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**LEAD TIME PERFORMANCE IN THE SUPPLY CHAIN:
a case study of the capital equipment supply environment
of the offshore oil exploration and production industry
on the UK Continental Shelf**

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ABSTRACT

This research study is an examination of the influencing factors on lead time performance in a capital equipment supply environment. The research is being undertaken as a case study of the capital equipment supply environment of the offshore oil exploration and production industry on the UK Continental Shelf. The study methodology is justified as a case supply environment, with multiple sources of data from research instruments including: exploratory and detailed interviews and structured survey methods. The literature review examines time-based approaches to supply chain improvement and the literature related to supply chain integration. Relevant literature related to supply chain systems/structures and relationships/infrastructure are examined as potential influencing factors on lead time performance. A background of the generic case environment is provided, along with relevant literature related to the supply chain in oil exploration and production. The results of a survey of the state of integration of the offshore supply chain are presented and analysed, followed by the results of a structured mail survey within the capital equipment environment. The survey information is used to inform the Case Research phase and define a division of the case environment related to different complexity levels. Individual cases are analysed based on the framework from the literature review and refined from the survey phase. The research questions are addressed at the level of each individual case and propositions derived which are then validated based on cross-case comparisons. Aspects of literature that are supported by the study are discussed along with those areas where there is a contribution to literature. Contribution to supply chain theory is justified related to the derivation of a Types Classification Model as a means of understanding the generic nature of a capital equipment supply chain. Contribution to methodology is justified, based on the use of a supply environment for study and the use of a supply chain trace-back method.

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Without the support of my wife Patricia it would have been impossible for this task to be completed. This work is dedicated to her with love, along with Nana who Patricia cared for unstintingly during the progress of this study but who did not live to see it finished.

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INTRODUCTION

1.1 Defining the Supply Chain

Supply Chain Management is concerned with the management of the linked value chain flow of materials from source of supply to the end-customer. The supply chain concept provides a strategic focus in its premise that benefits result from the improved operation of the chain as a whole. In most cases, this will involve the resources that support the chain crossing several functional boundaries within the organisation and will extend outwith the organisation, where the ownership and proliferation of the linkages can become even more complex. This holistic view extends the interest of Supply Chain Management to strategic areas such as organisational design and policies for procurement, operations and marketing.

One of the earliest writers to highlight the importance to organisations of how materials are managed in a broader sense was Peter Drucker (1962) and later (1990) he explains that his concept of a "new manufacturing system" will include independent suppliers at one end and customers at the other and that the plant itself will be "little more than a wide place in the manufacturing stream". This concept was expanded by Porter (1985) in his concept of "The Value Chain". Like Drucker, Porter points out that many of the value-adding activities will be performed *outwith* the organisation, but more importantly he emphasises that it is the linkages and relationships between the various value activities that are important. Expanding Porter's ideas, Johnston and Scholes (1988) highlight the need to undertake a resource analysis which is related to the decisions that have been made about the *linkages* between 'value activities' and also concerning the value chain of suppliers, channels of distribution and customers. The importance of linkages is highlighted by Christopher in his definition of Supply Chain Management:

"The goal of supply chain management is to link the market place, the distribution network, the manufacturing process and the procurement activity in such a way that customers are serviced at higher levels and yet at lower total costs." (Christopher, 1992)

The term 'supply chain' is the most commonly used term for the concepts under study, but there is an ongoing debate about the suitability of the term. Croom-Morgan (1994) has examined the value of concepts such as "supply chains", "pipelines", "networks" and "value streams". In a later paper, Croom-Morgan (1995) explores the complementary nature of network theory to this area of interest, which highlights influence (or power) as the central concept in network analysis, couched in the terms of the dependence/interdependence continuum. He emphasises the importance of the "facilitation" dimension relative to the effective management of supply chains. Hines (1993, 1996a, 1996b) has developed a 'Network Sourcing Model' with 10 dimensions, whilst the Lamming (1993) 'Lean Supply Model' embraces network considerations. Batchelor et al (1995) regard the firm as a nexus of learning networks, based on the adaptation of Porter's Strategic Positioning Model in the light of Williamson's work on transaction cost economics. Cravens et al (1996) attempt to classify the network paradigm based on the nature of network volatility and the nature of network relationships.

On balance, the term 'supply chain' has been increasingly adopted and recognised and will be used throughout this study. The study shall also use the terms 'downstream' as meaning supply chain material flow, information flow and relationship status from the supplier towards the customer and the term 'upstream' as meaning supply chain material flow, information flow and relationship status from the customer towards the supplier. This study shall focus on the material flow related to the production of capital equipment, although it is recognised that there are also services involved in these supply chains.

1.2 The Focus on Lead Times

A new wave of interest in the importance of time-based concepts to management is attributed by some to Stalk through the ideas developed in the book "Competing against Time" (Stalk & Hout, 1990). In these writings, time is elevated as a competitive weapon and a real source of competitive advantage for organisations: "The way leading companies manage time - in production, in new product development, in sales and

distribution represents the most powerful new sources of competitive advantage". These ideas were also central to Drucker's early predictive article on 'new manufacturing' approaches (Drucker, 1990).

Operations Management literature has been much concerned with the internal consideration of the reduction in production cycle times provided by concepts such as Just in Time (JIT). From a supply chain point of view, these approaches encouraged the reduction of the supplier base, single sourcing and the growth of closer relations with suppliers. Just in Time (JIT) ideas have been incorporated into supply chain thinking in concepts such as Quick Response (QR). Christopher (1992) suggests that QR can trigger a 'virtuous circle' emanating from reduced lead times having an effect on both information and physical flows. Through improved information systems, less stock can be held due to reductions in forecasting error, whilst the actual reduction of the time cycles reduces the pipeline inventory.

Porter's ideas of the Value Chain (Porter, 1985) are generally regarded as one of the founding principles of supply chain thinking and the important link between time and value has been an ongoing theme in the application of time-based approaches to the supply chain. "The requirement is to look across the functions at the lead times between the different elements of the organisation and to measure the time that is consumed and the 'value' that is added by the system as a whole" (Christopher & Braithwaite, 1989). The important link between time and value has also been an ongoing theme in the application of time-based principles to the supply chain and the development of concepts such as Strategic Lead Time Management (Christopher & Braithwaite, 1989; Horscroft & Braithwaite, 1990).

Firstly, short lead times contribute to an *efficient* supply chain measured on the basis of low non-value-adding time or alternatively related to low levels of inventory in the 'pipeline'. Secondly, short lead times contribute to an *effective* supply chain, measured on the basis of its ability to react rapidly to customer requirements. Thus lead time performance is a one of the key measures of supply chain efficiency and effectiveness.

This study shall thus focus on investigating the influencing factors on lead time performance. Data on lead times will be utilised, not as a basis for mathematical modelling in the positivist tradition, but instead the data shall be used to permit interpretation as to the reasons why lead times exist in any particular configuration.

1.3 The Generic Case Environment

If the premise is accepted that benefits in supply chain management result from the improved operation of the supply chain *as a whole*, this leads the researcher into considering a study methodology that captures holistic data. Case Research methodology permits this holistic view (Ragin & Becker, 1992) and has been adopted within this study. The researcher identified that much of the empirical work that has been carried out on supply chain improvement has been based on research in repetitive ‘make-to-stock’ manufacturing industry. It appeared, therefore, that a contribution could be made to supply chain understanding from additional empirical work on less repetitive ‘make-to-order’ or ‘design/make-to-order’ industries that might provide important comparative data.

The Capital Equipment supply chain was selected as a generic type and within this the Capital Equipment Supply Chain to the offshore oil exploration and production industry on the UK continental shelf was selected as a case supply environment. Its selection was appropriate due to the researcher’s knowledge of the industry and an ability to access the case environment due to the researcher’s own location in Europe’s oil capital, Aberdeen. The research methodology has been designed to use “multiple sources of evidence” (Ragin & Becker, 1992) to construct a generalisation of the influencing factors on lead time performance in this generic environment. From an orientation standpoint, the study shall be discussed based on the downstream and upstream supply chains from the capital equipment manufacturers.

In an attempt to classify the case environment as a generic type, recourse has been made to existing taxonomies (Sweeney & Szwejczewski, 1996; Bartezzaghi, 1994) and the time-based features of these environments (Babu, 1999; Bhattacharya, 1996; Ong, 1997; Gehani, 1995; Da Silvera, 1998).

1.4 Classification of Relevant Supply Chain Research

1.4.1 Time-based approaches to Supply Chain Improvement

An influential contribution to emphasising the importance of time-based management to the achievement of competitive advantage is provided by Stalk & Hout (1990) and Womack et al (1990). Literature on Just in Time has been adapted to the supply chain in concepts such as Lean Supply (Lamming, 1993), Quick Response (Christopher, 1992) and Just in Time Supply (Waters-Fuller, 1995).

Approaches for the improvement of the supply chain from a lead time point of view include Order Flow Logistics (Stalk & Hout, 1990), the Warwick Time-based Mapping Tool (Beesley, 1995), Strategic Lead Time Management (Christopher & Braithwaite, 1989; Horscroft & Braithwaite, 1990; Christopher, 1992) and Pipeline Mapping (Scott & Westbrook, 1991).

The application of lead time improvement to the generic capital equipment supply chain has underlying theory based on the optimisation of flow rates and derived from the Theory of Constraints (Goldratt & Cox, 1986). This was applied in engineering-to-order supply chains by Tersine & Hummingbird (1995). Stalk and Hout (1990) define the pre-conditions of time-based improvement to be based on: [1] Better and more timely information; [2] Shorter work cycles by removing obstacles; and [3] Synchronising lead times and capacities at tiers in the supply chain. This concept of 'throughput efficiency' and the importance of capacity (Christopher, 1992) is postulated to be particularly important in a capital equipment supply environment which may not be supported by inventory. This is the domain of service logistics where "the service logistician concentrates on capacity, not inventory" (Davis & Manrodt, 1994).

1.4.2 The Integrated Supply Chain

The importance of integration of the supply chain has been a key theme since early logistical articles (Bowersox, 1985). Two themes emerge as pre-conditions for integration [1] organisation structures with a more organic system (Burns & Stalker, 1966) or with 'boundary-spanning' roles (LaLonde & Masters, 1994) and [2] the contribution of information systems to integration (Bowersox & Daugherty, 1987).

Staged models of integration have been proposed and empirically investigated (Farrell, 1985 and 1987; McGinnis & Kohn, 1990; Stevens, 1989; Larson, 1994). Finally, the link between integration and improved manufacturing performance was empirically tested by Armistead and Mapes (1993). Within this literature, three themes emerge that characterise the inter-organisational integration of the supply chain: [1] the use of information communications systems; [2] the existence of co-ordinating mechanisms; and [3] the existence of co-operative relationships.

These themes can be further classified into two possible types of influential factors on lead time performance. The Hill (1991, p26) model has been adapted as a basis for this classification. Firstly, there is the influence of the *structural* aspects of the supply chain, including the information and physical materials flow systems. Secondly, there is the influence of *infrastructural* aspects, including culture and relationships. There has been a tendency for logisticians to concentrate on the structural influencers within the literature, whereas procurement literature is highly dependent on a study of relationship aspects. Literature on time-based performance clearly identifies that both these aspects must be considered to enable time-based performance improvement.

1.4.3 The influence of Supply Chain Systems and Structures on Lead Time Performance

Philosophically the Supply Chain can be regarded as an open system (Katz & Kahn, 1966) due to its integration with external environmental influences. Theoretical

convergence between open systems theory and supply chain understanding can be seen in the importance of 'information feedback'. This finds its expression in current supply chain research within the Systems Dynamics School based on the pioneering work of Forrester (Towill, Naim, Wilkner, 1992; Evans, Naim, Towill, 1993; Berry, Towill, Wadsley, 1994).

Structural issues of supply chain design of particular relevance to time-based performance includes the importance of the strategic positioning of inventory and the concepts of Order Penetration Point (OPP) and De-coupling Point (Sharman, 1984; Berry et al, 1994; Christopher, 1998). Other structural issues that have been identified as of relevance to a capital equipment supply environment are: [1] Design Standardisation (CRINE, 1999; Watson et al, 1999; Mayhew, 1999); [2] Contract Structures (CRINE, 1999); and [3] Information Communication Structures (CRINE, 1999; Watson, 1999; Stubbs, 1999; Spence et al, 1999; Mayhew, 1999).

1.4.4 The Influence of Supply Chain Relationships and Infrastructure on Lead Time Performance

The ability to provide a time-responsive supply chain has a basis in Dependency Theory (Oliver & Wilkinson, 1988). A further underlying theory is that of Transaction Cost Economics (Williamson, 1975), adapted via Social Network Analysis (Sako, 1992) to an emergent model of Network Organisation (Powell, 1990 in Sako, 1992). This provides a different economic basis: the possibility of reducing costs in networks by a conscious decision to build mutual trust.

The importance of these obligational, partnership-type relations to supply chain performance also finds substance in the concept of Lean Supply (Lamming, 1993), Network Sourcing (Hines, 1996a) and Relationship Positioning (Macbeth & Ferguson, 1994). The influence of trust and power in these dependent relationships is widely discussed (Cox, 1995; Burnes & New, 1996; Walton, 1996, Cooper & Gardner, 1993; Sako, 1992; Michell et al, 1998; Ali & Birley, 1998; Geyskins et al, 1996; Roy & Dugal, 1998; Blis, 1998; Ramsay, 1996; Stannack, 1996; Mudami & Schrunder, 1996).

Although many authors cite trust as a precursor to partnership-style relations, the iterative nature of the building of trust is becoming more fully recognised, with Hines (1996a) in particular, suggesting that trust is a result of successful partnerships, not a cause of them.

Finally, for obligational supply chain relationships to lead to improved cost or time-based performance the relationship must yield widespread transmission, and most importantly, sharing of information (Larson, 1994; Armistead & Mapes, 1993; Stevens, 1989).

