Cycle	Insignificant	Count	17	14	7	6	9	8	61
		% within Short Product Life Cycle	27.9%	23.0%	11.5%	9.8%	14.8%	13.1%	100.0%
		% within Sector	70.8%	53.8%	58.3%	27.3%	42.9%	53.3%	50.8%
	Less Significant	Count	5	5	3	11	6	2	32
		% within Short Product Life Cycle	15.6%	15.6%	9.4%	34.4%	18.8%	6.3%	100.0%
		% within Sector	20.8%	19.2%	25.0%	50.0%	28.6%	13.3%	26.7%
	Significant	Count	1	4	2	2	4	2	15
		% within Short Product Life Cycle	6.7%	26.7%	13.3%	13.3%	26.7%	13.3%	100.0%
		% within Sector	4.2%	15.4%	16.7%	9.1%	19.0%	13.3%	12.5%
	More Significant	Count	1	2		3	2	1	9
		% within Short Product Life Cycle	11.1%	22.2%		33.3%	22.2%	11.1%	100.0%
		% within Sector	4.2%	7.7%		13.6%	9.5%	6.7%	7.5%
	Highly Significant	Count		1				2	3
		% within Short Product Life Cycle		33.3%				66.7%	100.0%
		% within Sector		3.8%				13.3%	2.5%
Total		Count	24	26	12	22	21	15	120
		% within Short Product Life Cycle	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	25.431[a]	20	.185
Likelihood Ratio	24.562	20	.219
Linear-by-Linear Association	4.865	1	.027
N of Valid Cases	120		

a - 20 cells (66.7%) have expected count less than 5. The minimum expected count is .30.

High Unpredictability of demand levels * Sector Crosstabulation

			Sector						Total
			Process	Eng. Consumer goods	Eng. Capital kits	Electronics	Household	Food	
High Unpredictability of demand levels	Insignificant	Count		1			2		3
		% within High Unpredictability of demand levels		33.3%			66.7%		100.0%
		% within Sector		3.8%			9.5%		2.5%
	Less Significant	Count	6		2	1	1	4	14
		% within High Unpredictability of demand levels	42.9%		14.3%	7.1%	7.1%	28.6%	100.0%
		% within Sector	25.0%		16.7%	4.5%	4.8%	26.7%	11.7%
	Significant	Count	5	4	3	3	5	3	23
		% within High Unpredictability of demand levels	21.7%	17.4%	13.0%	13.0%	21.7%	13.0%	100.0%
		% within Sector	20.8%	15.4%	25.0%	13.6%	23.8%	20.0%	19.2%
	More Significant	Count	11	15	6	12	9	5	58
		% within High Unpredictability of demand levels	19.0%	25.9%	10.3%	20.7%	15.5%	8.6%	100.0%
		% within Sector	45.8%	57.7%	50.0%	54.5%	42.9%	33.3%	48.3%
	Highly significant	Count	2	6	1	6	4	3	22
		% within High Unpredictability of demand levels	9.1%	27.3%	4.5%	27.3%	18.2%	13.6%	100.0%
		% within Sector	8.3%	23.1%	8.3%	27.3%	19.0%	20.0%	18.3%
Total		Count	24	26	12	22	21	15	120
		% within High Unpredictability of demand levels	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.631[a]	20	.259
Likelihood Ratio	25.966	20	.167
Linear-by-Linear Association	.082	1	.774
N of Valid Cases	120		

a - 24 cells (80.0%) have expected count less than 5. The minimum expected count is .30.

APPENDIX 5

The results of the analysis of Research Question One (i.e. Drivers of volume flexibility) based on a collapsed scale are presented in this appendix. These are:

1. The percentage of responding plants rating the drivers on a 3-point significance rating scale across sectors.
2. Chi-square tests to determine whether differences in ratings are sector dependent.

An example of the SPSS Syntax programme used to collapse the scales is given below:

```
IF (demvar = 1) demva = 1 .
EXECUTE .

IF (demvar = 2 or demvar = 3) demva = 2 .
EXECUTE .

IF (demvar = 4 or demvar = 5) demva = 3 .
EXECUTE .
```

Demvar represents variable of demand variability on an uncollapsed scale
Demva represents new variable of demand variability on the collapsed scale.

An example of the SPSS Syntax programme used to compute the analysis is given below:

```
CROSSTABS
 /TABLES=demva  BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT ROW COLUMN .
```

High demand level variability (DEMVA) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
DEMVA	1.00	Count	1						1
		% within DEMVA	100.0%						100.0%
		% within Sector	4.2%						.8%
	2.00	Count	2	3	5	6	2	2	20
		% within DEMVA	10.0%	15.0%	25.0%	30.0%	10.0%	10.0%	100.0%
		% within Sector	8.3%	11.5%	41.7%	27.3%	9.5%	13.3%	16.7%
	3.00	Count	21	23	7	16	19	13	99
		% within DEMVA	21.2%	23.2%	7.1%	16.2%	19.2%	13.1%	100.0%
		% within Sector	87.5%	88.5%	58.3%	72.7%	90.5%	86.7%	82.5%
Total		Count	24	26	12	22	21	15	120
		% within DEMVA	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.620[a]	10	.191
Likelihood Ratio	11.763	10	.301
Linear-by-Linear Association	.292	1	.589
N of Valid Cases	120		

a - 4 cells (22.2%) have expected count less than 5. The minimum expected count is 1.10.

Short product shelf life (SHELIF) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
SHELIF	1.00	Count	15	18	11	14	14	3	75
		% within SHELIF	20.0%	24.0%	14.7%	18.7%	18.7%	4.0%	100.0%
		% within Sector	62.5%	69.2%	91.7%	63.6%	66.7%	20.0%	62.5%
	2.00	Count	8	6	1	6	5	6	32
		% within SHELIF	25.0%	18.8%	3.1%	18.8%	15.6%	18.8%	100.0%
		% within Sector	33.3%	23.1%	8.3%	27.3%	23.8%	40.0%	26.7%
	3.00	Count	1	2		2	2	6	13
		% within SHELIF	7.7%	15.4%		15.4%	15.4%	46.2%	100.0%
		% within Sector	4.2%	7.7%		9.1%	9.5%	40.0%	10.8%
Total		Count	24	26	12	22	21	15	120
		% within SHELIF	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.720[a]	10	.008
Likelihood Ratio	22.271	10	.014
Linear-by-Linear Association	5.908	1	.015
N of Valid Cases	120		

a - 3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.30.

Customer influence in lead time determination (LEADTIM) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
LEADTIM	1.00	Count	2	1		2		1	6
		% within LEADTIM	33.3%	16.7%		33.3%		16.7%	100.0%
		% within Sector	8.3%	3.8%		9.1%		6.7%	5.0%
	2.00	Count	10	10	9	8	8	3	48
		% within LEADTIM	20.8%	20.8%	18.8%	16.7%	16.7%	6.3%	100.0%
		% within Sector	41.7%	38.5%	75.0%	36.4%	38.1%	20.0%	40.0%
	3.00	Count	12	15	3	12	13	11	66
		% within LEADTIM	18.2%	22.7%	4.5%	18.2%	19.7%	16.7%	100.0%
		% within Sector	50.0%	57.7%	25.0%	54.5%	61.9%	73.3%	55.0%
Total		Count	24	26	12	22	21	15	120
		% within LEADTIM	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.578[a]	10	.314
Likelihood Ratio	12.988	10	.224
Linear-by-Linear Association	2.263	1	.133
N of Valid Cases	120		

a - 2 cells (11.1%) have expected count less than 5. The minimum expected count is 1.60.

Short Product life cycle (LIFCYCL) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
LIFCYCL	1.00	Count	17	14	7	6	9	8	61
		% within LIFCYCL	27.9%	23.0%	11.5%	9.8%	14.8%	13.1%	100.0%
		% within Sector	70.8%	53.8%	58.3%	27.3%	42.9%	53.3%	50.8%
	2.00	Count	6	9	5	13	10	4	47
		% within LIFCYCL	12.8%	19.1%	10.6%	27.7%	21.3%	8.5%	100.0%
		% within Sector	25.0%	34.6%	41.7%	59.1%	47.6%	26.7%	39.2%
	3.00	Count	1	3		3	2	3	12
		% within LIFCYCL	8.3%	25.0%		25.0%	16.7%	25.0%	100.0%
		% within Sector	4.2%	11.5%		13.6%	9.5%	20.0%	10.0%
Total		Count	24	26	12	22	21	15	120
		% within LIFCYCL	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.223[a]	10	.211
Likelihood Ratio	14.509	10	.151
Linear-by-Linear Association	4.343	1	.037
N of Valid Cases	120		

a - 3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.20.

Demand unpredictability (DEMUNPR) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
DEMUNPR	1.00	Count		1			2		3
		% within DEMUNPR		33.3%			66.7%		100.0%
		% within Sector		3.8%			9.5%		2.5%
	2.00	Count	11	4	5	4	6	7	37
		% within DEMUNPR	29.7%	10.8%	13.5%	10.8%	16.2%	18.9%	100.0%
		% within Sector	45.8%	15.4%	41.7%	18.2%	28.6%	46.7%	30.8%
	3.00	Count	13	21	7	18	13	8	80
		% within DEMUNPR	16.3%	26.3%	8.8%	22.5%	16.3%	10.0%	100.0%
		% within Sector	54.2%	80.8%	58.3%	81.8%	61.9%	53.3%	66.7%
Total		Count	24	26	12	22	21	15	120
		% within DEMUNPR	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.467[a]	10	.116
Likelihood Ratio	15.711	10	.108
Linear-by-Linear Association	.118	1	.731
N of Valid Cases	120		

a - 4 cells (22.2%) have expected count less than 5. The minimum expected count is 1.30.

APPENDIX 6

The results of the analysis of the first part of Research Question Two (i.e. Enablers of volume flexibility) based on a collapsed scale are presented in this appendix. These are:

1. The percentage of responding plants using the enablers based on a 3-point degree of usage rating scale across sectors.
2. Chi-square tests to determine whether differences in ratings are sector dependent.

An example of the SPSS Syntax programme used to execute the analysis is given below:

```
CROSSTABS
 /TABLES=overti0  BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT ROW COLUMN .
```

Overtio represents use of overtime hours by full time employees.

Overtime by full time employees (OVERTI0) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
OVERTI0	1.00	Count	3				2	1	6
		% within OVERTI0	50.0%				33.3%	16.7%	100.0%
		% within Sector	12.5%				9.5%	6.7%	5.0%
	2.00	Count	6	1	2	5	6	4	24
		% within OVERTI0	25.0%	4.2%	8.3%	20.8%	25.0%	16.7%	100.0%
		% within Sector	25.0%	3.8%	16.7%	22.7%	28.6%	26.7%	20.0%
	3.00	Count	15	25	10	17	13	10	90
		% within OVERTI0	16.7%	27.8%	11.1%	18.9%	14.4%	11.1%	100.0%
		% within Sector	62.5%	96.2%	83.3%	77.3%	61.9%	66.7%	75.0%
Total		Count	24	26	12	22	21	15	120
		% within OVERTI0	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.385[a]	10	.156
Likelihood Ratio	17.892	10	.057
Linear-by-Linear Association	.272	1	.602
N of Valid Cases	120		

a - 4 cells (22.2%) have expected count less than 5. The minimum expected count is 1.80.

Increased hours worked by part-time employees (PARTIMO) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
PARTIMO	1.00	Count	21	19	9	16	11	11	87
		% within PARTIMO	24.1%	21.8%	10.3%	18.4%	12.6%	12.6%	100.0%
		% within Sector	87.5%	73.1%	75.0%	72.7%	52.4%	73.3%	72.5%
	2.00	Count	2	4	1	2	5	2	16
		% within PARTIMO	12.5%	25.0%	6.3%	12.5%	31.3%	12.5%	100.0%
		% within Sector	8.3%	15.4%	8.3%	9.1%	23.8%	13.3%	13.3%
	3.00	Count	1	3	2	4	5	2	17
		% within PARTIMO	5.9%	17.6%	11.8%	23.5%	29.4%	11.8%	100.0%
		% within Sector	4.2%	11.5%	16.7%	18.2%	23.8%	13.3%	14.2%
Total		Count	24	26	12	22	21	15	120
		% within PARTIMO	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.223[a]	10	.607
Likelihood Ratio	8.518	10	.578
Linear-by-Linear Association	4.439	1	.035
N of Valid Cases	120		

a - 3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.60.

Temporary labour (TEMPO) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
TEMPO	1.00	Count	6	6	4	6	9	6	37
		% within TEMPO	16.2%	16.2%	10.8%	16.2%	24.3%	16.2%	100.0%
		% within Sector	25.0%	23.1%	33.3%	27.3%	42.9%	40.0%	30.8%
	2.00	Count	9	7	2	5	5	2	30
		% within TEMPO	30.0%	23.3%	6.7%	16.7%	16.7%	6.7%	100.0%
		% within Sector	37.5%	26.9%	16.7%	22.7%	23.8%	13.3%	25.0%
	3.00	Count	9	13	6	11	7	7	53
		% within TEMPO	17.0%	24.5%	11.3%	20.8%	13.2%	13.2%	100.0%
		% within Sector	37.5%	50.0%	50.0%	50.0%	33.3%	46.7%	44.2%
Total		Count	24	26	12	22	21	15	120
		% within TEMPO	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.309[a]	10	.789
Likelihood Ratio	6.295	10	.790
Linear-by-Linear Association	.784	1	.376
N of Valid Cases	120		

a - 4 cells (22.2%) have expected count less than 5. The minimum expected count is 3.00.

Job sharing contracts (JOBSHA0) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
JOBSHA0	1.00	Count	23	25	10	20	21	15	114
		% within JOBSHA0	20.2%	21.9%	8.8%	17.5%	18.4%	13.2%	100.0%
		% within Sector	95.8%	96.2%	83.3%	90.9%	100.0%	100.0%	95.0%
	2.00	Count	1	1	2	1			5
		% within JOBSHA0	20.0%	20.0%	40.0%	20.0%			100.0%
		% within Sector	4.2%	3.8%	16.7%	4.5%			4.2%
	3.00	Count				1			1
		% within JOBSHA0				100.0%			100.0%
		% within Sector				4.5%			.8%
Total		Count	24	26	12	22	21	15	120
		% within JOBSHA0	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.779[a]	10	.375
Likelihood Ratio	9.269	10	.507
Linear-by-Linear Association	.412	1	.521
N of Valid Cases	120		

a - 3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.10.

Annualised Hours Contracts (ANUALHO) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
ANUALHO	1.00	Count	19	25	11	18	19	13	105
		% within ANUALHO	18.1%	23.8%	10.5%	17.1%	18.1%	12.4%	100.0%
		% within Sector	79.2%	96.2%	91.7%	81.8%	90.5%	86.7%	87.5%
	2.00	Count	1	1		2			4
		% within ANUALHO	25.0%	25.0%		50.0%			100.0%
		% within Sector	4.2%	3.8%		9.1%			3.3%
	3.00	Count	4		1	2	2	2	11
		% within ANUALHO	36.4%		9.1%	18.2%	18.2%	18.2%	100.0%
		% within Sector	16.7%		8.3%	9.1%	9.5%	13.3%	9.2%
Total		Count	24	26	12	22	21	15	120
		% within ANUALHO	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.551[a]	10	.575
Likelihood Ratio	11.497	10	.320
Linear-by-Linear Association	.125	1	.724
N of Valid Cases	120		

a - 4 cells (22.2%) have expected count less than 5. The minimum expected count is 2.40.

Subcontracting (SUBCON0) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
SUBCON0	1.00	Count	15	7	3	5	15	12	57
		% within SUBCON0	26.3%	12.3%	5.3%	8.8%	26.3%	21.1%	100.0%
		% within Sector	62.5%	26.9%	25.0%	22.7%	71.4%	80.0%	47.5%
	2.00	Count	7	13	6	12	6	2	46
		% within SUBCON0	15.2%	28.3%	13.0%	26.1%	13.0%	4.3%	100.0%
		% within Sector	29.2%	50.0%	50.0%	54.5%	28.6%	13.3%	38.3%
	3.00	Count	2	6	3	5		1	17
		% within SUBCON0	11.8%	35.3%	17.6%	29.4%		5.9%	100.0%
		% within Sector	8.3%	23.1%	25.0%	22.7%		6.7%	14.2%
Total		Count	24	26	12	22	21	15	120
		% within SUBCON0	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.530	10	.002
Likelihood Ratio	31.157	10	.001
Linear-by-Linear Association	3.208	1	.073
N of Valid Cases	120		

a - 2 cells (11.1%) have expected count less than 5. The minimum expected count is 1.70.

Contract Employees (CONTRA0) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
CONTRA0	1.00	Count	17	18	7	15	16	13	86
		% within CONTRA0	19.8%	20.9%	8.1%	17.4%	18.6%	15.1%	100.0%
		% within Sector	70.8%	69.2%	58.3%	68.2%	76.2%	86.7%	71.7%
	2.00	Count	3	3	2	3	5	1	17
		% within CONTRA0	17.6%	17.6%	11.8%	17.6%	29.4%	5.9%	100.0%
		% within Sector	12.5%	11.5%	16.7%	13.6%	23.8%	6.7%	14.2%
	3.00	Count	4	5	3	4		1	17
		% within CONTRA0	23.5%	29.4%	17.6%	23.5%		5.9%	100.0%
		% within Sector	16.7%	19.2%	25.0%	18.2%		6.7%	14.2%
Total		Count	24	26	12	22	21	15	120
		% within CONTRA0	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.486[a]	10	.581
Likelihood Ratio	11.256	10	.338
Linear-by-Linear Association	2.338	1	.126
N of Valid Cases	120		

a - 3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.70.

Varying lead times (LEADTI0) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
LEADTI0	1.00	Count	8	8	3	4	7	9	39
		% within LEADTI0	20.5%	20.5%	7.7%	10.3%	17.9%	23.1%	100.0%
		% within Sector	33.3%	30.8%	25.0%	18.2%	33.3%	60.0%	32.5%
	2.00	Count	12	8	3	11	10	4	48
		% within LEADTI0	25.0%	16.7%	6.3%	22.9%	20.8%	8.3%	100.0%
		% within Sector	50.0%	30.8%	25.0%	50.0%	47.6%	26.7%	40.0%
	3.00	Count	4	10	6	7	4	2	33
		% within LEADTI0	12.1%	30.3%	18.2%	21.2%	12.1%	6.1%	100.0%
		% within Sector	16.7%	38.5%	50.0%	31.8%	19.0%	13.3%	27.5%
Total		Count	24	26	12	22	21	15	120
		% within LEADTI0	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.628[a]	10	.146
Likelihood Ratio	14.275	10	.161
Linear-by-Linear Association	1.025	1	.311
N of Valid Cases	120		

a - 5 cells (27.8%) have expected count less than 5. The minimum expected count is 3.30.