1.5 Research Justification

Justification for the undertaking of this research project can be considered relative to three levels: [1] Management Research; [2] Practitioner Relevance; and [3] Supply Chain Research.

1.5.1 Contribution of the Study to Management Research

'Competitiveness' is seen as one of the key themes for Management Research by the Commission for Management Research of the Economic and Social Research Council. Their report states:

"Companies in the UK must produce goods and services that meet the test of international markets while simultaneously maintaining and enhancing the real incomes of their employees. Research is needed to help companies formulate strategies to achieve these objectives and to identify options at a regional and national level that provide the most supportive environment for competitive industrial performance".

("Building Partnerships: enhancing the quality of Management Research", The Report of the Commission on Management Research, E.S.R.C., January 1994)

This research focuses on a key area of industrial competitiveness, that of lead time performance and is thus justified from the standpoint of the mainstream of management research.

1.5.2 Practitioner Relevance of the Study

At the level of the industry sector under study, the research is relevant due to the requirements for a mature U.K. oil sector to maintain competitiveness against a global production picture where it is regarded as a high cost producer. Whereas this is balanced by attractiveness in proximity to markets and a stable political environment, the industry is reaching a mature stage where economies of scale are being eroded by reduced production. Ability to extend the area of exploration activity has potential, particularly West of Shetland, but this brings with it even harsher weather conditions and deeper water than the North Sea. In a mature oil province, the size of reservoir discoveries is much smaller. This, in turn, requires 'fast-track-type' projects to realise an earlier flow of oil in order to achieve a satisfactory return on investment. This is the case for both new discovery locations and also for the exploitation of new reservoirs from existing production locations. Long delivery lead times for the capital equipment required for these projects is a major constraint in the achievement of the overall lead times required in this new economic climate. The industry is thus particularly interested in approaches that may improve lead times for capital equipment supply. Without a solution to these problems, the competitiveness of the U.K. oil industry is potentially under severe threat from more attractive investment opportunities overseas.

1.5.3 Potential Contribution of the Study to Supply Chain Research

In a review of Logistics thought and practice for the International Journal of Physical Distribution and Logistics Management, Stock (1990) notes that the majority of logistics research has been limited to examining how logistics can be performed more efficiently and effectively and not how it can affect corporate strategy and help create competitive advantage for a firm in the market-place or improve general economic and social conditions of society as a whole. He concludes that a future research agenda should extend the work of Porter's value chain analysis and incorporate the relationship with marketing planning, strategy and organisational behaviour. The limitations of previous logistics research has also been highlighted by Rushton and Saw (1992) who conclude

that most serious research has been completed at the level of individual parts of the chain, rather than at the 'holistic' level demanded to achieve understanding of the linking or integrating benefits that lie at the heart of the concept.

This research will thus contribute to knowledge in providing empirical research at the supply chain level through the study of a case supply environment. Previous empirical work has centred on manufacturing industry mainly related to sectors with repetitive manufacturing activities, such as the automotive and electronic sectors. Lamming (2000) has identified the problem of migrating theories and practice from one supply environment to another: "The problem for managers who have to cope with supply networks is that these accounts have typically explored particular industries, notably the automotive industry; managers in other industries, who may be dealing with some different business problems, thus lack the theoretical underpinning for managing their particular type of supply network". Lamming (2000) has thus concluded that it is necessary to provide a classification of supply networks. Key variables identified by Lamming are innovativeness/uniqueness and complexity. This study of capital equipment supply has the potential to provide understanding in more unique and complex product supply chains and will assist understanding about the differentiation of supply chains in general. In a proposed future research agenda for the Centre for Business Strategy and Procurement, Cox (1999a) maps out two objectives: [1] to map out a typology of supply chains; and [2] to understand the most appropriate ways and means of undertaking business strategy and operational alignment within each type of supply chain.

Cox (1999b) has also argued that when thinking about supply chains "what is appropriate in one context may be inappropriate in another". Contextual issues related to different 'power' scenarios in different business contexts leads Cox (1999b) to conclude that the conditions necessary for certain supply chain principles, such as 'Lean Supply', may not be universally applicable: "Just because other car companies have been able to replicate the power structures through which Toyota has been able to manage their supply chains.....does not mean that everyone can do so." (Cox, 1999b, p172). The particular

circumstances of regular flow of volume production parts makes it more feasible, according to Cox (1999b) for powerful players in the chain to become dominant. In other supply chains where the same structural properties do not exist, Cox (1999) considers ‘copying’ the practice of car assemblers to be either a waste of time, or potentially a disaster. Cox (1999b) thus concurs with Lamming that there is a requirement for “a proper understanding of the supply chains that exist” and suggests using an earlier classification by Saunders (1998 in Cox (1999b): [1] production items; [2] consumables; [3] capital equipment; [4] goods for resale; and [5] services. Cox (1999) thus suggests that a research agenda for supply chain management must take these considerations into account in order that a more proper understanding may be made of the structural properties of the supply chain. This study thus has the potential to provide a contribution by providing understanding of the structure and operation of Saunders category [4] capital equipment, and by doing this, assist in the conceptual understanding of supply chains as a whole.

The study will provide a potential contribution to knowledge in the following key areas:

- i Contribution to theory in the generation of propositions about the influencing factors on lead time performance, with upstream and downstream perspectives within the supply chain.
- ii Contribution to the literature in Supply Chain Management by providing comparative information to empirical studies in repetitive and consumer product industries on the influencing factors on lead time performance in a capital equipment supply environment.
- iii Contribution to methodology in evaluation of the use of supply chain trace-back methodology for the study of supply chains.
- iv Contribution of knowledge to the industry sector under study in providing improved understanding in the factors relevant to the improvement of lead time performance and in the conceptual development of a Time-based Improvement Process Model that will have practical application within a capital equipment supply chain.

1.6 Research Aims and Objectives

The aim of the research is as follows:

To evaluate the influencing factors on lead time performance in a capital equipment supply environment.

In order to achieve the above aim the main research objectives are as follows:

- i *To establish the state of integration of a capital equipment supply chain within the case environment of the offshore oil exploration/production industry on the UK Continental shelf.*
- ii *To establish the influencing factors on lead time performance within the case environment.*
- iii *To derive and validate propositions about the influencing factors on lead time performance in a capital equipment supply environment.*

1.7 Research Questions and Propositions

Overall Research Problem

What are the influencing factors on lead time performance in a capital equipment supply chain?

Lead time performance is defined as the length, variability and responsiveness of the supply chain. Length is measured on the basis of average, shortest and longest lead time performance. Variability is the range of lead time from shortest to longest. Responsiveness is the ability of a supply chain to deliver the shortest lead time in an urgent case. The lead time is the time from initial order of equipment to its delivery.

Based on the literature review (summarised in 1.4 above) the following research questions were developed:

Research Question No 1

How does the design-to-order nature of the capital equipment supply environment influence lead time performance?

It would be expected that where there is more standardised design of assemblies or use of more standardised components, that this would result in improved lead time performance. It thus might be expected that companies with systems for design standardisation or complexity/variety reduction are more likely to achieve standardised design solutions. Also, companies that are pro-active and interested in design standardisation would be expected to be more likely to realise benefits from design standardisation.

This led to the following more detailed research questions:

Research Question 1.1 *How do design standardisation systems influence lead time performance?*

Research Question 1.2 *How do design standardisation attitudes influence lead time performance?*

Research Question No 2

Are upstream (supplier) factors more important than downstream (customer) factors in influencing lead time performance improvement?

This research question was added during the course of the empirical research. The initial assumption was that lead time performance was essentially influenced by upstream factors. Triangulation of preliminary interviews consistently brought out the influence of upstream 'pacing' components as being the main reason for long or variable lead times. (A 'pacer' is a component that effects the overall pace of the lead time in a particular supply chain. It is on the 'critical path' and any increase in lead time for this component will result in a consequential increase in the overall lead time for the particular supply chain). As research progressed, more and more data challenged this assumption and

indicated that downstream (customer) factors were more important in influencing lead time performance improvement.

Research Question No 3

How do supply chain systems and structures influence lead time performance?

It would be expected that supply chain systems that permit rapid feedback and communication of information would influence improved lead time performance. Also, contract structures based on long-term agreements with broad trading frameworks would be expected to lead to improved lead time performance.

This leads to the following more detailed research questions:

Research Question 3.1 *How do Information Communication systems influence lead time performance?*

Research Question 3.2 *How do Contract Structures affect lead time performance?*

Research Question No 4

How do supply chain relationships and infrastructure influence lead time performance?

It would be expected that a supply chain infrastructure based on a collaborative type would have a positive influence on lead time performance. Firstly, it would be expected that a supply chain culture of information-sharing would positively contribute to lead time performance improvement. Secondly, it would be expected that obligational-type contract relations would be an influencer of lead time performance improvement.

1.8 Summary of Chapters

Chapters 2, 3, 4 and 5 comprise the literature review. Chapter 2 critically analyses the literature on time-based approaches to supply chain improvement, relating this to the generic supply environment.

Chapter 3 reviews theory related to supply chain integration. It examines contributing factors to integration, staged models of integration and relates the integration issue to the generic capital equipment supply environment.

Chapter 4 examines the systems requirements and structural conditions necessary for the achievement of an integrated supply chain. Underlying systems theory is analysed, with particular reference to systems dynamics and the importance of information feedback. Design aspects of the structure of the supply chain are reviewed with particular focus on the strategic positioning of inventory. These concepts are related to the generic supply environment where more specific influencing factors of design standardisation systems, contract structures and information communications structures are evaluated relative to their potential impact on lead time performance.

Chapter 5 provides a critical analysis of the relationship issues and infrastructure influencing factors on lead time performance. Underlying dependency theory and transaction cost economics theory is examined and its related approaches such as lean supply, supplier positioning and the development of obligational-type relations within the supply chain. The effects of trust and power in supply relationships are evaluated and the importance of attitudes to information sharing is discussed.

Chapter 6 provides a definition of the generic case environment and compares the features of the non-repetitive supply chain with repetitive models. Industry-specific literature related to the supply chain in case context is reviewed and analysed relative to the analytical structure of the literature review in chapters 2, 3, 4 and 5. On the basis of

this analysis, a conceptual model is developed of the influencing factors on lead time performance and specific definition of systems/structure and relationships/infrastructure influencing factors developed.

Chapter 7 explains the philosophical basis for the research and reviews methodologies used in supply chain research. The adopted methodology for the study is justified and the detailed research design is explained.

Chapter 8 analyses the findings of a survey of customers within the case context. The purpose of this survey was to investigate the state of integration of the supply chain in the supply environment and the contributing factors to supply chain integration.

Chapter 9 analyses the findings of a structured mail survey of suppliers. The aim of the survey was to provide information on the following: [1] Benchmark lead times for the capital equipment supply environment; [2] Data on the nature of the product and the approach to product/process design; [3] Data on supply chain systems/structures; and [4] Data on the type of supply chain relationships.

Chapter 10 analyses the findings of 6 case studies representative of the generic supply environment under study. This was divided into two units of analysis based on the value and complexity of the products. Individual case analyses are provided and cross-case comparisons are undertaken within the individual sub-environments and for the environment as a whole.

Chapter 11 analyses the case studies in the light of the evidence from the surveys in chapters 8 and 9, addresses the research questions and validates propositions by cross-case triangulation.

Chapter 12 provides the conclusion to the study, derives a Types Model and a Process Model from the findings. Contribution of the study is evaluated, limitations of the research are discussed and the potential for ongoing research is considered.

2. TIME-BASED APPROACHES TO SUPPLY CHAIN IMPROVEMENT

2.1 Time-based Management

The use of time as a tool for management has been prevalent in manufacturing since F W Taylor and the Scientific Management School of the 1920's. The approaches of work measurement and time studies were mainstream until around the 1970's, when the methodology gained a measure of disrepute mainly due to its application to bonus schemes and piecework and its related industrial strife. Meantime, the Japanese adoption of Just-in-Time approaches to manufacturing is well known and documented.

The emergence of the importance of time into the strategic arena and as a contributor to the competitive advantage of organisations, has been a more recent theme in management literature. Drucker (1962) suggests that time is the "remaining source of competitive advantage", echoed by Stalk and Hout (1990) as the "next source of competitive advantage" and codified in their book "Competing Against Time" where time is seen as a "competitive weapon". Even the UK Institute of Logistics proposed a definition that puts time at the heart of Logistics "Logistics is the time-related positioning of resources" (Canadine, 1994) and the time-based approach has been applied to the supply chain by Wilding and Newton (1996). Barker & Helms (1992) note that "time is a universal scale of measurement which is easy to understand and quantify and, as such, can be applied in any organisation at any stage of its development".

Stalk and Hout (1990) suggest that a new generation of companies are emerging that obtain remarkable results by focusing on flexibility and responsiveness using the following methods:

- Using time as the critical management and strategic parameter.
- Using responsiveness to stay close to customers and increase customers' dependence on them.
- Directing value delivery systems to the most attractive customers; forcing the least attractive customers towards competitors.
- Setting the pace of innovation in their industries.

The results include faster growth and improved profitability, together with “baffling their competitors” at their speed of response and innovation. The management tasks that are required to achieve these results centre on making the value-delivery system “two to three times more flexible and faster” than the competition, together with determining how individual customers value variety and responsiveness, permitting a focus on those customers with the greatest sensitivity and pricing accordingly.

Stalk and Hout (1990) highlight the relationship between costs and the variables variety and complexity. A variety index can be calculated which is typically a function of the number of product families and the degree of vertical integration. The relationship between variety and productivity, unit costs and break-even can then be investigated. Research is presented on the “complexity slope” that can be discovered in a variety of businesses: as operating divisions or structures increase, overheads increase as a percentage of sales. The traditional optimisation attitude to volume and variety is that as volume increases, unit costs decrease; whilst as variety increases, unit costs increase; thus there is an optimal volume-variety mix zone that would minimise unit costs. Similar to the difference between traditional and TQM quality costs, it is postulated that the application of *flexibility* can flatten this curve and substantially increase the amount of variety that can be achieved at low unit costs.