Rejecting orders (REJECO) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
REJECO	1.00	Count	21	21	8	17	17	13	97
		% within REJECO	21.6%	21.6%	8.2%	17.5%	17.5%	13.4%	100.0%
		% within Sector	87.5%	80.8%	66.7%	77.3%	81.0%	86.7%	80.8%
	2.00	Count	2	5	4	5	2	1	19
		% within REJECO	10.5%	26.3%	21.1%	26.3%	10.5%	5.3%	100.0%
		% within Sector	8.3%	19.2%	33.3%	22.7%	9.5%	6.7%	15.8%
	3.00	Count	1				2	1	4
		% within REJECO	25.0%				50.0%	25.0%	100.0%
		% within Sector	4.2%				9.5%	6.7%	3.3%
Total		Count	24	26	12	22	21	15	120
		% within REJECO	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.840[a]	10	.370
Likelihood Ratio	11.757	10	.302
Linear-by-Linear Association	.314	1	.575
N of Valid Cases	120		

a - 4 cells (22.2%) have expected count less than 5. The minimum expected count is 1.40.

APPENDIX 7

The results of the analysis of respondents' perception of costs of using enablers based on a collapsed 3-point scale are presented in this appendix. These are:

1. The percentage of responding plants in different sectors rating the enablers based on their perception of the relative costs of using the enablers.
2. Chi-square tests to determine whether differences in ratings are sector dependent.

An example of the SPSS Syntax programme used to execute the analysis is given below:

```
CROSSTABS
 /TABLES=overti1  BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT ROW COLUMN .
```

Overti1 represents the perception of relative costs of using overtime hours to achieve volume flexibility.

Overtime Hours by full time employees (OVERTI1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
OVERTI1	1.00	Count				2		1	3
		% within OVERTI1				66.7%		33.3%	100.0%
		% within Sector				9.1%		6.7%	2.5%
	2.00	Count	8	13	3	8	10	7	49
		% within OVERTI1	16.3%	26.5%	6.1%	16.3%	20.4%	14.3%	100.0%
		% within Sector	33.3%	50.0%	25.0%	36.4%	47.6%	46.7%	40.8%
	3.00	Count	16	13	9	12	11	7	68
		% within OVERTI1	23.5%	19.1%	13.2%	17.6%	16.2%	10.3%	100.0%
		% within Sector	66.7%	50.0%	75.0%	54.5%	52.4%	46.7%	56.7%
Total		Count	24	26	12	22	21	15	120
		% within OVERTI1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.701	10	.381
Likelihood Ratio	10.918	10	.364
Linear-by-Linear Association	2.093	1	.148
N of Valid Cases	120		

5 cells (27.8%) have expected count less than 5. The minimum expected count is 1.30.

Increased hours worked by part-time employees (PARTIM1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
PARTIM1	1.00	Count	4	5	4	6	4	4	27
		% within PARTIM1	14.8%	18.5%	14.8%	22.2%	14.8%	14.8%	100.0%
		% within Sector	16.7%	19.2%	33.3%	27.3%	19.0%	26.7%	22.5%
	2.00	Count	14	16	6	12	17	7	72
		% within PARTIM1	19.4%	22.2%	8.3%	16.7%	23.6%	9.7%	100.0%
		% within Sector	58.3%	61.5%	50.0%	54.5%	81.0%	46.7%	60.0%
	3.00	Count	6	5	2	4		4	21
		% within PARTIM1	28.6%	23.8%	9.5%	19.0%		19.0%	100.0%
		% within Sector	25.0%	19.2%	16.7%	18.2%		26.7%	17.5%
Total		Count	24	26	12	22	21	15	120
		% within PARTIM1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.095	10	.523
Likelihood Ratio	12.423	10	.258
Linear-by-Linear Association	1.218	1	.270
N of Valid Cases	120		

6 cells (33.3%) have expected count less than 5. The minimum expected count is 2.10.

Temporary labour (TEMP1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
TEMP1	1.00	Count	3	3	3	1	3	3	16
		% within TEMP1	18.8%	18.8%	18.8%	6.3%	18.8%	18.8%	100.0%
		% within Sector	12.5%	11.5%	25.0%	4.5%	14.3%	20.0%	13.3%
	2.00	Count	15	14	6	12	14	10	71
		% within TEMP1	21.1%	19.7%	8.5%	16.9%	19.7%	14.1%	100.0%
		% within Sector	62.5%	53.8%	50.0%	54.5%	66.7%	66.7%	59.2%
	3.00	Count	6	9	3	9	4	2	33
		% within TEMP1	18.2%	27.3%	9.1%	27.3%	12.1%	6.1%	100.0%
		% within Sector	25.0%	34.6%	25.0%	40.9%	19.0%	13.3%	27.5%
Total		Count	24	26	12	22	21	15	120
		% within TEMP1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.490	10	.679
Likelihood Ratio	7.716	10	.657
Linear-by-Linear Association	.551	1	.458
N of Valid Cases	120		

5 cells (27.8%) have expected count less than 5. The minimum expected count is 1.60.

Job sharing (JOBSHA1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
JOBSHA1	1.00	Count	5	8	5	3	3	4	28
		% within JOBSHA1	17.9%	28.6%	17.9%	10.7%	10.7%	14.3%	100.0%
		% within Sector	20.8%	30.8%	41.7%	13.6%	14.3%	26.7%	23.3%
	2.00	Count	11	14	5	18	17	10	75
		% within JOBSHA1	14.7%	18.7%	6.7%	24.0%	22.7%	13.3%	100.0%
		% within Sector	45.8%	53.8%	41.7%	81.8%	81.0%	66.7%	62.5%
	3.00	Count	8	4	2	1	1	1	17
		% within JOBSHA1	47.1%	23.5%	11.8%	5.9%	5.9%	5.9%	100.0%
		% within Sector	33.3%	15.4%	16.7%	4.5%	4.8%	6.7%	14.2%
Total		Count	24	26	12	22	21	15	120
		% within JOBSHA1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.463	10	.048
Likelihood Ratio	17.763	10	.059
Linear-by-Linear Association	1.527	1	.217
N of Valid Cases	120		

3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.70.

Annualised Hours Contracts (ANUALH1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
ANUALH1	1.00	Count	9	12	6	7	12	8	54
		% within ANUALH1	16.7%	22.2%	11.1%	13.0%	22.2%	14.8%	100.0%
		% within Sector	37.5%	46.2%	50.0%	31.8%	57.1%	53.3%	45.0%
	2.00	Count	14	11	5	12	7	5	54
		% within ANUALH1	25.9%	20.4%	9.3%	22.2%	13.0%	9.3%	100.0%
		% within Sector	58.3%	42.3%	41.7%	54.5%	33.3%	33.3%	45.0%
	3.00	Count	1	3	1	3	2	2	12
		% within ANUALH1	8.3%	25.0%	8.3%	25.0%	16.7%	16.7%	100.0%
		% within Sector	4.2%	11.5%	8.3%	13.6%	9.5%	13.3%	10.0%
Total		Count	24	26	12	22	21	15	120
		% within ANUALH1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.071	10	.809
Likelihood Ratio	6.303	10	.789
Linear-by-Linear Association	.242	1	.623
N of Valid Cases	120		

6 cells (33.3%) have expected count less than 5. The minimum expected count is 1.20.

Subcontracting (SUBCON1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
SUBCON1	1.00	Count		4	3	1	3	2	13
		% within SUBCON1		30.8%	23.1%	7.7%	23.1%	15.4%	100.0%
		% within Sector		15.4%	25.0%	4.5%	14.3%	13.3%	10.8%
	2.00	Count	7	13	5	9	8	2	44
		% within SUBCON1	15.9%	29.5%	11.4%	20.5%	18.2%	4.5%	100.0%
		% within Sector	29.2%	50.0%	41.7%	40.9%	38.1%	13.3%	36.7%
	3.00	Count	17	9	4	12	10	11	63
		% within SUBCON1	27.0%	14.3%	6.3%	19.0%	15.9%	17.5%	100.0%
		% within Sector	70.8%	34.6%	33.3%	54.5%	47.6%	73.3%	52.5%
Total		Count	24	26	12	22	21	15	120
		% within SUBCON1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.811	10	.105
Likelihood Ratio	18.622	10	.045
Linear-by-Linear Association	.237	1	.626
N of Valid Cases	120		

3 cells (16.7%) have expected count less than 5. The minimum expected count is 1.30.

Contract employees (CONTRA1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
CONTRA1	1.00	Count		5	2	1	2	2	12
		% within CONTRA1		41.7%	16.7%	8.3%	16.7%	16.7%	100.0%
		% within Sector		19.2%	16.7%	4.5%	9.5%	13.3%	10.0%
	2.00	Count	7	7	4	11	13	5	47
		% within CONTRA1	14.9%	14.9%	8.5%	23.4%	27.7%	10.6%	100.0%
		% within Sector	29.2%	26.9%	33.3%	50.0%	61.9%	33.3%	39.2%
	3.00	Count	17	14	6	10	6	8	61
		% within CONTRA1	27.9%	23.0%	9.8%	16.4%	9.8%	13.1%	100.0%
		% within Sector	70.8%	53.8%	50.0%	45.5%	28.6%	53.3%	50.8%
Total		Count	24	26	12	22	21	15	120
		% within CONTRA1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.376	10	.119
Likelihood Ratio	17.270	10	.069
Linear-by-Linear Association	4.294	1	.038
N of Valid Cases	120		

7 cells (38.9%) have expected count less than 5. The minimum expected count is 1.20.

Varying lead times (LEADTI1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
LEADTI1	1.00	Count	2	5	2	4	2	3	18
		% within LEADTI1	11.1%	27.8%	11.1%	22.2%	11.1%	16.7%	100.0%
		% within Sector	8.3%	19.2%	16.7%	18.2%	9.5%	20.0%	15.0%
	2.00	Count	15	13	6	10	14	7	65
		% within LEADTI1	23.1%	20.0%	9.2%	15.4%	21.5%	10.8%	100.0%
		% within Sector	62.5%	50.0%	50.0%	45.5%	66.7%	46.7%	54.2%
	3.00	Count	7	8	4	8	5	5	37
		% within LEADTI1	18.9%	21.6%	10.8%	21.6%	13.5%	13.5%	100.0%
		% within Sector	29.2%	30.8%	33.3%	36.4%	23.8%	33.3%	30.8%
Total		Count	24	26	12	22	21	15	120
		% within LEADTI1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.992	10	.948
Likelihood Ratio	4.121	10	.942
Linear-by-Linear Association	.075	1	.784
N of Valid Cases	120		

4 cells (22.2%) have expected count less than 5. The minimum expected count is 1.80.