Stalk and Hout present a set of “emerging” empirical rules, which they call their “*Rules of Response*”, summarised as follows:

- *The 0.05 to 5 Rule*

The amount of time required to execute a service or order is far less than the actual time that the service or product spends in the value-delivery system: most products and services are only receiving value for between 0.05 and 5% of the time. A study by Blackburn (1992) of white-collar administrative activities indicated that “only a tiny

fraction of the cycle time for administrative processes is actually devoted to activities that deliver value to the customer”.

- *The 3/3 Rule*

During the 95 to 95.95% of time a product or service is not receiving value, the product or service is *waiting*. Three components of waiting time have been isolated: (1) completion of batches together, including some ahead of time; (2) physical and intellectual work to be completed and (3) delays to decision-making.

- *The ¼-2-20 Rule*

That companies that attack the consumption of time in their value-chain achieve remarkable performance improvements: for every quartering of the time interval the productivity of labour and working capital can often double, which can result in as much as 20% reduction in costs.

- *The 3 x 2 Rule*

Growth rates for companies with time compression strategies are three times industry average and twice the average industry profit margin.

Time and customers

Stalk and Hout (1990) highlight the disruptive influence of demanding customers, who disrupt work schedules and cause other customers to wait, due to demanding non-standard products or delivery requirements. It is suggested that there are three choices available in response: (1) fight customers by forcing them to accept standard delivery performance; (2) insulate the organisation from customers by building inventory or in

service businesses by getting them to do their own work; or (3) embrace them and make sure they are more satisfied than they could ever have imagined.

Time and innovation

Stalk and Hout (1990) identify the relationship between complexity and time in product development. Several functions were identified as having the potential to delay the process at many stages. These were often 'support' functions, which would "gate" the process, forcing key activities to wait in queues until the support activity could perform its task. These support facilities added very little monetary costs but added substantial time costs.

Organisational Design and Time

People in time-based companies see themselves as part of "an integrated system, a linked-chain of operations and decision-making points that continuously delivers for its customers."

Time-based Performance Measures

Whereas many organisations may use terms like *lead-time*, *on-time delivery* and *response time* in describing customer service, time-based companies use time-based metrics as a diagnostic tool throughout the organisation.

2.2 Just-in-Time and Quick Response

Related to Time-based management is the large body of literature linked to Japanese management approaches, such as Just-in-Time (JIT). JIT approaches have linked with supply chain management in such concepts as Lean Supply (Womack et al, 1990;

Lamming, 1993) and to Logistics in the concept of Quick Response (QR) (Christopher, 1992).

Ferrin (1994) establishes a model of JIT Supply based on influencing factors on planning decisions and outcome variables. The model is based on an adaptation of 'channel theory', where he identifies sub-processes which are termed 'micro-channels'. Applied to three manufacturing companies, contextual factors such as *product complexity*, *production volume* and *product diversity* are identified as having an influence on JIT Supply implementation. The research also suggests that *organisational culture*, *organisational structure* and *evaluation/control systems* influence JIT Supply objectives and implementation. In one particular case, a clear distinction in responsibility and authority between corporate and assembly plant management resulted in a loss of supply management continuity, as none of the management control systems crossed that boundary.

The 'pull' orientation of JIT, as portrayed in the Drum-Buffer-Rope (DBR) technique, has the potential to support reduced manufacturing lead times according to Fry et al (1991). In DBR, inventories are only provided to accommodate upstream variations in workflow. Thus queues are limited to 'bottleneck' processes. By definition, excess capacity is not possible for bottlenecks. It is suggested therefore, that instead of using inventory to 'de-couple' processes, the DBR approach uses instead 'excess capacity'. The importance of *capacity* is also highlighted in the Davis & Manrodt (1991) concept of Service Logistics: "when the customer makes a request the traditional logistician checks inventory to determine whether the product is available, while the Service Logician checks *capacity* to see if the resources are available to deliver the desired benefit". The pivotal concept of the service era is that the value of these benefits is determined by 'fit' – the conformance of benefits to individual customer needs. The result is a responsive organisation which has firstly, highly skilled personnel to plan and schedule capacity and secondly, customer contact personnel who are able to diagnose customer requirements.

This concept of response is at the heart of the adaptation of JIT to the service sector: Quick Response (QR) (Christopher, 1992). Whiteoak (1993) and Fiorito et al (1995) identify both 'soft' and 'hard' pre-conditions for QR to work in the retail environment. Partnership between manufacturer and retailer is based on sharing risks as well as benefits on one hand; whilst on the other hand there requires to be understanding of the components that make up lead time, which included the use of technology such as barcode scanning, EDI and automatic replenishment systems. From the manufacturers perspective, Gehani (1995) identifies the importance of modular production to the improvement of time responsiveness. Waters-Fuller (1995) defines JIT Purchasing: "JIT Purchasing requires small but frequent deliveries of total quality parts from single sourced, local suppliers, with whom there is a close relationship grounded on mutual dependency and trust". There is, however, a suggestion that firms attempt to implement the easier aspects of JIT but fail to embrace more difficult issues such as long-term contracts, sole sourcing, data exchange and levelling schedules. The impact of proximity on JIT success is an interesting issue for the logistician and has been evaluated by Wafa et al (1996). The study indicated that as geographic distance increases, JIT success decreases and that JIT success is very much related to communication and information linkages. The study indicates that Supplier Certification programmes are important to fostering JIT success, as they tend to facilitate the establishment of technical specifications and the building of trust. Finally, the sharing of production plans was also found to be consistent with JIT success, which is consistent with other literature on this particular topic. Aspects of JIT purchasing such as suppliers' representatives working in customer firms (called JIT II) are highlighted by Pragman (1996) as an important part of the partnership required in this approach.

Logistics cost trade-offs, the stuff of traditional logistics costing, may come back into play in the JIT approach. Swenseth et al (1990) found that implementation of a JIT strategy led to logistics costs 27% higher than traditional strategies due to increased transportation, inventory carrying and expected stock-out costs. In simple terms, the reduction of in-process inventories was being supported by higher finished goods safety stocks. Tracy et al (1995) identifies bodies of literature that argue both ways with regard

to the impact of JIT on logistics costs. The Tracy study indicates that as a consequence of overall JIT ideology, modifications are prompted in supply operations. Inbound logistics operations improve as reliable, on-time, damage-free delivery of small shipments becomes commonplace. Theoretically, small and frequent deliveries of inbound supplies should increase transportation cost. In reality, organisations find ways of achieving the impossible and the study indicated that inbound transportation costs of JIT firms were actually *lower* than for non-JIT firms, due to innovative transportation methods. When other variables are added such as reduced in-transit inventories and the 'expected' stock-outs suggested by Swenseth et al (1990) in reality result in a lower stock-out situation, then the benefits in inbound logistics are obvious. It would seem, however, that the disagreement between writers on this issue may be due to differences between the benefits in inbound logistics compared to possible dis-benefits in outbound distribution. The benefits would thus be realised most importantly by A-type plants, where a large number of components make a small number of finished products, but may be less beneficial in V or T-type plants where the opposite is the case. In a V-type plant variety is built up gradually in the process to produce a large number of finished products, whilst in T-type plants a large product range is produced by postponing variety until the final stage of the process.

2.3 Strategic Lead Time Management

The extension of time-based management ideas throughout the supply chain is undertaken by Christopher & Braithwaite (1989) in the 'Strategic Lead Time Management' approach. This recognises the need to "look across the functions at the lead times between different elements of the organisation and to measure the time that is consumed and the 'value' that is added by the system as a whole". The approach suggests that there are two parallel tracks to be addressed: (1) throughput efficiency and (2) process efficiency. Throughput efficiency is related to the amount of inventory 'cover' required to support the supply chain. Process efficiency is the measure of the process cycle, with all the components being treated as additive. The approach emphasises the importance of information systems and their ability to provide 'visibility'

throughout the supply chain. Horscroft & Braithwaite (1990) suggest that the 'driver' of a company's logistics performance is the sequence of administrative and control processes.

The reduction of cycle time is regarded as a key logistics strategy by LaLonde & Masters (1994). This paper identifies that cycle time reduction will reduce the time that material is held in inventory and thus improve inventory turnover and in consequence return on assets; but also that cycle time reduction will impact on customer service by increased response times. The writers thus see supply chain efficiency and supply chain effectiveness strategies as complementary, but barriers of high complexity and lack of trust are seen as key issues. The importance of the development of logistics strategies based on time is emphasised by Persson (1991) who suggests that these areas have been poorly explored, analysed or conceptually developed.

The requirement to measure time-based performance is modelled by Barker (1993), using a similar approach to that of 'Strategic Lead Time Management': value-adding and cost adding activities are identified. This permits the identification of constraints in order of priority, allowing the longest periods of non-value-adding activity to be removed first. This approach links the identification of bottlenecks with the identification of waste.

Two main areas of focus for lead time improvement have been 'Design to Market Time' and 'Delivery Lead Time' (Christopher, 1992; Beesley, 1995). These two cycles become at least partially combined in engineer-to-order type markets. In addition, Christopher (1992) identifies two separate cycles that can be applied to either of the above: the 'Procurement to Payment Cycle' and the 'Order to Delivery Cycle'.

2.4 Time-based Process Mapping and the identification of Wasted Time

The mapping of Order Flow Logistics by Stalk & Hout (1990) takes the standard system of process mapping and centres it on the customer order flow. As in all improvement initiatives, a first step is to identify current practice. Wilding & Newton (1996) suggest

that conventional process mapping tools, such as IDEFO do not have a time base and thus are difficult to audit. They also suggest that these approaches tend to be “ a reflection of the local procedures manual rather than what people actually do”. The use of the Gantt Chart, well known in Project Management, was adapted by the Warwick Manufacturing Group to produce a Time-based Mapping Tool (Beesley, 1995). The tool centres on the visual display of value-adding and non-value-adding time, together with inventory cover (also measured on a time base in days of inventory). Braithwaite (1992 and 1993) maps cumulative cycle time against total turnaround time configured for both make-to-order and configurations based on make-to-stock or configure from sub-assembly modules.

The Warwick methodology and the Strategic Lead Time Management approach (Christopher & Braithwaite, 1989) both centre on the identification of ‘non-value-adding’ time. They agree with the “virtuous circle” suggested by Christopher (1992), viz: that time-based systems with an emphasis on speeding up process times result in a reduction in cumulative lead time; this results in lower inventory and thus a further reduction in response time. The application of the tool by Warwick Manufacturing has borne out the Stalk & Hout (1990) “rules” (discussed in 3.1 above) that value-adding time typically accounts internally for only around 5% of total time consumed and in a total supply chain context it can be as low as 0.1%. Beesley (1995) highlights the importance of the analysis of inventory in the Warwick methodology. In line with similar approaches, ‘stock cover’ is identified in terms of ‘days of inventory’, but the methodology also attempts to identify those elements of stock that are not related to ‘cover’, such as bottleneck stocks. Tersine & Hummingbird (1995) suggest, however, that consensus as to what actually constitutes wasted time is “far from unanimous”. For example, they suggest that inventory is considered waste in environments where cost is of high importance, but that that inventory is a form of value in high service level environments. Non-value-adding time is also classified within the Warwick methodology as follows: management indecision (waiting time), queue time (associated with a capacity constraint such as a bottleneck, set-up times, batch sizes or inventory storage) and re-work time (repeating a previous part of the process). Definitions of value-adding time are established based on three criteria: (1) that the process is physically changing the nature

of the item; (2) that this change produces something that the customer values and may be willing to pay for; and (3) that the process is 'right first time' and will not have to be repeated to achieve the desired result. The methodology can also include consideration of process capacity and complexity/variety, mainly by labelling the bars on the Gantt chart accordingly.

The Warwick methodology concurs with Braithwaite (1992) in the importance of the identification of the 'de-coupling point' where customer order demand meets production driven by forecast. This concept, also called the 'Order Penetration Point (OPP)' has been identified as an important issue for time-based management by Andries & Gelders (1995). This idea of the strategic positioning of inventory is a common theme of supply chain writers, including the idea of 'postponement' when the final configuration of the customer order is left to the last possible moment.

2.5 Critical Path and the Theory of Constraints

The application of the Goldratt et al (1990) 'Theory of Constraints (TOC)' to time-based improvements has tended to be used in internal optimisation of repetitive processes. In chains of 'supply to order' or 'engineer to order' types the OPP is clearly very high upstream in the process, if it exists at all. Some of these chains may even approximate to a full JIT 'pull-type' orientation, but without any of the consequential time-reductions. The benefit of the TOC approach is that it centres on the capacity issues that are so important in service-delivery processes and in 'make to order' environments. Barker & Helms (1992) note that "in using a time-based strategy, the objective is to reduce throughput time by removing constraints and bottlenecks so value is added for a much greater length of time than before". In line with previous writers they conclude that constraints are likely to be due to technology, control systems, poor communication or project weaknesses.

Tersine & Hummingbird (1995) suggest that the use of TOC within a continuous improvement framework will permit 'engineer-to-order' products to realise lead times comparable with 'make-to-order' products. The writers modify the Alderson (in Tersine & Hummingbird, 1995) 'multiple gap framework' to establish: *time gaps* (not available at required time); *space gaps* (not available at the right place); *quantity gaps* (not available in quantity that the customer requires); and *variety gaps* (customer requires more specific product or choice than available).

The contribution of "removing obstacles" to lead time compression is highlighted by Towill (1996), who records significant successes in reducing cycle times using this method. He concurs with Stalk and Hout (1990) that synchronisation of lead times and capacities is important. Rahman (1998) in a comprehensive review of TOC emphasises that TOC thinking views constraints as positive and that the existence of constraints represents opportunities for improvement. Rahman (1998) noted that the majority of studies tackled production problems in the manufacturing environment and there was little evidence of its application to purchasing.

Kumar & Motwani (1995) summarise a body of literature that focuses on measures for time-based competition, termed "Agility". They define this in a very narrow fashion compared to later literature as "the ability to accelerate the activities on critical path". The research identified determinants that influenced agility: (1) material/information flow disciplines ['pull' systems and minimal sourcing]; (2) computer-aided technology [Computer Aided Design/Computer Aided Manufacture (CAD/CAM) Electronic Data Interchange (EDI)]; (3) organisational/human resource factors [training, flexible workforce, flatter organisations, multi-skilling]; (4) Quality [Quality Function Deployment (QFD), Statistical Process Control]; (5) Flexibility [innovation, process flexibility]; and (6) General Factors [continuous improvement, value analysis].

2.6 Process Design Considerations for Time-based Improvement

The time-based approaches to the re-engineering of the supply chain are recognised by Hise (1995) as resulting from two basic ideas: (1) the elimination of wasteful steps rather than trying to complete them faster; and (2) the completion of steps in parallel instead of in sequence. Thus the best opportunities for time-compression result in processes with a series of sequential steps. The importance of the avoidance of delays due to slow decision making is highlighted by Percy Barnevik, CEO of ABB: "it is more advantageous to make a decision quickly, even if it turns out to be wrong, than to suffer the delay required to make certain the decision is right." (in Hise, 1995).

The issue of variety/complexity was raised by Stalk & Hout (op cit) as a key issue for time-compression. Cooper & Griffiths (1994) notes that in the automotive industry component variety can be created by market/legal/personal choice issues identified by the customer. Whereas some of these may be avoidable, further variety is created by a desire to reduce component purchase cost and also sourcing from a variety of suppliers. Cooper encapsulates the experience of the automotive manufacturers in single sourcing and reducing variety through a 'Rule of Three': (1) Increased variety tends to add to the complexity of logistics operations and so increases both direct and indirect costs; (2) Variety should only be increased when it contributes to added value; and (3) System redesign can enhance added value through reducing the cost impact of an increase in variety.

The differences between different industries has led to a contingency view of time-based competition proposed by Bozarth & Chapman (1996). In particular the difference between production configurations is recognised, viz: engineer-to-order; make-to order; assemble-to-order and make-to-stock. The differences in where to locate strategic buffer stocks is identified, with the buffer being forced upstream in the engineer-to-order scenario. The difference in management task upstream and downstream of the buffer barrier is identified. Upstream, efficiency and reliability are important as the planning and control systems are focused on the replenishment of the buffer barrier. At the

downstream (customer) side of the barrier, flexibility and responsiveness are paramount. Thus all processes upstream of the buffer barrier should be moved 'offline' so that they do not add to the customer order cycle. In contrast, downstream processes are 'online'; in that they can only be started once a customer order arrives.

Regarding the re-engineering of supply chains Tersine & Hummingbird (1995) identify that a key source of wasted time is the serialisation of activities that are actually independent of each other. They couple this with the non-synchronisation of activities that are, in fact, dependent on each other. The interaction at this upstream/downstream boundary (or order penetration point) has been studied by Forza (1996). Variables isolated in this study include: involvement of customers in product designs; involvement by customers on quality; JIT links with customers; open orders and EDI.

2.7 Supply Chain Structure and Network Sourcing

The fact that much of the research into supplier relationships has tended to be towards dyadic relationships is seen as a weakness by some writers (Harland, 1996). Harland suggests that the existing partnership/relationship literature "does not make visible any possible explanation that may be attributed to position in the Chain. Similarly, this body of research does not adequately recognise the significance of the network context." This has led to consideration of the application of network models (Hakansson in Harland, 1996). Harland investigates a number of supply networks within health supplies. A conceptual framework is developed based on: end customer; competitive priorities based on Hill's order/winning qualifying criteria); supply network structure (number, size, concentration of suppliers, etc); supply network infrastructure ('soft' control issues including quality, human resources, production planning, etc); and key concepts (service management, JIT, lean supply, project management, etc).

Hines (1994b) reports on the "Strategic Competitive Positioning Model" based on work at Cardiff Business School and its application in 'Kyoroku Kai'. This was earlier based

on the establishment of a “10-force Partnership Model” (Hines, 1993) and later developed in to the ‘Network Sourcing Model’ (Hines, 1996b).

Bhattacharya et al (1996) compares the vertically-integrated Japanese supply structures with multi-company structures exhibited in the West. The traditional Western supply chain, the writers suggest, involve much more sharing of suppliers at both primary and secondary levels. Battacharya suggests that western firms have adopted Japanese supply chain strategies without equal attention being paid to the supply structure. Opportunities are noted for outsourcing more value and changing the value boundaries within the supply chain: particularly related to involvement of suppliers in product and process design. However, there is a contention that unless the re-distribution of capabilities in the supply chain is matched with some equitable re-distribution of margins, that the structure will be unstable in the long run. Battacharya leaves us with a “structure conundrum” as to whether organisations should let industry structure emerge on the multi-customer pattern or play a more active role in forming a more vertical structure under which they have control.

Based on earlier writings, Cravens et al (1996) provides a classification of network organisations based on two variables: (1) the nature of network relationships from collaborative to transactional; and (2) the extent of environmental volatility. The result is four types of network: (1) virtual network; (2) value-added network; (3) hollow network; and (4) flexible network. Saunders (1995) concludes that the terms ‘chains’, ‘pipelines’ networks and ‘value streams’ are more fruitful if they are understood as metaphors and “ideal types” rather than “objective entities”. They are of value as heuristic tools to interpret situations.

Cooper and Ellram (1993) identify a key gap in the literature: that identified supply chain characteristics may have different levels of importance at different stages in the process. They identify appropriate areas for further research such as: How do supply chain members that are more than one level apart interact? How many levels of management are involved in interfirm activities? Are supply chains characterised by one strong leader

or does a multi-firm leadership approach also work? Are all hypothesised characteristics present in all supply chains to some degree or are there key drivers that must exist while others appear in varying combinations?

2.8 Supply Relationship Conditions for Time-based Improvement

The 'relationship' literature does not generally emphasise the time-based results of relationship improvement. This is perhaps not unexpected, as the measurement devices established by this school of thought tend to evaluate the relationship itself, rather than evaluating the *results* of relationship improvement. Within the Lean Supply literature, the link between the Lean Supply relationship and Just-in-Time (JIT) is evident. Lamming (1993) identifies that there are a number of misconceptions about JIT at the '*resolved model*' phase of Lean Supply (i.e. the stage before '*partnership*'). In particular, at this stage of development, organisations tended to view JIT in terms of lower inventory levels and increased delivery frequency, rather than the more fundamental principles of quality improvement, elimination of waste and motivation. Variations of JIT thus developed include the tactical transfer of inventories to suppliers, the use of 'consignment stocks' and the use of 'milk-round' component collection controlled by the assembler. Within the '*partnership model*', the move towards true JIT was regarded by Lamming as a responsibility for first-tier suppliers. Lamming also emphasises that "there is no evidence to suggest that close geographical proximity is a requisite part of lean supply" (Lamming, 1993, p198), although "managing logistics over long distances, including internationally, in a JIT manner, will remain an occasional requirement within lean supply". It was also noted that there has not been a clear preference for 'door-step' plants in Europe and North America.

The Partnership Sourcing approach of Macbeth & Ferguson (1994), draws more widely on 'systems-based' literature for its support, although the causal link between 'partnership' and systems improvement is generally implied rather than demonstrated.

Lead time in delivery and product development activities is discussed, as is serial and parallel working of processes. Lead times are also included within the 'Relationship Positioning Tool', but only within the 'information flow' evaluation.

2.9 Information Systems Pre-conditions for Rapid Feedback

The importance of fast and accurate information feedback on supply chain improvement is the main contribution of the 'Industrial Dynamics' school. The work of the Cardiff Industrial Systems Dynamics (CISD) Group and published by Towill, Naim and Wilkner (1992) is based on Burbidge and Forrester effects. The key criteria to improve this dynamic information exchange were identified by Evans, Naim and Towill (1993) as: (1) implementation of integrated information systems along the supply chain (essentially a technological step of simply implementing EDI and relatively straightforward software systems); (2) significant attitude changes in sharing information (which may only be achieved through partnerships).

In turn, Berry et al (1994) identified and modelled four distinct phases of re-engineering: (1) Reduction of lead time by JIT techniques; (2) Interplant planning and logistics integration via EDI; (3) Vendor integration linking suppliers directly using EDI especially to generate material "pull" signals; and (4) Time-based management providing an environment which encouraged integration of development and manufacturing personnel within the company and its vendors.

2.10 The Influence of Supply Types on Lead Time

The relationship between the design configuration of the supply chain and time-based approaches is evident in a number of areas. Sharman (1984) noted that the "Order Penetration Point" (OPP) would be different for different types of products and markets.

If competitive pressure is substantial, Sharman suggests that there shall be a greater incentive to provide better service by moving the OPP downstream and increasing the range of models available from stock. The greater the cost and complexity of the products, the incentive will reverse to move the OPP upstream. Braithwaite (1992) contributes with a similar concept regarding identification of a suitable "*Point of Engagement*" (i.e. the order is fulfilled from the point in the organisation consistent with the lead time that the customer requires). Braithwaite, Christopher (1992) and Berry et al (1994) all identify the importance of the '*Decoupling Point*' as the point in the supply chain where strategic inventory should be held. The extremes of the argument are highlighted by Berry: (1) Hold the inventory early in the chain (less value added and less customer configuration); or (2) Hold inventory as close to the customer as possible (this ensures the quickest service, but the service will only be quick and efficient if the correct materials are stocked).

The use of I-V-A-T analysis is considered by MacBeth et al (1994) and Hines (1994a) as a means of representing the different patterns of material flow. 'I'-shape is a unidirectional flow of multiple identical items (such as in process plants); 'V'-shape has limited raw materials at the input stage resulting in a diverging pattern with variety gradually building up in the transformation process; 'A'-shape has numerous raw materials with a converging pattern towards a very limited variety of finished product; and 'T'-shape establishes a simple I-shape until the last possible moment when products are configured to high variety.

2.11 A Preliminary Conceptual Model of the Influences on Lead Times in the Supply Chain

A preliminary conceptual model for the investigation of the generic supply environment under study (engineer-to-order high value capital equipment) would appear to have the following variables:

Dependent Variables

The dependent variables that will determine Delivery Lead time Performance (the study is not attempting to investigate product development lead times) shall be:

- *length* (the normal lead time)
- *variability* (the range of possible lead times from longest to shortest)
- *flexibility/agility* (the ability to respond to an emergency request for a substantially reduced lead time).

Independent Variables

From the literature review it is proposed to classify the influences according to:

- *Supply Chain Integration*

Reviewed in further detail in Chapter 4 (Supply Chain Integration).

- *Supply Chain Systems*

Reviewed in further detail in Chapter 5 (Supply Chain Systems).

- *Supply Chain Relationships*

Reviewed in further detail in Chapter 6 (Supply Chain Relationships)

Finally all the above require to be investigated upstream and downstream from the capital equipment manufacturers.

2.12 Summary of Literature Relevant to Time Based Approaches to Supply Chain Improvement

An influential contribution to emphasising the importance time-based management to industrial competitiveness is provided by Stalk & Hout (1990). Literature on Just in Time, has been adapted to the supply chain in concepts such as Just in Time Supply (Waters-Fuller, 1995), Lean Supply (Lamming, 1993), Quick Response (Christopher,

1992; Fiorito et al, 1995) and Efficient Consumer Response (Whiteoak, 1993). Methodologies to improve the supply chain from a lead time point of view include Order Flow Logistics (Stalk & Hout, 1990), the Warwick Time-based Mapping Tool (Beesley, 1995), Strategic Lead Time Management (Christopher & Braithwaite, 1989; Horscroft & Braithwaite, 1990; Christopher, 1992), and Pipeline Mapping (Scott & Westbrook, 1991). Underlying theory on the optimisation of flow rates is the Theory of Constraints (Goldratt & Cox, 1986) applied in engineer-to-order supply chains (Tersine & Hummingbird, 1995).

On the basis of this literature review a model with three variables as categories of influencing factors has been developed: [1] Supply Chain Integration; [2] Supply Chain Systems; and [3] Supply Chain Relationships. These factors shall be investigated in more detail in the literature reviews in Chapters 3, 4, and 5.

3. THE INTEGRATED SUPPLY CHAIN IN A CAPITAL EQUIPMENT SUPPLY ENVIRONMENT

3.1 Introduction

The importance of integration of the supply chain has been a key theme since early normative articles. A seminal article by LaLonde and Mason (1990) considering logistics perspectives for the 1990's had a proposition that logistics decision-making would increasingly shift from an internal corporate focused activity to a boundary spanning external view.

3.2 Organisational Structure Issues

In an analysis of U.K. industrial firms, Burns and Stalker (1966) suggest two forms of organisational structure: [1] The mechanistic system: rigid and more appropriate to stable conditions: and [2] The organic system: more fluid and appropriate to changing conditions.

Summarising the characteristics of mechanistic and organic organisations, Litterer (1973), notes the wide network basis of authority and communication in the organic structure and links it with the need for lateral interaction. The fact that many organisations are a mix of the mechanistic and organic to reflect a hybrid structure was suggested by Wilkins (1987), where senior staff may act in a bridging role between groups because his position in the hierarchy both permits and enables this role to be undertaken. The concepts of 'differentiation' and 'integration' were investigated in an empirical study by Lawrence and Lorsch (1969). Their view of integration as "the quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment" is a useful definition that merits testing in the materials supply environment.

The contingency approach to organisational design suggests that there is no one universal structure for organisations. The approach takes an 'if-then' orientation based on suiting

structure to factors and conditions such as size, technology and the business environment. Pfohl and Zollner (1987) extend this approach to the organisation of logistics. The logistical overlay of production, environmental and organisational contingencies is examined by these writers from the point of view of logistics and they suggest that it should be possible to test contingency factors empirically and define them in such a way that is relevant to the design of logistics tasks in an organisation.