Rejecting orders (REJEC1) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
REJEC1	1.00	Count		4	1	3	1		9
		% within REJEC1		44.4%	11.1%	33.3%	11.1%		100.0%
		% within Sector		15.4%	8.3%	13.6%	4.8%		7.5%
	2.00	Count	1			1	1	1	4
		% within REJEC1	25.0%			25.0%	25.0%	25.0%	100.0%
		% within Sector	4.2%			4.5%	4.8%	6.7%	3.3%
	3.00	Count	23	22	11	18	19	14	107
		% within REJEC1	21.5%	20.6%	10.3%	16.8%	17.8%	13.1%	100.0%
		% within Sector	95.8%	84.6%	91.7%	81.8%	90.5%	93.3%	89.2%
Total		Count	24	26	12	22	21	15	120
		% within REJEC1	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.803	10	.551
Likelihood Ratio	12.160	10	.275
Linear-by-Linear Association	.022	1	.883
N of Valid Cases	120		

5 cells (27.7%) have expected count less than 5. The minimum expected count is 1.40.

APPENDIX 8

The results of the analysis of future desirability of enablers of volume flexibility based on a collapsed 3-point scale are presented in this appendix. These are:

1. The percentage of responding plants in different sectors rating the enablers in terms of the extent of future desirability of the enablers.
2. Chi-square tests to determine whether differences in ratings are sector dependent.

An example of the SPSS Syntax programme used to execute the analysis is given below:

```
CROSSTABS
 /TABLES=overti3  BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT ROW COLUMN .
```

Overti3 represents the future desirability of the use of overtime hours to achieve volume flexibility.

Overtime hours by full time employees (OVERTI3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
OVERTI3	1.00	Count	3	2	1	1	1	5	13
		% within OVERTI3	23.1%	15.4%	7.7%	7.7%	7.7%	38.5%	100.0%
		% within Sector	12.5%	7.7%	8.3%	4.5%	4.8%	33.3%	10.8%
	2.00	Count	15	9	5	13	10	7	59
		% within OVERTI3	25.4%	15.3%	8.5%	22.0%	16.9%	11.9%	100.0%
		% within Sector	62.5%	34.6%	41.7%	59.1%	47.6%	46.7%	49.2%
	3.00	Count	6	15	6	8	10	3	48
		% within OVERTI3	12.5%	31.3%	12.5%	16.7%	20.8%	6.3%	100.0%
		% within Sector	25.0%	57.7%	50.0%	36.4%	47.6%	20.0%	40.0%
Total		Count	24	26	12	22	21	15	120
		% within OVERTI3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.052	10	.073
Likelihood Ratio	15.288	10	.122
Linear-by-Linear Association	.097	1	.755
N of Valid Cases	120		

7 cells (38.9%) have expected count less than 5. The minimum expected count is 1.30.

Increased hours worked by part-time employees (PARTIM3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
PARTIM3	1.00	Count	16	15	8	9	8	9	65
		% within PARTIM3	24.6%	23.1%	12.3%	13.8%	12.3%	13.8%	100.0%
		% within Sector	66.7%	57.7%	66.7%	40.9%	38.1%	60.0%	54.2%
	2.00	Count	6	4	4	7	5	3	29
		% within PARTIM3	20.7%	13.8%	13.8%	24.1%	17.2%	10.3%	100.0%
		% within Sector	25.0%	15.4%	33.3%	31.8%	23.8%	20.0%	24.2%
	3.00	Count	2	7		6	8	3	26
		% within PARTIM3	7.7%	26.9%		23.1%	30.8%	11.5%	100.0%
		% within Sector	8.3%	26.9%		27.3%	38.1%	20.0%	21.7%
Total		Count	24	26	12	22	21	15	120
		% within PARTIM3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.658	10	.243
Likelihood Ratio	15.477	10	.116
Linear-by-Linear Association	4.404	1	.036
N of Valid Cases	120		
N of Valid Cases	120		

4 cells (22.2%) have expected count less than 5. The minimum expected count is 2.60.

Temporary labour (TEMP3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
TEMP3	1.00	Count	7	8	5	6	8	3	37
		% within TEMP3	18.9%	21.6%	13.5%	16.2%	21.6%	8.1%	100.0%
		% within Sector	29.2%	30.8%	41.7%	27.3%	38.1%	20.0%	30.8%
	2.00	Count	11	6	2	7	5	7	38
		% within TEMP3	28.9%	15.8%	5.3%	18.4%	13.2%	18.4%	100.0%
		% within Sector	45.8%	23.1%	16.7%	31.8%	23.8%	46.7%	31.7%
	3.00	Count	6	12	5	9	8	5	45
		% within TEMP3	13.3%	26.7%	11.1%	20.0%	17.8%	11.1%	100.0%
		% within Sector	25.0%	46.2%	41.7%	40.9%	38.1%	33.3%	37.5%
Total		Count	24	26	12	22	21	15	120
		% within TEMP3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.668	10	.661
Likelihood Ratio	7.739	10	.654
Linear-by-Linear Association	.110	1	.740
N of Valid Cases	120		

5 cells (27.8%) have expected count less than 5. The minimum expected count is 3.70.

Job sharing (JOBSHA3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
JOBSHA3	1.00	Count	13	16	7	15	10	8	69
		% within JOBSHA3	18.8%	23.2%	10.1%	21.7%	14.5%	11.6%	100.0%
		% within Sector	54.2%	61.5%	58.3%	68.2%	47.6%	53.3%	57.5%
	2.00	Count	8	7	4	5	11	3	38
		% within JOBSHA3	21.1%	18.4%	10.5%	13.2%	28.9%	7.9%	100.0%
		% within Sector	33.3%	26.9%	33.3%	22.7%	52.4%	20.0%	31.7%
	3.00	Count	3	3	1	2		4	13
		% within JOBSHA3	23.1%	23.1%	7.7%	15.4%		30.8%	100.0%
		% within Sector	12.5%	11.5%	8.3%	9.1%		26.7%	10.8%
Total		Count	24	26	12	22	21	15	120
		% within JOBSHA3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.172	10	.344
Likelihood Ratio	12.132	10	.276
Linear-by-Linear Association	.058	1	.809
N of Valid Cases	120		

5 cells (27.7%) have expected count less than 5. The minimum expected count is 1.30.

Annualised hours contracts (ANUALH3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
ANUALH3	1.00	Count	4	7	3	7	7	4	32
		% within ANUALH3	12.5%	21.9%	9.4%	21.9%	21.9%	12.5%	100.0%
		% within Sector	16.7%	26.9%	25.0%	31.8%	33.3%	26.7%	26.7%
	2.00	Count	10	9	8	9	5	4	45
		% within ANUALH3	22.2%	20.0%	17.8%	20.0%	11.1%	8.9%	100.0%
		% within Sector	41.7%	34.6%	66.7%	40.9%	23.8%	26.7%	37.5%
	3.00	Count	10	10	1	6	9	7	43
		% within ANUALH3	23.3%	23.3%	2.3%	14.0%	20.9%	16.3%	100.0%
		% within Sector	41.7%	38.5%	8.3%	27.3%	42.9%	46.7%	35.8%
Total		Count	24	26	12	22	21	15	120
		% within ANUALH3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.001	10	.440
Likelihood Ratio	10.911	10	.365
Linear-by-Linear Association	.135	1	.714
N of Valid Cases	120		

4 cells (22.2%) have expected count less than 5. The minimum expected count is 3.20.

Subcontracting (SUBCON3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
SUBCON3	1.00	Count	12	4	2	9	11	9	47
		% within SUBCON3	25.5%	8.5%	4.3%	19.1%	23.4%	19.1%	100.0%
		% within Sector	50.0%	15.4%	16.7%	40.9%	52.4%	60.0%	39.2%
	2.00	Count	10	16	4	8	7	5	50
		% within SUBCON3	20.0%	32.0%	8.0%	16.0%	14.0%	10.0%	100.0%
		% within Sector	41.7%	61.5%	33.3%	36.4%	33.3%	33.3%	41.7%
	3.00	Count	2	6	6	5	3	1	23
		% within SUBCON3	8.7%	26.1%	26.1%	21.7%	13.0%	4.3%	100.0%
		% within Sector	8.3%	23.1%	50.0%	22.7%	14.3%	6.7%	19.2%
Total		Count	24	26	12	22	21	15	120
		% within SUBCON3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.311	10	.019
Likelihood Ratio	21.215	10	.020
Linear-by-Linear Association	1.491	1	.222
N of Valid Cases	120		

3 cells (16.7%) have expected count less than 5. The minimum expected count is 2.30.

Contract employees (CONTRA3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
CONTRA3	1.00	Count	15	8	6	8	10	11	58
		% within CONTRA3	25.9%	13.8%	10.3%	13.8%	17.2%	19.0%	100.0%
		% within Sector	62.5%	30.8%	50.0%	36.4%	47.6%	73.3%	48.3%
	2.00	Count	7	14	4	10	8	2	45
		% within CONTRA3	15.6%	31.1%	8.9%	22.2%	17.8%	4.4%	100.0%
		% within Sector	29.2%	53.8%	33.3%	45.5%	38.1%	13.3%	37.5%
	3.00	Count	2	4	2	4	3	2	17
		% within CONTRA3	11.8%	23.5%	11.8%	23.5%	17.6%	11.8%	100.0%
		% within Sector	8.3%	15.4%	16.7%	18.2%	14.3%	13.3%	14.2%
Total		Count	24	26	12	22	21	15	120
		% within CONTRA3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.233	10	.340
Likelihood Ratio	11.837	10	.296
Linear-by-Linear Association	.005	1	.941
N of Valid Cases	120		

5 cells (27.8%) have expected count less than 5. The minimum expected count is 1.70.