In the context of the supply chain, Jones and Riley (1985) highlight that the barriers to integration are due to the fact that the objectives and measures of functions are fundamentally in conflict. Inventories are “owned” and managed separately and thus the impact of inventory on the achievement of customer service will be related to the functional benefit rather than the overall perspective. Authors such as Gattorna et al (1991) go so far as to suggest that traditional supply chain thinking is a theoretical “myth” that has rarely been realised in practice. Kathawala and Nauo (1989) concur that integrated materials management is more of a concept than an organisational form. Like Gattorna, they highlight the fact that organisational hierarchies are based on power and personnel relationships that are resistant to changes in the patterns of decision-making. The study of the concept, they conclude thus requires an 'holistic' approach. The contingency approach has also been adopted by Christopher (1986) where considerations such as task predictability, complexity and product group autonomy must be embraced by logistics organisation structures, giving rise to the use of matrix forms of organisational structures. The problem here would appear to be that traditional models of organisational structure are predicated on communication systems that pre-date the development of the information network. Local Area Networks (LAN's), Wide Area Networks (WAN's) and the opportunity to communicate outside organisational boundaries using Electronic Data Interchange (EDI) and the Internet create the opportunity for complex communication webs which may have little to do with the formal organigrams of organisations.

3.3 Staged Models of Integration

Consultants have been propounding models of staged progress to supply chain integration throughout the 1980's and 90's. Kearney (1995) propose a 4-stage model and Stevens (1989), of the (then) Peat Marwick McLintock suggests similar. The four stages are the non-improved baseline position, the move towards functional integration and then an internally integrated supply chain and finally the external integration with customers and suppliers. Stevens (1989) notes that the final stage not only means a change in scope but a change in attitude from the adversarial to one of mutual support and co-operation.

Empirical work on investigating and measuring integration is not substantial, but four approaches will be examined for their usefulness. The first three are US-based studies and the fourth based on work by Cranfield University in the UK:

Customer-service Support System (Williamson, Spitzer & Bloomberg, 1990)

Total Cost Analysis Approach (Larson, 1994)

Stages Paradigm (McGinnis & Kohn, 1990)

Supply Chain Integration and Performance (Armistead and Mapes, 1993)

Customer-service Support System

The operational framework for this approach draws on the early models that the writers adapt to provide a conceptual model of the Customer Service Support System. They suggest that "the output of logistical performance *is* customer service" (the italics are in the original quote). Although the authors indicate that these service levels will be different, depending on whether the organisation under study is a low-cost supplier or a firm differentiating itself competitively on superior service, they appear not to highlight the related requirement for resource productivity. The authors divide the supply chain into three distinct operating areas: materials management, conversion management and distribution management. They suggest that each of these relationships is created and

sustained by five logistics functions: transportation, facility structure, inventory, material handling and communications/ information.

They note that the five functions are not discretely identifiable, but they go on to apply 23 specific activities, based on frequency of mention in literature. The empirical study attempts to aggregate the 23 activities into the five functional groups and attempts then to measure the degree of control exercised over these groups by specialised management in a sample of member firms of the Council for Logistics Management (U.S.A.). The research was conducted by Likert style opinion questionnaire.

Total Cost Analysis Approach

Larson (1994) notes that the two prominent concepts in business logistics literature are: integrated logistics management (I.L.M.) and Pipeline or Supply Chain Management. Larson's research centres on the inter-organisational functional integration between buyer and supplier. The Total Cost Analysis (TCA) approach attempts a performance measure for logistics based on the costs of performing logistics activities in such a way that customer service objectives are achieved. Reviewing the literature, Larson identifies three areas of conceptual background for the functional integration construct: [1] Channel co-operation; [2] Integrated Logistics Management (I.L.M.); and [3] Just in Time (J.I.T.). Larson postulates that these three all support the view that "More inter-organisational functional integration yields lower total costs". The measurement is based on total cost approaches such as the 'Total Cost of Ownership Model'. Larson's empirical study included three scales (see Table 3.1).

A	Functional integration - between departments	Engineering; Inventory control; Manufacturing; Marketing; Quality control; Transportation
B	Functional integration - co-operative sentiments	Unity of purpose; Mutual respect; Co-ordination of effort; Mutual trust; Detailed communication; Teamwork
C	Perceived Total Costs	Inventory carrying; Transportation; Order processing; Back-order; Inspection; Rework; Scrap; Purchase price

Table 3.1: TCA Approach Scales (from: Larson, 1994)

Although scales A and C fall outwith the scope of the present study, the study is valuable in that it attempts to move beyond the more basic structural aspects of organisational integration with its consideration of co-operative sentiments (scale B).

Stages Paradigm

The perspective of staged development of logistics activities was discussed by Bowersox in the 1970's. These ideas have been embraced by practitioners such as Stevens (1989) and A T Kearney (1995) who have constructed normative models of a staged development towards the externally integrated supply chain. Stevens' model has 4 stages (see Table 3.2), but it is only at stage 4 that integration extends outwith the organisation.

Stage 1 (Baseline)	staged and fragmented inventories; independent and often incompatible control systems; organisational boundaries.
Stage 2 (Functional Integration)	emphasis on cost reduction rather than performance improvement; discrete business functions buffered by inventory; time-phased MRP techniques; orders are still "thrown over the wall" to manufacturing (i.e. distribution is 'decoupled' from manufacturing).
Stage 3 (Internal Integration)	integrated planning and control system; Distribution Resource Planning (DRP) systems integrated to MRPII; use of Just in Time (JIT) where applicable; full systems visibility from distribution through to purchasing.
Stage 4 (External Integration)	extension of integration to suppliers and customers; move from product to customer orientation; use of Electronic Data Interchange (EDI); change of attitudes from adversarial to mutual support and co-operation.

Fig 3.2: Integration Stages Model (from; Stevens, 1989)

Academic work on this "Stages Paradigm" can be traced in empirical studies by McGinnis and Kohn (1990) through to studies by Farrell (1985 and 1987).

The research is useful in a number of ways. Firstly, it attempted a factor analysis of logistics strategy which was then cluster analysed in terms of 'integrated strategy'. The link between "stage" and "strategy" was then investigated and the study concluded that

the two were independent of each other. The definition of the stages paradigm is important, however, because it is based on the range of logistics activities reporting to a single executive. Thus, 19.4% of firms were found that had achieved high levels of logistics co-ordination, integration and effectiveness without moving *organisationally* from Stage 1 and this figure rose to 69.4% that had achieved these attributes at Stage 3.

Bowersox and Daugherty (1987), suggest that the Stages Paradigm may be appropriate in process industries, but that in market-oriented and information-oriented industries the paradigm did not fit. Although McGinnis and Kohn (1990) conclude that this evidence, together with the previous findings of Bowersox and Daugherty (1987), throw doubt on the usefulness of the Stages Paradigm, it would appear that an overlay of organisational understanding, such as the identification of the nature of the organisation on such as the Litterer (1973) continuum of mechanistic/organic, might bring further understanding.

McGinnis and Kohn's findings (1990) on the Value Chain Model leave little doubt that value chain and value linkages play a major role in logistics strategy, although the means of co-ordination (information systems integration, daily interpersonal contact, periodic meetings, co-ordinated planning process) is variable and appears to require a combination of approaches to be used simultaneously. The findings related to "time responsiveness" confirm this to be a significant component of logistics strategy and the authors suggest that over-structuring of co-ordination and integration may inhibit the ability of the system to respond to changing needs.

Supply Chain Integration and Performance

Clearly, although the integration issue features widely in logistics literature and there is an assumption that it is beneficial from both an efficiency and an effectiveness point of view, there is a paucity of empirical evidence to support this contention. Armistead and Mapes (1993) have undertaken a survey of managers from companies that participated in the UK Best Factory Audit conducted by Management Today and Cranfield School of

Management. The hypothesis being tested was that: Improved manufacturing performance is associated with higher levels of integration across the supply chain. Evidence of integration was identified by a number of factors and also by evidence of the use of integrative techniques and practices (see Table 3.3).

<i>Evidence of integration was identified by the following factors:</i>	<i>The use of techniques and practices by operations managers was also considered as evidence for integration:</i>
<ul style="list-style-type: none"> ● shared ownership of the master production schedule ● level of adherence to manufacturing plans ● job titles spanning traditional functions ● integration of information systems ● visibility and spread of information 	<ul style="list-style-type: none"> ● <i>planning techniques:</i> MRP, MRP II, DRP ● <i>partnership practices:</i> EDI, sharing call-off plans with customers and suppliers, delivery to the point of use, supplier self-certification ● <i>performance improvement practices:</i> set up time reduction, TQM, SPC, use of bar-coding

Table 3.3: Integration Factors (from: Armistead and Mapes, 1993)

Managers were also asked to indicate their plant performance on a number of criteria relating to quality, delivery, flexibility, and price relative to the competition. The research findings indicated support for the hypothesis. An encouraging link was found between performance and integration factors which are designed to share information through a supply network or value chain and some evidence was found that this process may be helped by organisational re-structuring which creates jobs with wider spans along value chains.

Supply Chain Integration and Effectiveness

Scott and Westbrook (1991) suggest a series of actions for the achievement of an effective supply chain, many of which concur with the thinking of Armistead and Mapes (1993). The common purpose of these actions is to act on the physical material flow to

the end user or the "backwards" information flow along the chain of organisations and processes. Suggested actions are as follows: set-up time reduction; layout; pull (Kanban) system; handling methods; shared forward call-off plans; quicker and more accurate data capture; combining processes; resequencing processes to postpone variety (variety funnel); rationalisation of product design (component rationalisation); EDI; JIT supplies (more frequent, smaller deliveries).

3.4 Summary of Relevant Aspects of Literature on Supply Chain Integration

The literature on organisational structure issues and the contribution of information systems to integration in 3.2 and 3.3 above tends to take an ‘internal’ view of the supply chain. Although these are an important backdrop to understanding supply chain integration, it is the literature in 3.3 on staged models of integration that takes the debate into the wider, cross-organisational, supply chain arena. It is from this literature, therefore, that the relevant theory to underpin the investigation of integration within this study shall be drawn.

Three themes are evident that would characterise inter-organisational integration of the supply chain: [1] the use of information communications systems; [2] the existence of co-ordinating mechanisms; and [3] the existence of co-operative relationships. The themes are analysed in Table 3.4.

	<i>Information Communica- tions Systems [1]</i>	<i>Co-ordinating Mechanisms [2]</i>	<i>Existence of Co-operative Relationships [3]</i>
McGinnis & Kohn (1990)	“information systems integration”	“daily interpersonal contact, periodic meetings, co-ordinated planning”	
Armistead & Mapes (1993)	“EDI”	“sharing call-off plans, delivery to point of use, supplier self-certification”	
Stevens (1989)	“EDI”	“move from a product to a customer orientation”	“change of attitudes from adversarial to mutual support and co-operations”
Larson (1994)		“co-ordination of effort, dedicated communication, teamwork”	“unity of purpose, mutual respect, mutual trust”

Table 3.4: Analysis of Integration Literature

It can be seen that McGinnis & Kohn (1990) and Armistead & Mapes (1993) tend to take a more 'systems-based' approach to integration detailing the requirement for information systems and organisational co-ordination mechanisms. Stevens (1989) and Larson (1994) take the debate a little further, including the need for co-ordinating 'relationships' based on mutual co-operation by the members of the supply chain. These themes shall be taken up in more detail in chapters 4 and 5 respectively.

3.5 Possible Differences in the Capital Equipment Supply Environment

The majority of the research that underpins the theories analysed in 3.4 above is based on a range of different industries, but with a possible bias towards repetitive manufacturing. The capital equipment sector has already been identified as high value, less-repetitive and as design and/or make-to-order. It is the area of 'repeaters' and 'strangers', rather than 'runners' in the production process. In this environment, it is postulated that there may be some differences in the nature of and effect of the identified integrating mechanisms.

With regard to theme [1], where investment and payoff is required in information systems to provide communication between customers and suppliers (and vice versa), this is less likely in the capital equipment supply environment. Electronic Data Interchange (EDI) and its related protocols are more highly developed in centralised and highly repetitive supply environments, such as in retail food or automotive sectors. The existence of cross-sectoral protocols such as EDIFact will clearly permit more low-cost inter-computer communication as will the growth of the internet. Turning to theme [2], the frequency of interpersonal contact is likely to be reduced in a less repetitive supply environment. The willingness to devote time to regular meeting schedules or cross-organisational teamwork is likely to be lower in a capital equipment environment due to the reduced payback for the investment of time necessary for these co-ordinating mechanisms. On the other hand, where the value of the equipment is high, the ability to invest time in co-ordination may be ameliorated. Finally the relationships in theme [3] are likely to be built up on the basis of regular communication and co-ordination and thus these are likely to be built up more slowly in a less repetitive environment. Again, where equipment value is high, it is more

likely that relationships may have the opportunity to build towards more co-operative modes.

Further discussion of the generic nature of the Capital Equipment supply chain systems and structures is provided in 4.9.

4. INFLUENCES OF SUPPLY CHAIN SYSTEMS AND STRUCTURES ON LEAD TIME PERFORMANCE

4.1 Introduction

In Chapter 3 the pre-requirements for an integrated supply chain were discussed. The key aspects of the integration concept related to the co-ordination and communication of information and material flows within organisations and across organisational boundaries. This chapter will examine the systems conditions and structural requirements necessary for this integration to be achieved. In both information flow and material flow there are clearly different types and configurations of possible systems which provide the structural aspects of the supply chain. The literature is examined to identify underlying general and more specific theories related to supply chain systems. The time-based implications of these systems is examined, in particular, those related to lead time performance. Finally, the nature of the capital equipment supply environment is classified and the specific systems and structures issues in this environment are critically examined.

4.2 Philosophical Foundations in Systems Theory

The utility of Systems Theory as a philosophical basis for supply chain research lies in its definition as the application of logical thinking to the structure of "wholes". One of the founders of the approach, von Bertalanffy (1950), was a biological scientist and the recognition by biologists and psychologists that the clarification of the "problem of wholes" was essential for progress in the understanding of organisms was identified by Angyal (1941). The awareness of this problem led to the discovery of general principles formulated by the *Gestalt* psychologists, the most common thesis being: 'The whole is greater than the sum of its parts'. Angyal goes on to formulate this statement clearly differentiating between the aggregation of parts and the situation in 'wholes' where parts are arranged in a system.

The development of systems thinking in pure science also centred much around the concept of 'equilibrium'. Koeler (1938) considered the advisability of comparing the 'normal state' of an organism with an 'equilibrium' in physics. The inconsistencies between biological and the more abstracted physical systems led to the concepts that systems could be classified as 'open' or 'closed'. An explanation of the difference between the two is provided, as follows:

" A system is closed if no material enters or leaves it; it is open if there is import and export and, therefore, change of components".

(von Bertalanffy, 1950).

It is possible, therefore, for the term 'system' to cover a wide range of phenomena. Some of these are conceptual constructs, whilst others are physical entities. Ackoff (1960) proposed that systems research was only concerned with 'behavioural systems' which are subject to control by human beings and he thus excluded from systems research such systems as the 'solar system'. Ackoff's 'behavioural system', however, was one which included both conceptual construct and physical entity depending on the way it was conceptualised.

4.3. Symbolic Representation of the Supply Chain System

In order to understand system behaviour, the first step is to attempt to represent the system itself, the parts that make it up and how these parts are linked. The main technique used is the flow diagram, which has its roots in the systems approach to Operation/Production Management and derives from Method Study. The Flow Diagram and its near relative, the Flow Process Chart, was a simple representative tool developed from the work on Method Study. The purpose of the chart was firstly to record sequence of work methods and secondly to classify and analyse the work content. These diagrams have been adapted to the more specific requirements of the supply chain to produce pipeline diagrams and time-based activity maps which shall be discussed in detail later.

4.4. The Supply Chain as an Open System

The supply chain has been defined as an 'open' system because of its clear interaction with the external environment of the organisation. Thus another area in which systems thinking may assist supply chain understanding is in the nature of 'open' systems. Perhaps the most important characteristic of systems theory for supply chain systems is the characteristic of "information feedback". It is this feedback that enables the system to correct its own malfunctioning or for changes in the environment in order to maintain homeostasis. Secondly, the understanding that this homeostatic balance is a dynamic rather than a static one will have an impact on the research methods used to obtain Supply Chain understanding. Thirdly, the consideration that open systems are characterised by the principle of equifinality will draw the Supply Chain researcher towards the use of comparative analysis in the examination of differential initial conditions and paths of development towards the model of an effective Supply Chain system.

4.5 Optimisation Models within the Supply Chain

Optimisation theory has been used for the construction of models based on mathematical constructs. Variables are selected and assumptions made which by nature simplified reality to permit understanding. Problems arise due to the mechanistic application of optimisation theory and the failure to properly take into account that the models constructed were a simplification of reality. Ackoff (1979) summarises the reality of the situation, most successfully, as follows:

"The optimal solution to a model is *not* an optimal solution of a problem unless the model is a perfect representation of the problem, which it never is. Therefore, in testing a model and evaluating solutions derived from it, the model itself should never be used to determine the relevant performance measures." (Ackoff, 1979).

Optimisation Models

The use of optimisation models of safety stock levels has received widespread attention in literature. The requirement to plan a level of safety stock becomes necessary due to demand uncertainty, coupled with the additional protection that safety stock provides against forecast inaccuracy and production/supplier delays. Basic models of safety stock use normal probability distributions to establish confidence levels, generally known as stock service levels. The fact that these systems fail is clearly exhibited in the fact that this term has been extended to a range of 'failure' measurements suggested by Hill (1990) as suitable for the retail environment. These 'stock service levels' measure instead the amount of demand lost during stockouts. The other main variable, of course, is the order quantity or lot size. Traditional abstracted models for Economic Order Quantity (E.O.Q.) deal with the simple trade-off between the two variables of 'Ordering Cost' and 'Holding Cost', the inadequacies of which are well documented, including the often erroneous assumption that these costs are known in the first place. The use of independent demand assumptions in models for optimising inventory is widespread and research by Zinn & Charnes (1992) is helpful in highlighting the need to examine demand patterns when using these as possible building blocks towards the construction of Supply Chain models.

The inadequacy of cost minimisation models for inventory investment has been highlighted by Nyerges (1992), who provides a conceptual framework viewing inventory investment decisions as a series of problems to be resolved by a range of tools which can be finally consolidated using standard risk/return considerations. This work, based on the study of raw material stocks, includes the aspect of price variability, cash flow considerations and the consideration of futures: practical issues which are seldom considered in logistics. The work has yet to be generalised towards an overall optimal solution, but highlights the complex issues that are involved in any holistic view of the Supply Chain.

The fact that Supply Chain research has taken an 'optimisation' route is perhaps not all that surprising as the development of the Supply Chain Concept in many ways mirrors

the development of systems theory on which it is based. Supply Chain research and practice has emanated from the Purchasing/Procurement, Logistics/Distribution activity and also from Production/Operations Management activities. Early research centred on the optimisation of inventory levels and location within the chain and the enabling means of Information Systems to support these models. The fact that the largest body of Logistics research has been published in this area is perhaps not surprising, as the adoption of the principles of the management science on which the research is based was already well advanced in Production/Operations Management. This is particularly the case in academia in the U.S.A. where academic journals appear to attract abstracted mathematical models in abundance. However, most serious research, as Rushton and Saw (1992) remarked, has been completed at the level of individual parts of the chain, rather than at the 'holistic' level demanded to achieve understanding of the linking or integrating benefits that lie at the heart of the concept.

Bowersox and Closs (1989), in a review of simulation practice in Logistics Research, highlight the difference between Analytic/Optimisation methodologies and Heuristic models. The primary difference between the two is, firstly, in the degree of mathematical precision and secondly, in practicality when utilised in complex situations. Analytical/Optimisation approaches are clearly more precise than heuristic models, but the latter provide greater capability to replicate complex problems.

4.6 Dynamic Models of Supply Chain Behaviour

The essential difference between static and dynamic modelling is that in dynamic modelling the model is adapted and amended by feedback mechanisms over time. Computer simulation gives the benefit of asking "what if" questions without disturbing the behaviour or performance of the system under study. Whereas the static models previously mentioned can be simulated in a deterministic fashion, probabilistic simulation provides another dimension. Process times within the system can be generated using computer-based random number generators within pre-determined

probability distributions. Basic logic has to be determined and the model can be expanded to accommodate increased complexity and level of detail. Problems remain with the validation of the model to "real" circumstances and it should be remembered that no matter how realistic the results, they are still artificial. The benefit of simulation, however, is the ability to cope with complex systems. It is interesting to note that Sussams (1992) when writing a chapter on strategic models in his book "Logistics Modelling" uses heuristics and optimisation, but never mentions simulation.

Systems Dynamics School

The impact of information systems on Dynamic Supply Chain Performance has been substantially investigated by the Cardiff Industrial Systems Dynamics (CISD) Group and published by Towill, Naim and Wilkner (1992). The thinking is based on the "Law of Industrial Dynamics" and the postulation of Burbridge (1987 in Towill et al 1992): "if demand for products is transmitted along a series of inventories using stock control ordering then the demand variation will increase with each transfer". The Forrester (1961 in Towill et al 1992) model is used as a benchmark.

Later work by Evans, Naim and Towill (1993) demonstrated a 73% reduction in on-costs and a 50% improvement in manufacturing lead time from the implementation of integrated information systems along the supply chain, essentially a technological step of simply implementing EDI and relatively straightforward software systems. A second strategy of feeding forward the actual customer demand to all the players in the chain secured an 88% reduction in on-costs. Less costly in technological terms, Evans et al (1993) concluded that parting with this information requires significant attitude changes which may only be achieved through partnerships.

The Cardiff Framework for Supply Chain Design is mapped out conceptually by Naim & Towill (1994) and clearly establishes a qualitative and quantitative phase to the process: [1] Qualitative Phase: material flow analysis; information flow analysis; production control/analysis; and [2] Quantitative Phase: control theory techniques; computer simulation; statistical analysis. The framework thus encompasses the use of "soft"

systems analysis with "hard" systems design to provide a structured approach to supply chain design.

The importance of dynamics to the understanding of supply chain behaviour is underlined by Berry, Towill & Wadsley (1994) in their work on electronic product based supply chains. Referring to the pioneering work of Forrester (1961 in Berry et al 1994) on the poor dynamic behaviour of supply chains due to 'demand amplification'; Berry suggests that quantified evidence for the amplification effect is meagre, considering the enormous overstocking costs that it indicates. An explanation of supply chain behaviour is provided by the construction of a 'causal loop model of supply chain behaviour'. Ongoing work is suggested in extending this review to reveal common properties and distinctive features of the electronic product based supply chain. The use of the causal loop model together with simulation models are suggested as essential steps in this process, together with the further step of comparing with other market sectors.

The approach uses dynamic models of supply chains and to test them to establish improvements possible under both "normal" and "uncertain" conditions. The results of improvement of the chains through re-engineering can then be evaluated. Berry has identified and modelled four distinct phases of re-engineering: [1] Reduction of "door to door" manufacturing lead times by JIT techniques (50% improvement within a 10 year period); [2] Interplant planning and logistics integration (linking all MRP systems via Electronic Data Interchange (EDI), resulting in a reduction of information flow delays throughout the chain of 75%); [3] Vendor integration linking suppliers directly using EDI especially to generate material "pull" signals; [4] Time-based management providing an environment which encouraged integration of development and manufacturing personnel within the company and its vendors and led to further improved ordering and distribution systems. The modelling indicates large reductions in demand amplification at each phase of re-engineering. A 'rule of thumb' reduction from a peak of 16:1 with a baseline of 4:1 reducing after the four stages to 1.35:1.

Systems Dynamics thus provides an interesting insight into supply chain behaviour and is a key theoretical basis for the study of lead times in the supply chain. However, its utility is fundamentally rooted to the behaviour of repeatable and cyclical systems. The approach is thus primarily suited to the study of repeated or cyclical environments, rather than design/engineer to order environments, where one order cycle may be different from the next. Aspects that appear suited to this study, however, are the Berry et al (1994) approach to the systematic examination of a chain through a key “active” component.

4.7 Design Aspects of Supply Chain Systems

Aspects of supply chain design that are appropriate for understanding differentiation in supply chain structure return the debate to the consideration of material flows, the information flows that support them and the strategic location of inventory at various points long the supply chain.

Supply Chain Complexity and Order Decoupling

One line of thought in relation to the interaction between the twin flows of information and materials has been the concepts of the order penetration and the de-coupling point. This considers how far customer or supplier information penetrates into organisations and at what point, and in what form, material stocks are located within the chain.

The complications in the order cycle have been illustrated by Sharman (1984) in his view that the "Order Penetration Point" (OPP) will be different for different types of products and markets. His thesis is that an optimum logistics configuration depends on a balance between competitive pressure, product cost and complexity. If competitive pressure is substantial, Sharman suggests that there shall be a greater incentive to provide better service by moving the OPP downstream (towards the customer) and increasing the range of models available from stock. The greater the cost and complexity, the incentive will reverse to move the OPP upstream (towards the supplier).

Berry et al (1994) suggest that there are two conflicting ideals that require to be balanced when considering the point at which to locate stock in the supply chain:

1. Hold the inventory early in the chain.

This ensures that least value has been added and thus the allocation of inventory can possibly be redirected towards another product. Whilst a useful consideration in the context of Berry's study of Electronic supply chains, the suitability for less repetitive chains requires more detailed consideration. In a totally new concept design-to-order product, the ability to hold any but the simplest of consumable componentry may be impossible.

2. Hold inventory as close to the customer as possible

This ensures the quickest service, but the service will only be quick and efficient if the correct materials are stocked. At the higher (assembler) tiers of a capital equipment supply chain finished goods stock is impractical, both due to the value of the finished product and also the 'special' nature of individual customers' requirements.

Berry notes that the de-coupling point concept can be helpful in determining both where and in what physical form stock should be held to best systems advantage. Determining that the extremes of 1 and 2 above are unlikely to be a suitable supply chain design for the capital equipment environment, the possibility of stockholding at some intermediate point remains worthy of consideration. The other consideration that requires some thought is the extent to which this concept is transferable across organisational boundaries along the supply chain.

Information Flow to support the Order Penetration Point

The implications of the information support for the OPP integration on the information systems that support such a regime are analysed by Braithwaite (1992), where the application of the time-based simulation tool (Horscroft and Braithwaite 1990) are highlighted to have implications for organisational design. The two areas of prime importance from a time perspective are:

1. *Point of Engagement*: that the order should be fulfilled from the point in the organisation consistent with the lead time that the customer requires.
2. *Decoupling Point*: the point in the supply chain where strategic inventory should be held.

The Decoupling Point approach implies different points for each product and market conditions as distinct from the standard forecast-driven safety buffers in standard material requirements planning systems. This is the point where customer demand (pull) meets the forecast-driven stocks (push). The consequent supporting information systems must permit access and execution throughout the chain: the achievement of the 'visibility' highlighted as so important by Christopher (1992). A similar concept can be found in the Customer Order Decoupling Point, derived from the empirical work of van Amstel (1990).