Varying lead times (LEADTI3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
LEADTI3	1.00	Count	9	9	4	10	7	10	49
		% within LEADTI3	18.4%	18.4%	8.2%	20.4%	14.3%	20.4%	100.0%
		% within Sector	37.5%	34.6%	33.3%	45.5%	33.3%	66.7%	40.8%
	2.00	Count	9	12	5	10	10	5	51
		% within LEADTI3	17.6%	23.5%	9.8%	19.6%	19.6%	9.8%	100.0%
		% within Sector	37.5%	46.2%	41.7%	45.5%	47.6%	33.3%	42.5%
	3.00	Count	6	5	3	2	4		20
		% within LEADTI3	30.0%	25.0%	15.0%	10.0%	20.0%		100.0%
		% within Sector	25.0%	19.2%	25.0%	9.1%	19.0%		16.7%
Total		Count	24	26	12	22	21	15	120
		% within LEADTI3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.960	10	.536
Likelihood Ratio	11.068	10	.352
Linear-by-Linear Association	2.562	1	.109
N of Valid Cases	120		

5 cells (27.8%) have expected count less than 5. The minimum expected count is 2.00.

Rejecting orders (REJEC3) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
REJEC3	1.00	Count	24	26	12	19	21	15	117
		% within REJEC3	20.5%	22.2%	10.3%	16.2%	17.9%	12.8%	100.0%
		% within Sector	100.0%	100.0%	100.0%	86.4%	100.0%	100.0%	97.5%
	2.00	Count				3			3
		% within REJEC3				100.0%			100.0%
		% within Sector				13.6%			2.5%
Total		Count	24	26	12	22	21	15	120
		% within REJEC3	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.706	5	.018
Likelihood Ratio	10.532	5	.061
Linear-by-Linear Association	.255	1	.613
N of Valid Cases	120		

APPENDIX 9

This appendix presents the results of the calculations used to classify the strength of the identified enablers of volume flexibility using an unweighted combination model.

The strength of each enabler is determined by a factor I_u, calculated from the following formula:

$$I_u = \frac{I_A + I_B + I_C}{3}$$

I_A = Factor for the proportion of plants that used the enabler extensively (i.e. I_A = % of plants using the enabler extensively/100)

I_B = Factor for the proportion of plants that perceive the use of the enabler not to be costly (i.e. I_B = % of plants that perceive the use of the enabler not to be costly/100)

I_C = Factor for the proportion of plants that desire the use of the enabler in future (i.e. I_C = % of plants that desire the use of the enabler in future/100)

Enablers	I_A	I_B	I_C	$I_u = \frac{I_A + I_B + I_C}{3}$
Overtime hours by full time employees	0.75	0.025	0.4	0.392
Increased hours worked by part time employees	0.142	0.225	0.217	0.195
Temporary labour	0.442	0.133	0.375	0.317
Job sharing	0.008	0.233	0.108	0.116
Annualised hours contracts	0.092	0.45	0.358	0.300
Subcontracting	0.142	0.108	0.192	0.147
Contract employees	0.142	0.10	0.142	0.128
Varying lead times	0.275	0.15	0.167	0.197
Rejecting orders	0.033	0.075	0.0	0.036

APPENDIX 10

This Appendix presents the results of statistical analysis undertaken to determine *substitute* and *complementary* enablers of volume flexibility. *Substitutes* are defined as those strategies, which can be replaced or can replace other strategies to achieve volume flexibility. *Complements* are those strategies which when used by a plant are likely to encourage the use of other specific strategies.

Substitute and complementary enablers are determined by correlating the strategies employed to achieve volume flexibility with each other. A significant negative correlation provides likely candidates for substitutes. A significant positive correlation provides candidates for complementary enablers. Only the results of significant correlation are presented in this appendix. Results of likely substitute and complements are shaded in the displayed SPSS output tables.

The SPSS Syntax programme used to run this analysis is given below:

```
CROSSTABS
 /TABLES=overti0  BY partim0 BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CORR
 /CELLS= COUNT ROW COLUMN .
```

Overti0 represents the use of overtime hours by full time employees
Partim0 represents increased hours worked by part time employees

Use of overtime hours vs. temporary labour. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	.038	.175	.177	.861
	Ordinal by Ordinal	Spearman Correlation	.097	.193	.457	.652
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	-.180	.091	-.897	.379
	Ordinal by Ordinal	Spearman Correlation	-.189	.095	-.941	.356
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	-.415	.150	-1.443	.180
	Ordinal by Ordinal	Spearman Correlation	-.424	.150	-1.482	.169
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	.273	.232	1.269	.219
	Ordinal by Ordinal	Spearman Correlation	.242	.236	1.115	.278
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	.335	.166	1.549	.138
	Ordinal by Ordinal	Spearman Correlation	.355	.182	1.653	.115
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	.517	.181	2.178	.048
	Ordinal by Ordinal	Spearman Correlation	.515	.212	2.165	.050
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.

The use of overtime hours vs. annualised hours contracts. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	-.743	.113	-5.206	.000
	Ordinal by Ordinal	Spearman Correlation	-.606	.174	-3.573	.002
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.040	.028	.196	.846
	Ordinal by Ordinal	Spearman Correlation	.040	.028	.196	.846
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	.135	.082	.430	.676
	Ordinal by Ordinal	Spearman Correlation	.135	.082	.430	.676
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	-.288	.243	-1.344	.194
	Ordinal by Ordinal	Spearman Correlation	-.305	.241	-1.434	.167
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	-.501	.196	-2.522	.021
	Ordinal by Ordinal	Spearman Correlation	-.467	.161	-2.302	.033
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	-.385	.350	-1.505	.156
	Ordinal by Ordinal	Spearman Correlation	-.246	.331	-.916	.376
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.

Use of overtime hours vs. contract employees. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	-.502	.206	-2.724	.012
	Ordinal by Ordinal	Spearman Correlation	-.479	.194	-2.560	.018
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.126	.066	.620	.541
	Ordinal by Ordinal	Spearman Correlation	.131	.069	.649	.523
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	.351	.134	1.185	.264
	Ordinal by Ordinal	Spearman Correlation	.365	.138	1.240	.243
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	.346	.093	1.650	.115
	Ordinal by Ordinal	Spearman Correlation	.364	.097	1.747	.096
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	.064	.176	.280	.782
	Ordinal by Ordinal	Spearman Correlation	.021	.204	.094	.926
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	.242	.095	.898	.385
	Ordinal by Ordinal	Spearman Correlation	.273	.108	1.023	.325
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.

Use of overtime hours vs. varying lead times. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	.171	.247	.816	.423
	Ordinal by Ordinal	Spearman Correlation	.216	.241	1.037	.311
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.260	.127	1.319	.200
	Ordinal by Ordinal	Spearman Correlation	.255	.124	1.292	.209
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	.674	.170	2.887	.016
	Ordinal by Ordinal	Spearman Correlation	.632	.171	2.582	.027
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	.263	.153	1.219	.237
	Ordinal by Ordinal	Spearman Correlation	.280	.154	1.305	.207
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	.260	.183	1.175	.255
	Ordinal by Ordinal	Spearman Correlation	.269	.200	1.219	.238
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	.182	.181	.669	.515
	Ordinal by Ordinal	Spearman Correlation	.106	.234	.384	.707
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.

Use of overtime hours vs. rejecting orders. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	.250	.078	1.211	.239
	Ordinal by Ordinal	Spearman Correlation	.285	.089	1.395	.177
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.098	.053	.480	.635
	Ordinal by Ordinal	Spearman Correlation	.098	.053	.480	.635
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	.316	.130	1.054	.317
	Ordinal by Ordinal	Spearman Correlation	.316	.130	1.054	.317
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	-.224	.235	-1.026	.317
	Ordinal by Ordinal	Spearman Correlation	-.224	.235	-1.026	.317
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	-.131	.169	-.574	.572
	Ordinal by Ordinal	Spearman Correlation	-.111	.212	-.488	.631
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	-.564	.284	-2.463	.029
	Ordinal by Ordinal	Spearman Correlation	-.280	.337	-1.053	.312
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.

Increased hours worked by part-time employees vs. job sharing. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	-.074	.042	-.347	.732
	Ordinal by Ordinal	Spearman Correlation	-.079	.045	-.370	.715
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.473	.204	2.627	.015
	Ordinal by Ordinal	Spearman Correlation	.394	.180	2.101	.046
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	-.245	.108	-.801	.442
	Ordinal by Ordinal	Spearman Correlation	-.256	.111	-.837	.422
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	.081	.219	.363	.720
	Ordinal by Ordinal	Spearman Correlation	.174	.254	.790	.439
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	. (d)			
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	. (d)			
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.
d No statistics are computed because JOBSHA0 is a constant.