Supply Chain Re-engineering

Hewitt (1994) provides a review of supply chain improvement from a process analysis viewpoint. He defines Effectiveness as the ability of the system to deliver the right products to customers at the right place and in the right time and Efficiency as the reciprocal of total supply chain costs. These include the cost of holding inventory to overcome the 'inertia' within the system. Hewitt used a free-form, iterative discussion approach to represent a panel consensus from a set of over 30 successful supply chain redesign practitioners selected from companies identified to be at a stage of inter-company and intra-company integrated process management. Three dimensions of process redesign emerged: [1] Work redesign characteristics; [2] Information redesign characteristics; and [3] Authority redesign characteristics.

A general framework for logistics process re-design has been drawn up by Persson (1995) based on his work with companies in the 1980's. He suggests that any logistics process redesign will involve one or several of three concepts: [1] The response cycle

(the transaction between two components in a delivery system); [2] Structural characteristics (related to the exchange process); and [3] Managerial or administrative setting (for the exchange process). The response cycle is called by Persson 'the operational characteristics of a logistics process'.

4.8 Contract Structures and Supply Base Considerations

The structure of the supply base in relation to the number of suppliers and the nature of the contract with those suppliers has been an important theme in purchasing and supply literature. This theme of supply base rationalisation has been particularly prevalent in the automobile industry (Christopher, 1998 p232). Substantial reduction of the supplier base and moves towards supply structures with single or dual, rather than multiple, sources are seen as structures that can support supplier development and supply chain improvement (Lamming, 1993; Harland, Lamming & Cousins, 1999).

Waters-Fuller (1995) identify time-based improvement of supply chains as providing a significant area of debate in relation to the advantages and disadvantages of single sourcing and long-term contracts. Waters-Fuller concludes, however, that there is little disagreement over the nature of JIT purchasing practices which he defines as: "small but frequent deliveries of total quality parts from single sourced, local suppliers, with whom there is a close relationship grounded on mutual dependency and frequent communication". This author also concludes that there is evidence that organisations fail to implement some of the more difficult aspects of the JIT philosophy, such as long-term contracts, sole sourcing, data exchange and levelling of schedules. Thus some of the problems related to the implementation of time-based approaches to supply chain improvement appear to be influenced by the underlying contract structures adopted. A lack of communication and a resistance by buyers to abandon "competitive bidding and price first selection criteria" (Water-Fuller, 1995) was also noted.

4.9 Influences of Supply Chain Systems and Structures in Capital Equipment Supply on Lead Time Performance

The engineer-to-order nature and the inclusion of the design phase in the order cycle (discussed in 4.9 above) are thus important factors that differentiate the capital equipment supply environment. Much of the focus of industry-based research in capital equipment supply in the offshore oil industry centres on cost reduction rather than lead time performance, but many of the principles are similar. Three particular structural aspects that have a potential impact on lead time performance are reviewed below: design standardisation, agreement structures and information communication systems and structures.

Design Standardisation

A study of downhole (capital equipment used down oilwells) completion equipment supply to the offshore oil industry (Watson et al, 1999) identified a number of features of the supply environment: [1] insufficient control over the number and range of materials in use; [2] a high degree of non-standardisation with a significant proportion of expenditure on “specials”; [3] roles and responsibilities of those involved in product selection and approval poorly defined; and [4] synergy with other companies was difficult because of absence of commonality – in fact there was clear evidence of divergence. This lack of standardisation in the supply environment concurs with CRINE (Cost Reduction in a New Era) findings (CRINE, 1994) which reported widespread use of company-specific specifications rather than the use of industry-wide standards. The related issue of the importance of standards based data exchange and sharing was identified by Mayhew (1999) where true classes of equipment can be identified. The report also highlighted “endemic over-engineering” within the industry, together with lack of use of targets for re-usability or percentage reductions in existing specifications or part numbers. Respondents regularly mentioned major potential benefits arising from Early Supplier Involvement (ESI).

Contract Structures

The CRINE (1994) Report highlighted useful structural devices in the nature of supply agreements within the offshore oil industry. It reported on the successful use of 'Framework Agreements', where an outline contractual framework is established agreeing terms, scope, pricing basis, (usually) year-on-year improvement targets and expected medium-term volumes of work. However, only 20% of spend on average was covered by this type of agreement for survey respondents. Agreements with a supply chain orientation would be expected to have appropriate risk-reward mechanisms and alignment of objectives related to lowest life-cycle costs rather than lowest price.

Information Communication Structures

The use of multi-functional team structures is well documented as a means of providing improved communications (Watson, 1999; Stubbs, 1999; Spence et al, 1999; Mayhew, 1999). The CRINE (1999) Report identified a lack of a structural mechanism for feedback to and from customers and suppliers.

Positioning of Strategic Inventory

Whereas the positioning of strategic inventory at the Order Penetration/De-coupling point (discussed in 4.7 above) is likely to be less critical in a less repeatable design/engineer-to-order supply environment, CRINE (1999) discovered over-ordering "driven through fear of non-availability" as being a costly issue for the offshore industry. Also that "a ramification of non-standardisation is that of excessive inventory holdings".

4.10 Summary

Philosophically the Supply Chain can be regarded as an open system (Katz & Kahn, 1966). Theoretical convergence between open systems theory and supply chain understanding can be seen in the importance of 'information feedback'. This finds its

expression in modern supply chain research within the Systems Dynamics School based on the pioneering work of Forrester (Towill, Naim, Wilkner, 1992; Evans, Naim, Towill, 1993; Berry, Towill, Wadsley, 1994). Whereas this provides a more complete and holistic understanding than optimisation models (Zinn & Charnes, 1992; Mahmoud, 1992; Nyerges, 1992; Bowersox & Closs, 1989), its approach is fundamentally rooted to repeatable and cyclical systems and thus of limited application in the capital equipment supply environment.

Structural issues of direct relevance are related to the strategic positioning of inventory and the concepts of Order Penetration Point (OPP) and De-coupling Point (Sharman, 1984; Berry et al, 1994; Christopher, 1998). Other structural issues that have been identified as of relevance to this environment are Design Standardisation (CRINE, 1994; Watson et al, 1999; Mayhew, 1999), Agreement Structures (CRINE, 1999) and Information Communication Structures (CRINE, 1999; Watson, 1999; Stubbs, 1999; Spence et al, 1999; Mayhew, 1999).

5. INFLUENCES OF SUPPLY CHAIN RELATIONSHIPS AND INFRASTRUCTURE ON LEAD TIME PERFORMANCE

5.1 Introduction

Exploring the literature related to supply chain relationships moves the investigation into an area that has tended to be dealt with, not by logisticians or operations management researchers, but by those more specifically within the purchasing discipline and more generally those within strategic management research. The first world-wide research symposium on Purchasing and Supply Chain Management took place in Tempe, Arizona in March 1995 and the four research papers tracks were: Supply Chain Management; Strategic Supply Management; Buyer/Supplier Relationships and Advanced Concepts in Purchasing. Within the Supply Chain Management track only one paper out of seven dealt with systems issues and the balance dealt with 'soft' relationship issues. There is clearly a growing and substantial amount of normative and empirical writing about the area of supplier relationships. Relative to this research project the review of this area is focused on the supply chain relationship and in particular where this relationship impacts on the management of lead times.

5.2 Dependency Theory

The impact of supplier relationships on the supply chain has early origins in the quality gurus W E Deming and J Juran and the adoption of their principles by Japanese industry. Quality Management also has a productivity element, as illustrated by Ohno at Toyota in the construction of the "7 sources of waste". In pursuing this philosophy, the Toyota Motor Company engaged in a system called the Toyota Production System (TPS) which was based on Just in Time (JIT) scheduling. The consequence of this strategy was a need to more closely interface with customers and suppliers. Bicheno (1991) defines JIT as "meeting demand instantaneously, with perfect quality and no waste". A key consideration in this approach is high dependency theory (Oliver & Wilkinson, 1988). In simple terms, if inventory is removed the lack of 'buffering' from safety stocks increases mutual dependency between the supplier and the customer. Traditional Economic Order

Quantity (EOQ) models are based on assumptions of a trade-off between the cost of ordering and the cost of holding inventory. Sniederjans (1993) derives JIT/EOQ models based on splitting lot sizes into smaller deliveries, thus reducing average inventory holding. An assumption of the EOQ model derivation is that ordering costs are incurred each time an order is placed, whereas in the JIT model ordering costs remain constant no matter how many orders are scheduled. This is clearly possible by implementation of period orders (with automatic call-offs that reduce or eliminate ordering costs) and in particular by the implementation of automatic re-ordering systems through Electronic Data Interchange (EDI).

5.3 Transactional Cost Economics and the Network Organisation

Transaction Cost Economics focuses on the relative cost efficiencies of market versus hierarchy. According to Transaction Cost Theory (Williamson, 1975) the goal of the organisation is to minimise the costs of exchanging resources in the environment and the costs of managing exchanges within the organisation. Organisations will try to minimise transaction costs because they do not add value. Those with a transaction-cost orientation take the view that organisations have evolved in an efficient way. Their functionalist orientation means that their explanation about why a particular trading pattern exists and the efficiency of an existing trading pattern are one and the same thing (Sako, 1992). Sako goes on to apply social network analysis (Wellman, 1983 in Sako, 1992) to overlay the idea that every economic action is embedded in social relations, some of which are based on mutual trust and obligation. The thesis then is that whereas traditional transactional cost theory seeks formal contract arrangements to avoid 'opportunistic' behaviour, behavioural norms are not necessarily based on this 'bounded rationality'. Sako draws on members of the 'networks as strategy school' such as Jarillo (1988 in Sako, 1992) who consider the possibility of reducing costs in networks by a conscious decision to build mutual trust. These ideas have lead to the emergence of concepts such as the 'network organisation' (Powell, 1990 in Sako 1992) in which the organisation takes neither a 'market' nor a 'hierarchy' form and suggest that the 'network' form provides a different economic model than traditional transaction-cost approaches.

5.4 Lean Supply

Research by the Massachusetts Institute of Technology, within the automotive industry, culminated in the introduction of the concepts of 'lean production' in the book *The Machine that Changed the World* (Womack et al, 1990). This concept was extended to the consideration of the relationship between customers and suppliers arriving at the concept of 'lean supply' (Lamming, 1993). Lamming's 'lean supply model' has four phases: [1] *Traditional*: where the nature of competition is closed but friendly and sourcing decisions are price-based on lost bids; [2] *Stress*: where competition is closed but deadly, based on price-based 'Dutch Auctions'; [3] *Resolved*: competition is closed but becoming more strategic with some collaboration and sourcing is based on price together with quality and delivery; and [4] *Partnership*: Competition is collaborative and sourcing is based on performance history and long-term source relationships.

Lamming draws on the Sako (1992) ideas of a spectrum of relationships between arm's length contractual relations (ACR) to obligational contract relations (OCR). He also draws on Sako's key dimensions that differentiate between the two types of relationship ('goodwill trust' and 'competence trust').

In relation to the Supply Chain, a key issue is the change in shape of supply chain structures that emanate from the adoption of the practices associated with this concept. The reduction in the supplier base (i.e. the number of direct suppliers) is well documented within manufacturing sectors. The result is that many suppliers who were originally direct (known as a 'first tier') suppliers become indirect or 'second tier' suppliers. Lamming suggests that to make a transition towards a wholly direct supplier would clearly involve a need for the supplier to align itself more closely with the customer/industrial sector, because a direct supplier will focus on the needs of the customer and interpret and communicate these needs to lower tier suppliers. Thus suppliers may be classified as direct or indirect and aligned or unaligned. Lamming (1993) suggests three reasons as to why tiers form: [1] Technologies may be more diverse

than the skills available to the first-tier supplier; [2] Some components may be specialised and thus are made by a small number of firms; and [3] Simple, low added-value items may be undertaken on a sub-contract basis.

Lamming suggests that Japanese-style *keiretsu*, quasi-ownership tiers, are unlikely outside Japan, but that *kyoryokukai* (supplier associations) are already being formed in the UK. Hines (1994) adapts the simplified Alps structure of tiered suppliers based on Nishiguchi to produce an Interlocking Network Sourcing Model and goes on to produce a Ten Force Partnership model as a macro view of Network Sourcing. Hines comments that the model, based on two networks for simplicity, would in reality have a multitude of interlocking supplier networks. Interactions in the network by cross-network spread of beneficial developments within the subcontractors (force 3) due to one-to-one developments (force 2) and group (force 4: *kyoryokukai*) developments. Hines suggests that this may be seen by some as a good reason *not* to engage in supplier development, as benefits leak to competitors. Macbeth et al (1994) and Christopher (1998) overcome this objection by suggesting that it is supply chains and not firms that compete.

5.5 Supplier Positioning

Scott and Westbrook (1991) highlight the concept of supplier positioning as a means of understanding nature of supplier relations in the supply chain. Two key indicators are suggested: [1] Number of suppliers to end customer (relative to the complexity of its product range or product assembly); and, [2] Closeness of relationship with the suppliers. It is suggested that the factors determining these relations include:

1. Extent of dependence on the chain (% suppliers sales dedicated).
2. Longevity of relationships.
3. Technological or process links (call-off schedules, EDI).
4. Existence of legal ties (contracts, shared patents)
5. Length and complexity of the chain (existence of tertiary suppliers and stages beyond that).

One of the main pieces of empirical work on supply relationships related to the integrated supply chain has been the work of Glasgow University Supply Chain Management Group (Macbeth and Ferguson, 1994). Their Relationship Positioning Tool (RPT) has been validated and refined based on research firstly in Original Equipment Manufacturers (OEM's) within the electronics industry and later with a broader spectrum of manufacturers, mainly winners of the Management Today Best Factory Award. The methodology is based on questionnaires to customers and suppliers gathering over 300 pieces of data related to the categories on the 'roots' of the diagram. For the supplier these categories are: supplier capability and information flow supplier to customer. For the customer the categories are: customer strategy and information flow from customer to supplier. Each response is scored against 'best practice' identified from research and client information, the comparison producing a score. The scores for the elements are then aggregated to produce a score for the factors.