Subcontracting vs. contract employees. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	.336	.246	1.672	.109
	Ordinal by Ordinal	Spearman Correlation	.191	.238	.914	.370
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.034	.207	.168	.868
	Ordinal by Ordinal	Spearman Correlation	.091	.212	.447	.659
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	.000	.320	.000	1.000
	Ordinal by Ordinal	Spearman Correlation	.000	.312	.000	1.000
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	.516	.157	2.697	.014
	Ordinal by Ordinal	Spearman Correlation	.485	.191	2.478	.022
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	-.106	.200	-.465	.647
	Ordinal by Ordinal	Spearman Correlation	-.106	.200	-.465	.647
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	-.172	.075	-.628	.541
	Ordinal by Ordinal	Spearman Correlation	-.195	.086	-.715	.487
	N of Valid Cases		15			

a Not assuming the null hypothesis.
b Using the asymptotic standard error assuming the null hypothesis.
c Based on normal approximation.

Subcontracting vs. varying lead times. Symmetric Measures

Sector			Value	Asymp. Std. Error (a)	Approx. T (b)	Approx. Sig. (c)
Process	Interval by Interval	Pearson's R	.267	.191	1.298	.208
	Ordinal by Ordinal	Spearman Correlation	.231	.195	1.116	.277
	N of Valid Cases		24			
Engineering Consumer goods	Interval by Interval	Pearson's R	.531	.178	3.070	.005
	Ordinal by Ordinal	Spearman Correlation	.529	.184	3.052	.005
	N of Valid Cases		26			
Engineering Capital kits	Interval by Interval	Pearson's R	.142	.311	.454	.659
	Ordinal by Ordinal	Spearman Correlation	.167	.308	.535	.605
	N of Valid Cases		12			
Electronics	Interval by Interval	Pearson's R	.097	.199	.437	.667
	Ordinal by Ordinal	Spearman Correlation	.087	.210	.391	.700
	N of Valid Cases		22			
Household	Interval by Interval	Pearson's R	-.021	.214	-.093	.927
	Ordinal by Ordinal	Spearman Correlation	-.019	.215	-.082	.935
	N of Valid Cases		21			
Food	Interval by Interval	Pearson's R	.302	.193	1.143	.274
	Ordinal by Ordinal	Spearman Correlation	.317	.249	1.205	.250
	N of Valid Cases		15			

a Not assuming the null hypothesis.

APPENDIX 11

The results of the analysis of inhibitors of volume flexibility based on a collapsed 3-point scale are presented in this appendix. These are:

1. The percentage of responding plants in different sectors rating the inhibitors based on how problematic they are to the achievement of volume flexibility.
2. Chi-square tests to determine whether differences in ratings are sector dependent.

An example of the SPSS Syntax programme used to execute the analysis is given below:

```
CROSSTABS
 /TABLES=overti4  BY sector
 /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT ROW COLUMN .
```

Overti4 represents "getting full time employees to work overtime hours"

Hiring full time employees (HIRIN4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
HIRIN4	.00	Count	2	2		1	4		9
		% within HIRIN4	22.2%	22.2%		11.1%	44.4%		100.0%
		% within Sector	8.3%	7.7%		4.5%	19.0%		7.5%
	1.00	Count	5	5	1	2	2	5	20
		% within HIRIN4	25.0%	25.0%	5.0%	10.0%	10.0%	25.0%	100.0%
		% within Sector	20.8%	19.2%	8.3%	9.1%	9.5%	33.3%	16.7%
	2.00	Count	12	4	6	8	7	6	43
		% within HIRIN4	27.9%	9.3%	14.0%	18.6%	16.3%	14.0%	100.0%
		% within Sector	50.0%	15.4%	50.0%	36.4%	33.3%	40.0%	35.8%
	3.00	Count	5	15	5	11	8	4	48
		% within HIRIN4	10.4%	31.3%	10.4%	22.9%	16.7%	8.3%	100.0%
		% within Sector	20.8%	57.7%	41.7%	50.0%	38.1%	26.7%	40.0%
Total		Count	24	26	12	22	21	15	120
		% within HIRIN4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.435[a]	15	.123
Likelihood Ratio	23.051	15	.083
Linear-by-Linear Association	.003	1	.954
Linear-by-Linear Association	.003	1	.954
N of Valid Cases	120		
N of Valid Cases	120		

a - 14 cells (58.3%) have expected count less than 5. The minimum expected count is 1.90.

Getting full time employees to work overtime hours (OVERTI4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
OVERTI4	.00	Count	1						1
		% within OVERTI4	100.0%						100.0%
		% within Sector	4.2%						.8%
	1.00	Count	9	11	6	7	7	5	45
		% within OVERTI4	20.0%	24.4%	13.3%	15.6%	15.6%	11.1%	100.0%
		% within Sector	37.5%	42.3%	50.0%	31.8%	33.3%	33.3%	37.5%
	2.00	Count	12	13	4	12	12	7	60
		% within OVERTI4	20.0%	21.7%	6.7%	20.0%	20.0%	11.7%	100.0%
		% within Sector	50.0%	50.0%	33.3%	54.5%	57.1%	46.7%	50.0%
	3.00	Count	2	2	2	3	2	3	14
		% within OVERTI4	14.3%	14.3%	14.3%	21.4%	14.3%	21.4%	100.0%
		% within Sector	8.3%	7.7%	16.7%	13.6%	9.5%	20.0%	11.7%
Total		Count	24	26	12	22	21	15	120
		% within OVERTI4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.908[a]	15	.927
Likelihood Ratio	7.054	15	.956
Linear-by-Linear Association	1.514	1	.219
Linear-by-Linear Association	1.514	1	.219
N of Valid Cases	120		
N of Valid Cases	120		

a - 7 cells (29.2%) have expected count less than 5. The minimum expected count is 1.10.

Getting part time employees to work increased hours (PARTIM4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
PARTIM4	.00	Count	12	13	7	7	5	7	51
		% within PARTIM4	23.5%	25.5%	13.7%	13.7%	9.8%	13.7%	100.0%
		% within Sector	50.0%	50.0%	58.3%	31.8%	23.8%	46.7%	42.5%
	1.00	Count	8	6	3	2	6	4	29
		% within PARTIM4	27.6%	20.7%	10.3%	6.9%	20.7%	13.8%	100.0%
		% within Sector	33.3%	23.1%	25.0%	9.1%	28.6%	26.7%	24.2%
	2.00	Count	3	5	2	9	7	2	28
		% within PARTIM4	10.7%	17.9%	7.1%	32.1%	25.0%	7.1%	100.0%
		% within Sector	12.5%	19.2%	16.7%	40.9%	33.3%	13.3%	23.3%
	3.00	Count	1	2		4	3	2	12
		% within PARTIM4	8.3%	16.7%		33.3%	25.0%	16.7%	100.0%
		% within Sector	4.2%	7.7%		18.2%	14.3%	13.3%	10.0%
Total		Count	24	26	12	22	21	15	120
		% within PARTIM4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.134[a]	15	.311
Likelihood Ratio	18.813	15	.222
Linear-by-Linear Association	5.157	1	.023
Linear-by-Linear Association	5.157	1	.023
N of Valid Cases	120		
N of Valid Cases	120		

a - 5 cells (20.8%) have expected count less than 5. The minimum expected count is 1.20.

Securing temporary labour (TEMP4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
TEMP4	.00	Count	6	3	3	4	5		21
		% within TEMP4	28.6%	14.3%	14.3%	19.0%	23.8%		100.0%
		% within Sector	25.0%	11.5%	25.0%	18.2%	23.8%		17.5%
	1.00	Count	3	5	3	2	6	9	28
		% within TEMP4	10.7%	17.9%	10.7%	7.1%	21.4%	32.1%	100.0%
		% within Sector	12.5%	19.2%	25.0%	9.1%	28.6%	60.0%	23.3%
	2.00	Count	11	13	3	8	5	2	42
		% within TEMP4	26.2%	31.0%	7.1%	19.0%	11.9%	4.8%	100.0%
		% within Sector	45.8%	50.0%	25.0%	36.4%	23.8%	13.3%	35.0%
	3.00	Count	4	5	3	8	5	4	29
		% within TEMP4	13.8%	17.2%	10.3%	27.6%	17.2%	13.8%	100.0%
		% within Sector	16.7%	19.2%	25.0%	36.4%	23.8%	26.7%	24.2%
Total		Count	24	26	12	22	21	15	120
		% within TEMP4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.817[a]	15	.052
Likelihood Ratio	25.909	15	.039
Likelihood Ratio	25.909	15	.039
Linear-by-Linear Association	.001	1	.971
Linear-by-Linear Association	.001	1	.971
N of Valid Cases	120		
N of Valid Cases	120		

a - 4 cells (16.7%) have expected count less than 5. The minimum expected count is 2.10.

Implementing job sharing (JOBSHA4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
JOBSHA4	.00	Count	14	21	7	11	13	7	73
		% within JOBSHA4	19.2%	28.8%	9.6%	15.1%	17.8%	9.6%	100.0%
		% within Sector	58.3%	80.8%	58.3%	50.0%	61.9%	46.7%	60.8%
	1.00	Count	4	2	1	4	2	3	16
		% within JOBSHA4	25.0%	12.5%	6.3%	25.0%	12.5%	18.8%	100.0%
		% within Sector	16.7%	7.7%	8.3%	18.2%	9.5%	20.0%	13.3%
	2.00	Count	3		2	3	1	2	11
		% within JOBSHA4	27.3%		18.2%	27.3%	9.1%	18.2%	100.0%
		% within Sector	12.5%		16.7%	13.6%	4.8%	13.3%	9.2%
	3.00	Count	3	3	2	4	5	3	20
		% within JOBSHA4	15.0%	15.0%	10.0%	20.0%	25.0%	15.0%	100.0%
		% within Sector	12.5%	11.5%	16.7%	18.2%	23.8%	20.0%	16.7%
Total		Count	24	26	12	22	21	15	120
		% within JOBSHA4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.873[a]	15	.762
Likelihood Ratio	13.032	15	.600
Likelihood Ratio	13.032	15	.600
Linear-by-Linear Association	1.199	1	.273
Linear-by-Linear Association	1.199	1	.273
N of Valid Cases	120		
N of Valid Cases	120		

a - 8 cells (33.3%) have expected count less than 5. The minimum expected count is 1.10.

Implementing annualised hours contracts (ANUALH4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
ANUALH4	.00	Count	14	19	7	11	12	4	67
		% within ANUALH4	20.9%	28.4%	10.4%	16.4%	17.9%	6.0%	100.0%
		% within Sector	58.3%	73.1%	58.3%	50.0%	57.1%	26.7%	55.8%
	1.00	Count	2	1	1	4	2	3	13
		% within ANUALH4	15.4%	7.7%	7.7%	30.8%	15.4%	23.1%	100.0%
		% within Sector	8.3%	3.8%	8.3%	18.2%	9.5%	20.0%	10.8%
	2.00	Count	3	2		3	2	4	14
		% within ANUALH4	21.4%	14.3%		21.4%	14.3%	28.6%	100.0%
		% within Sector	12.5%	7.7%		13.6%	9.5%	26.7%	11.7%
	3.00	Count	5	4	4	4	5	4	26
		% within ANUALH4	19.2%	15.4%	15.4%	15.4%	19.2%	15.4%	100.0%
		% within Sector	20.8%	15.4%	33.3%	18.2%	23.8%	26.7%	21.7%
Total		Count	24	26	12	22	21	15	120
		% within ANUALH4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.915[a]	15	.532
Likelihood Ratio	14.946	15	.455
Linear-by-Linear Association	1.399	1	.237
Linear-by-Linear Association	1.399	1	.237
N of Valid Cases	120		
N of Valid Cases	120		

a - 7 cells (29.2%) have expected count less than 5. The minimum expected count is 1.30.

Subcontracting (SUBCON4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
SUBCON4	.00	Count	10	3	2	5	9	7	36
		% within SUBCON4	27.8%	8.3%	5.6%	13.9%	25.0%	19.4%	100.0%
		% within Sector	41.7%	11.5%	16.7%	22.7%	42.9%	46.7%	30.0%
	1.00	Count	1	5	1	3		4	14
		% within SUBCON4	7.1%	35.7%	7.1%	21.4%		28.6%	100.0%
		% within Sector	4.2%	19.2%	8.3%	13.6%		26.7%	11.7%
	2.00	Count	6	13	7	10	7	2	45
		% within SUBCON4	13.3%	28.9%	15.6%	22.2%	15.6%	4.4%	100.0%
		% within Sector	25.0%	50.0%	58.3%	45.5%	33.3%	13.3%	37.5%
	3.00	Count	7	5	2	4	5	2	25
		% within SUBCON4	28.0%	20.0%	8.0%	16.0%	20.0%	8.0%	100.0%
		% within Sector	29.2%	19.2%	16.7%	18.2%	23.8%	13.3%	20.8%
Total		Count	24	26	12	22	21	15	120
		% within SUBCON4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.428[a]	15	.075
Likelihood Ratio	26.471	15	.033
Linear-by-Linear Association	1.598	1	.206
Linear-by-Linear Association	1.598	1	.206
N of Valid Cases	120		
N of Valid Cases	120		

a - 4 cells (16.7%) have expected count less than 5. The minimum expected count is 1.40.

Securing contract employees (CONTRA4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
CONTRA4	.00	Count	11	11	5	5	12	8	52
		% within CONTRA4	21.2%	21.2%	9.6%	9.6%	23.1%	15.4%	100.0%
		% within Sector	45.8%	42.3%	41.7%	22.7%	57.1%	53.3%	43.3%
	1.00	Count	3	6	2	3		4	18
		% within CONTRA4	16.7%	33.3%	11.1%	16.7%		22.2%	100.0%
		% within Sector	12.5%	23.1%	16.7%	13.6%		26.7%	15.0%
	2.00	Count	6	8	2	7	6	2	31
		% within CONTRA4	19.4%	25.8%	6.5%	22.6%	19.4%	6.5%	100.0%
		% within Sector	25.0%	30.8%	16.7%	31.8%	28.6%	13.3%	25.8%
	3.00	Count	4	1	3	7	3	1	19
		% within CONTRA4	21.1%	5.3%	15.8%	36.8%	15.8%	5.3%	100.0%
		% within Sector	16.7%	3.8%	25.0%	31.8%	14.3%	6.7%	15.8%
Total		Count	24	26	12	22	21	15	120
		% within CONTRA4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.566[a]	15	.234
Likelihood Ratio	22.227	15	.102
Likelihood Ratio	22.227	15	.102
Linear-by-Linear Association	.212	1	.645
Linear-by-Linear Association	.212	1	.645
N of Valid Cases	120		
N of Valid Cases	120		

a - 6 cells (25.0%) have expected count less than 5. The minimum expected count is 1.80.

Getting customers to agree to variation in lead times (LEADTI4) * Sector Crosstabulation

			Sector						Total
			Process	Engineering Consumer goods	Engineering Capital kits	Electronics	Household	Food	
LEADTI4	.00	Count	5	2	1		4	3	15
		% within LEADTI4	33.3%	13.3%	6.7%		26.7%	20.0%	100.0%
		% within Sector	20.8%	7.7%	8.3%		19.0%	20.0%	12.5%
	1.00	Count		1				1	2
		% within LEADTI4		50.0%				50.0%	100.0%
		% within Sector		3.8%				6.7%	1.7%
	2.00	Count	7	7	4	9	7	3	37
		% within LEADTI4	18.9%	18.9%	10.8%	24.3%	18.9%	8.1%	100.0%
		% within Sector	29.2%	26.9%	33.3%	40.9%	33.3%	20.0%	30.8%
	3.00	Count	12	16	7	13	10	8	66
		% within LEADTI4	18.2%	24.2%	10.6%	19.7%	15.2%	12.1%	100.0%
		% within Sector	50.0%	61.5%	58.3%	59.1%	47.6%	53.3%	55.0%
Total		Count	24	26	12	22	21	15	120
		% within LEADTI4	20.0%	21.7%	10.0%	18.3%	17.5%	12.5%	100.0%
		% within Sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.564[a]	15	.636
Likelihood Ratio	15.143	15	.441
Linear-by-Linear Association	.065	1	.799
Linear-by-Linear Association	.065	1	.799
N of Valid Cases	120		
N of Valid Cases	120		

a - 8 cells (33.3%) have expected count less than 5. The minimum expected count is 2.20.

APPENDIX 12

ENGICO: HANDBOOK ON NEW WORKING PATTERNS

1. Summary of Proposed Annual Hours Scheme

1.1 The annual hours scheme at Engico has three main aims:-

- To accommodate a reduction in working time for industrial staff and an increase for Engico staff, both groups being established on an average working week of 38.25 hours.

- To permit the company to expand production in key plants, and to respond to growth and change in its business.

- To provide the opportunity of varying working hours to meet a fluctuating workload, and to reduce the company's dependence on overtime.

1.2 The essence of the scheme is to introduce a flexible working day, which can be varied between 35 and 42.5 hours per week and at the same time have a reserve of hours which can be built up or run down to accommodate fluctuations in workload. The great majority of employees will be covered by either the 'Committed Days' (CD) version of this concept or the 'Committed Shifts' (CS) version.

1.3 The Extended Double Days (EDD) work pattern does not have the same variability. It is a fixed rota with summer period adjustments to provide sufficient time for at least a fortnight's holiday during this period. There are no reserve hours in the EDD pattern.

1.4 Weekend overtime will still continue to be available and will be paid as worked. However, such overtime will be controlled and it is anticipated that it will reduce substantially. Overtime may also be earned if the weekday hours exceed the upper limit of variability.

1.5 The benefits of the scheme for employees are that it increases leisure time and days off for industrial staff and transfers into guaranteed pay part of the fluctuating overtime earnings. There are also more opportunities for job variety and minimal unsocial hours working.

2. Operation of Annual Hours Scheme

2.1 *Definitions:* All industrial and Engico staff will have an annual hours contract of 1744 hours per annum.

2.2 *Committed Hours*: Each employee will be committed to *at least 1687.5 hours in the form* of days or shifts. The minimum commitment under the CD and CS patterns is 225 working days.

2.3 Each day or shift that is committed can be extended by taking hours from reserve. The week can be shortened by working five hours instead of seven and a half on Fridays in low activity periods. The hours are put back in the reserve account.

2.4 The 'flexiday' or 'flexishift' *may have staggered starts and finishes to meet operational* needs. The nominal hours are:-

	Normal Weeks	'Short' Weeks
Committed Days – Industrial	08:00 – 16:00	13:00 } Friday
- Staff	08:15 – 16:15	13:15 } finish

2.5 A time account will operate throughout the year and the enployee and employer must ensure that the account is in balance at the year end, both for committed and reserve hours.

2.6 *Reserve Hours*: The reserve hours will be a maximum of 56.5 hours at the beginning of the annual hours year. This may increase in low activity periods.

2.7 In normal circumstances, management will ensure that the reserve hours are fully taken up. However, in exceptional circumstances where these are not used, the employee has the pay benefit of the unused balance.

2.8 If more than the flexible reserve is required during the year, the additional hours will count as overtime. The same principle applies if the limit of 5 hours per week of flexible reserve is exceeded. This assumes that the employee is not substantially in deficit on his time account for committed hours. He will normally be expected to bring his committed hours into balance before being offered "overtime".

2.9 Reserve hours may not be used for 'paying off' deficits on the time account for committed hours.

2.10 *Notice Period*: The employee has the right to refuse to work flexible reserve hours if the notice period is too short. For this purpose, the employee must be notified by no later than the end of the previous working day or shift.

2.11 A minimum of a week's notice will be given in normal circumstances should the management want to make a change from one established work pattern to another established work pattern. The same notice will normally apply in the case of 'short weeks' in low activity periods.

2.12 A minimum of three months' notice will be given should the management wish to change any of the established working patterns in a significant way (e.g. the introduction of semi-continuous or fully continuous shift patterns). This will be the subject of consultation and acceptance by the employees concerned.

2.13 *Absence*: In the case of certified sickness absence the rostered or committed days or shifts lost will be deducted from the employees time account for the period of absence. In the case of long-term sickness, pro rata adjustments to the outstanding reserve hours balance will be made to ensure equitable treatment.

2.14 In the case of unauthorised absence, no deduction from the time account will be made for the hours lost. The same principle will apply in normal circumstances to concessionary time off at the employee's request except where this is part of an employer-recognised arrangement.

2.15 Inability to complete the committed annual hours will result in pro-rata adjustments to annualised, equalised pay.

2.16 *Holidays*: Apart from the EDD and VSD patterns (where special arrangements for a summer holiday period apply) holidays will be restricted on the basis of not more than one employee on holiday out of a team of five.

2.17 In normal circumstances there will be no carry-over of surplus or deficit hours from one annual hours year to another. The accumulated leave scheme can continue to operate as can the holiday entitlement based on service anniversary dates.

2.18 *Quarterly Time Accounts*: It will not normally be permitted for an employee to be in overall surplus or deficit on his time account (committed and reserve hours) by more than 60 hours each quarter. The final quarter is expected to be brought into balance for the year end. The actual hours used can be compared with the anticipated or rostered usage week by week to ensure effective control and to prevent substantial surpluses or deficits occurring. Every employee will be entitled to have access to his own time account on request at any time.

New Working Patterns (1) Committed days

Purpose of Work Patterns:To permit variation of weekday working hours to meet operational and business needs.

Annual Hours Contract: The contract is for 1744 hours per annum, which is equivalent to 38.25 hours per week on average.

Working Hours: Nominally 08:00 – 16:00 with half hour (unpaid) lunch break and one (paid) tea break per day for industrial staff and supervision. For administrative staff the hours are 08:15 – 16:15. During 'short' weeks industrial staff will finish at 13:00 on Friday and administrative staff at 13:15 with no lunch break in the morning period.

Working Pattern: During busy periods hours are extended at either end of the day to meet requirements. The extended hours are taken from reserve. During low activity periods the short week is worked with early finish on Friday. 2.5 hours per week are added to reserve.

Committed Days: The individual is normally committed to working 45 weeks of 37.5 hours per week except when 'short weeks' are worked. This is 225 working days per annum of 7.5 hours per day or 1687.5 annual hours.

Reserve Hours: 56.5 hours are held in reserve to be used for extending the length of the working day. The individual would not normally be asked to utilise more than 5 of the reserve hours in any week. Additional week day reserve hours are created by the addition of the 'short week' hours.

Notice Period: Notice for working short weeks will be given by the end of the previous week. Notice for working extended days will be given by the end of the previous working day.

Annual Hours Reconciliation :

	Annual Hours
Committed weekdays (maximum):	1687.5
Reserve weekday hours (minimum):	56.5
Contract Total:	1744.0

Weekend Working: Weekend working is normally regarded as "overtime" and will be paid at the normal premium rates.

Annual Holidays: Free time will not be restored, but it is normally expected that not more than 1 in 5 employees will be off at any one time. The leave accumulation scheme will continue on the basis of surplus committed days being carried forward. It would be expected that holidays are minimised in the period leading up to the financial year end.

New Working Patterns (2) Committed Shifts

Purpose of Work Pattern: To create a shift working regime for workflow and operational requirements combined with variations to meet a fluctuating workload.

Annual Hours Contract: The contract is for 1744 hours per annum, which is equivalent to 38.25 hours per week on average.

Working Hours: (A) 06:00 – 13:30; 13:20 – 21:20 or
(B) 06:30 – 14:00; 13:50 – 21:50

A flexible paid half hour meal break is taken during the shift.
During 'short' weeks employees on morning shift will move onto normal days, with employees on afternoon shift rostered off.

Working Pattern: During busy periods hours are extended at the beginning of the morning shift (normally by no more than half an hour) and at the end of the afternoon shift (normally

finishing no later than the end of the extended double daywork pattern). The extended hours are taken from reserve.
During low activity periods the short week is worked with an average of 3.75 hours to be added to reserve per week over a fortnight.

Committed Shifts: 225 working shifts are committed per annum, of 7.5 hours per shift.

Reserve Hours: 56.5 hours are held in reserve to be used for extending the length of the shift. The individual would not normally be asked to utilise more than 5 hours of the reserve in any week.
Additional week day reserve hours are created by the addition of the "short week" hours.

Notice Period: Notice for working short weeks will be given by the end of the previous week. Notice for working extended shift will be given before the end of the previous shift for the individuals concerned.

Annual Hours Reconciliation

	Annual Hours
Committed weekdays (maximum):	1687.5
Reserve weekday hours (minimum):	56.5
Contract Total:	1744.0

Weekend Working: Weekend working is normally regarded as "overtime" and will be paid as worked at the normal premium rates.

Annual Holidays: Free time will not be rostered, but it is normally expected that not more than 1 in 5 employees will be off at any one time. The leave accumulation scheme will continue on the basis of surplus committed days being carried forward.
It would be expected that holidays are minimised in the period leading up to the financial year end.

New Working Patterns (3) Extended Double Days

Purpose of Work Pattern: To increase operating hours on key plant and equipment and to achieve flexibility between day and shift working.

Annual Hours Contract: The contract is for 1744 hours per annum, which is equivalent to 38.25 hours per week on average.

Working Hours: Mornings 06:00 – 15:00
Afternoons 14:50 – 23:45 Monday to Thursday
14:50 – 22:10 Friday
Days 07:30 – 16:39 (with half hour unpaid lunch)

Working Pattern

Crew	Week	M	T	W	Th	F	S	S	Total
A	1	M	M	M	M	M	-	-	45
B	2	A	A	A	A	A	-	-	43
C	3	D	D	D	D	D	-	-	42.5
D	4	A	A	A	A	A	-	-	43
E	5	M	M	M	M	M	-	-	45
F	6	O	O	O	O	O	O	O	0
									218.5
							Average		36.42

Summer Period: A fortnight's summer holiday is created by moving week 3 and forgoing a dayworking plant during part of the twelve week holiday period. Thus the employee can virtually choose his holiday fortnight so long as not more than one other person from the crew of six has chosen the same or overlapping weeks.

APPENDIX 13

TELECO: PROPOSAL FOR BANKING HOURS

Introduction

This proposal builds upon the success of the 1997/98 local flexible hours agreement. For the period 1st August 1998 to 31st March 199, banking hours with the following guidance is possible. Recovery of hours will be possible up to the 31st April 1999.

Scope

This proposal covers all Direct Operational personnel

Increasingly our customer requirements vary considerably and changes to production capacity are required at very short notice.

This scheme enables the voluntary agreement between employees and the company to adjust attendance hours based upon capacity requirements and personal needs.

We will be limiting this variation in hours to ensure it remains practical for both implementation and recovery. The key principles of how it will work are given below:

Key Principles

- Banking of hours will be accommodated by employees being asked to take time off in lieu of hours being recovered at a later date.

- Within the capacity plan, Production Management will seek to advise employees a minimum of 7 days in advance of the need to reduce attendance hours.

- Employees can volunteer to reduce their working patterns. Production Management will seek to accommodate these requests, but agreement will always be dependent upon the immediate capacity and skills requirement.

- Hours will be recovered with premium within strict time periods (Monday to Friday) within the variable weekly capacity demands we have to manage. A minimum of 3 days notice will be given, and wherever possible, 7 days notice of the need to attend work to recover hours.

- Production Management will be sympathetic and accommodate requirements, taking due notice of employees' personal circumstances.

- Hours recovered on Saturday will be derated to accommodate overtime regulator.

- Recovery of banked hours on Saturday will be entirely voluntary.

- Maximum time that can be banked initially is 40 hours. This will be reviewed monthly and may be extended to 50 hours based upon capacity forecasts.

- Minimum time that can be banked is 4.5 hours.

Recovery of hours generally will be restricted to the following time spans, depending upon the individual's working pattern at the time of recovery.

		Working Pattern
Monday – Thursday Friday	2.00pm – 4.00pm 11.30am – 4.30pm	6 – 2
Monday – Thursday Friday	12.00am – 2.00pm 9.30am – 11.30am	2 – 10
Monday – Thursday Friday	4.30pm – 6.30pm 12.45pm – 5.15pm	7.45 – 4.30

APPENDIX 14

FONGOODS: REVISED BANK DAY SYSTEM FOR GENERAL PRODUCTION OPERATORS

An alternative to lay off days

- Bank days to be credited to the bank

- Full weeks pay provided including bonus but no shift pay for any banked days

- Days to be paid back when production demand increases or for cover in the case of absenteeism

- As a general rule, 48 hours notice required in request for bank days to be paid back bearing in mind special circumstances.

- Persons with the most bank days accrued will be approached first when bank days are paid back

- Bank days paid back during the week or Saturdays to be reduced by 1.5 times i.e. 8 hours banked, 5.5 hours to work.

- Bank days paid back during Sunday to be reduced by 2 times i.e. 8 hours banked, 4 hours to work.

- A maximum of 6 days or 48 hours can be banked.

- In the event of someone reaching this cut of level, further discussions will take place.

- In the event of anyone not showing a reasonable amount of co-operation with regard to bank day pay off, individual discussions will take place on how to reduce their level of banked days to an acceptable level.

- Bank days owed at the end of the calendar year will be written off providing reasonable co-operation has been seen.

This system will be reviewed on an ongoing basis.