Macbeth & Ferguson (1994) provide a rare link between the 'hard' aspects of supply chain physical and information systems and the 'soft' aspects of supply relationships. However, their empirical work appears to centre on the relationship aspects rather than in any way evaluating the impact of the relationship improvement process on the chain itself.

The impact of relationships on potential supply chain design can be found in the work of Gattorna et al (1991) in the concept of 'pathways to customers'. Gattorna suggests that the results of Supply Chain Management in practice are a manifestation of behaviour and thus we must look to behavioural science for explanation, by recognising differential behaviour patterns in a cross-cultural situation such as the supply chain. Their approach goes on to suggest that following the observation of behaviour it is possible to cluster disparate groups according to "natural logics" to provide different "pathways" for different market situations.

5.6 Supply Chain Relationships and Trust

The contrasting two types of supply relationships (adversarial and collaborative) are almost universally recognised in the literature. The Lamming (1993) four-phase model of customer-supplier relations identifies relationships moving from price-based cut-throat competition in phase 1 towards collaboration in phase 4. Macbeth & Ferguson (1994) chart the operational paradigms connected with adversarial and collaborative relationships based on five perspectives: time span of interaction, personal attitudes, behaviours, organisational processes and measurement. With regard to collaborative behaviour Macbeth and Ferguson suggest that a collaborative relationship has a “tendency to look for and offer trust and backs this up in actions” and “will fight against attempts to take advantage of others’ trust”. Cox (1995) produces a ‘step-ladder’ of external and internal contractual relationships moving from ‘adversarial leverage’, through ‘preferred supplier’, ‘single sourcing’, ‘network sourcing’ through to ‘strategic alliances’. Adversarial behaviour is seen by Cox (1995) as “arm’s length and the recipient of leverage is in a dependent situation in terms of power”. At the other end of the scale ‘strategic supplier alliances’ involve a closer relationship than under other forms of contracting “because power in the relationship is based on equivalence”. Burnes and New (1996) suggest for a relationship based on partnership and co-operation has a key requirement of ‘trust’ and suggest that a ‘key metaphor’ for this model would be ‘marriage’. Burnes and New (1995) identified the issue of ‘dependency’ between buyers and sellers as vital, but in their research uncovered that organisations were relatively unconcerned about this. They discovered that “firms are highly concerned about avoiding dependency on their customers, even although they commonly wish to increase their customers’ dependence on them”. Walton’s research (1996) discovered that interdependence explained variance in partnership satisfaction. Walton’s respondents “believed that there was a limited sharing of benefits and burdens between partners” and in preliminary interviews “managers admitted to not being satisfied with the current level of sharing present in their existing partnerships”. Cooper and Gardner (1993) contrast ‘asymmetry’ (ability to exert power, influence or control over another organisation) and ‘reciprocity’ (mutually beneficial goals or interests, implying co-operation, collaboration

and co-ordination). Ellram and Hendrick (1995) develop a dyadic perspective to partnering characteristics that highlights the importance of risk-sharing.

A coherent conceptual framework of buyer-supplier relations is provided by Sako (1992): Arm's Length Contractual Relations (ACR) "dealings conducted at arm's length, to avoid due familiarity and with neither party controlled by the other". Obligational Contractual Relations (OCR) "is embedded in more particularistic social relations between trading partners who entertain a sense of mutual trust". Sako produces a model of features for these relationship types that includes issues such as: dependence; bidding procedure; trading length; contract documents; technology transfer; communication channels and intensity; risk-sharing ; and finally trust. Sako identifies three types of trust: 'contractual trust' (keeping promises); 'competence trust' (performing a role competently) and finally 'goodwill trust' (willingness to do more than is formally expected). Sako provides an example to clarify the difference between contractual and competence trust: a supplier may fail to deliver on time: this may be due to a failure in contractual trust (he took on the order with full knowledge that the capacity was unavailable) or it may be due to a failure of competence trust (the order was late due to machine breakdowns and poor production control).

Michell et al (1998) explore the foundations of trust based on four constructs and 22 variables: [1] *Probity*: confidence, truthfulness, integrity, professional standing, reputation - focuses on honesty; [2] *Equity*: fair-mindedness, benevolence, caring, values, sincerity, helpful advertising - pivots on trust being an implied contract with mutual expectations and perceived obligations; [3] *Reliability*: warranties, dependability, quality consistency, quality standing, predictability and corporate name guarantee - relating to the firm having the expertise to perform its business effectively and reliably; and [4] *Satisfaction*: personal experience, opinion, the purchasing duration, the experience of peers, the standard of delivery - related to duration of trust. Michell's exploratory survey revealed that seven variables correlated highly with trust: fair-mindedness, truthfulness, confidence, personal experience, quality standing and predictability.

Ali and Birley (1998) approached the question of trust from three perspectives: [1] bases of trust (rule of law or interpersonal interaction), [2] antecedent factors of trust (based on demonstration of trust) and [3] forms of trust ('affect-based' and 'cognition-based' trust). Geyskens et al (1996) identify two types of commitment: 'affective commitment' (maintaining a supplier because the relationship is enjoyable) and 'calculative commitment' (retaining a supplier because it would be too expensive to terminate the relationship). Roy and Dugal (1998) integrated theories of cognitive flexibility, co-operative arrangement and levels of trust. Blois (1998) identifies that trust involves "the expectation, not just of a lack of ill-will, but an element of goodwill from the person trusted". Blois also identifies that much of trust is unconscious. Bolis's paper re-examines a case study from a 'power' and a 'trust' standpoint. From the latter standpoint the case illustrates a 'win' by the customer over the supplier. But from a trust standpoint the case suggests that both parties were worse off due to the handling of the relationship in an adversarial manner.

Hines (1996a) suggests that there is some confusion in the causality in partnership-style relations. The Hines research discovered that high trust relationships had a limited causal effect on partnership criteria and suggests that trust is a result of successful partnerships, not a cause of them.

5.7 Supply Chain Relationships and Power

Lamming et al (1996) have produced a Relationship Assessment Programme model, which moves vendor assessment onwards to consider relationship assessment. The facets of the model that are intrinsic to the relationship itself are: closeness (predictability of each party's reaction); depth (the type and number of actions performed jointly); power (the result of the ability of each party to impose its will upon each other); dependence (the reliance of each party upon the other). Lamming suggests that 'dependence' involves each party's perception of level of dependence as well as the actual dependence situation also 'power' in a relationship is identified as based on each party's perception of the power balance, in addition to the actual power balance.

Ramsay (1996) concurs with the fact that the relationship between actual power and perception of power is important. He concludes that logic would suggest that partnerships are more likely to grow out of situations of equal power balance, but that casual observance indicated that 'partnerships' are most commonly found in relations between powerful dominant buyers and smaller more subservient suppliers. Stannack (1996) responds to Ramsay's paper and suggests that supply chain management power is about "the reduction, direction or increase of supplier alternatives and thus the reduction, direction and increase of actual actions within an interaction or series of interactions." Mudami and Schrunder (1996) suggest that the level of partnership development for small and medium-sized companies is not high and suggest that "the unequal distribution of power and differences in the availability of resources make an easy transfer of (partnership) to small company settings almost impossible".

5.8 Information Communication and Sharing

For supply chain relations to result in improved performance of the integrated chain the relations must lead to improved communication of information. A number of authors go further than this and suggest that sharing of information must also take place. An operational definition to allow empirical measurement of functional integration by Larson (1994) involves two measures:

- (1) Co-operative behaviour between purchasing and key supplier firms, and
- (2) Co-operative attitudes and sentiments.

Drawing from previous literature, six indicators of co-operative sentiment were adopted: teamwork, trust, unity, co-ordination and respect. Larson also identifies that these are also major concepts in Total Quality Management (TQM). The study went on to investigate the link between inter-organisational functional integration and buyer's perceptions of total costs, based on Total Cost Analysis (TCA) approaches, for different suppliers. The study showed integration to be linked to lower total costs.

Stage 4 of Stevens (1989) Staged Integration Model (introduced in Chapter 3) sees integration extended outwith the organisation to suppliers and customers:, supported by EDI. Stevens views this stage as representing not just a change in scope, but also a change in attitude relative to the sharing of information.

In the UK, work by Armistead and Mapes (1993) attempted to test the hypothesis that: *improved manufacturing performance is associated with higher levels of integration across the supply chain.*

Measures used included:

- Shared ownership of master production schedule
- Job titles spanning traditional boundaries (e.g. Supply Chain Manager)
- Integration of information systems
- Visibility and spread of transmission of information

Thus the Armistead & Mapes (1993) measures included not just the ability to integrate information systems to permit information spread and visibility, but also the attitude requirement that information must be shared. The survey was sent to companies who had participated in the Best Factory Audit conducted by Cranfield School of Management and Management Today. The sample was thus constructed from firms that were actively interested in improving their manufacturing performance. The results showed an encouraging link between perception of performance and integration factors

5.9 Supply Chain Relationships in Capital Equipment Supply

The possibility that partnership-type supply chain relationships are more likely to develop in some scenarios than others is identified by Elram (1991). Three specific areas are identified: [1] Recurrent transactions requiring moderately specialised assets - in this scenario partnership is most likely; [2] Recurrent transactions requiring highly specialised

assets - as the supplier will probably be supplying to only one customer, partnership is also pertinent in this scenario; finally, [3] Operating under conditions of moderate to high uncertainty – in this situation partnership integration is unlikely, but risks and threats can be reduced if good supply relationships can be established.

With regard to Capital Equipment Supply, the assembler level profiles with scenario [2], but lower supply tiers are more likely to profile with scenario [3].

5.10 Summary

The ability to provide a time-responsive supply chain has a basis in Dependency Theory (Oliver & Wilkinson, 1988). A further underlying theory is that of Transaction Cost Economics (Williamson, 1975), adapted via Social Network Analysis to an emergent model of Network Organisation which provides a different economic basis: the possibility of reducing costs in networks by a conscious decision to build mutual trust (Sako, 1992).

The importance of these obligational, partnership-type relations to supply chain performance also finds substance in the concept of Lean Supply (Lamming, 1993), Network Sourcing (Hines, 1994) and Relationship Positioning (Macbeth & Ferguson, 1994). The influence of trust and power in these dependent relationships is widely discussed (Cox, 1996; Burnes & New, 1996; Walton, 1996, Cooper & Gardner, 1993; Sako, 1992; Michell, 1998; Ali & Birley, 1998; Geyskins et al , 1996; Dugal, 1998; Blios, 1998; Ramsay, 1996; Stannack, 1996; Mudami & Schrunder, 1996). Although many authors cite trust as a precursor to partnership-style relations, the iterative nature of the building of trust is becoming more fully recognised, with Hines (1996) in particular, suggesting that trust is a result of successful partnerships, not a cause of them.

Finally, for obligational supply chain relationships to lead to improved cost or time-based performance the relationship must yield widespread transmission, and most importantly, sharing of information (Larson, 1994; Armistead & Mapes, 1993; Stevens, 1989).

Relating this to capital equipment supply, the nature of recurrence of the transactions and the asset specificity are highlighted by Elram (1991) as important variables.

6. THE GENERIC CASE ENVIRONMENT: the Capital Equipment Supply Chain in oil exploration and production on the United Kingdom Continental Shelf (UKCS)

The generic case environment for the study was defined in 1.3 and 4.9 above. The motivation for the study was based on the problems being experienced due to long lead times being experienced for capital equipment. This was posing a problem for the smaller field developments that were becoming more common due to the maturity of the oil reserves. In a more mature oil province, current developments become smaller scale due to the fact that large-scale reserves have mainly been discovered and only smaller-scale reserves remain for ongoing development. These small-scale developments require reduced development time periods in comparison to earlier large-scale developments. The historical background to the case environment is provided in Appendix F.

6.1 Strategies in a Mature Extractive Industry

In a mature extractive industry, such as the oil industry on the UKCS, the impact of the profile of an oil operator's North Sea assets and its subsequent strategy is an area of substantial growing interest. This has been highlighted by BP [now BPAmoco], an operator with substantial asset spread, as a key issue for future strategic interest (Bambridge, 1995). In the mid 1990's there was a major divestment by oil majors of these mature assets to smaller operating companies or the consideration of rationalisation of operatorship amongst investment partners. The phases of oilfield life cycle are essentially similar to a product life cycle (see Table 6.1).

Partially related to the asset maturity profile, is the actual maturity of the company involved and its impact on strategy and the decision-making culture. Amerada Hess, for example, profiles itself as a "new generation" oil and gas exploration company (Operator Profile, Euroil, July 1993). Although active in partnership with Amoco in the North Sea since 1963, Amerada Hess first achieved operator status in the 8th Licensing Round in 1983. Between this time and the early 1990's the company expanded from a company of 59 people to a staff of over 600, the 9th largest operator in the North Sea.

<i>Life Cycle Phase</i>	<i>Objective</i>
<u>Exploration/Construction</u>	Managed for return on capital; clear link between capital expenditure and payback which is achieved only when the oil flows; time factors and project duration are thus critical and override costs.
<u>Production Growth</u>	Managed for cash flow; timing of the flow is critical and remains so at least within the payback period.
<u>Production Maturity/Decline</u>	Managed for cost/barrel; the fixed cost nature of the activity requires to maintain a solution to the maintenance of the margin between operating cost and price.

Table 6.1: Asset Maturity Profile

These types of company are described as follows: "New generation oil companies are smaller, leaner, willing to try out new ways of solving problems and adapt their methods to suit new conditions. They are in tune with today's world environment which calls for companies that have the ability to act quickly, have a flexible approach in management and are decisive in carrying through innovation, a direct line progression from the pioneers of the oil business" (Euroil Profile, July 1993). The risk strategy of the company in its exploration for oil, subsequently discovered in the Scott field, appears to exhibit the pioneering spirit noted in the statement and perhaps indicates an entrepreneurial spirit permitted by less mature industry participants.

6.2 The Offshore Supply Chain in the UKCS

The progress towards the integrated supply chain in the offshore industry has been traced by Cardale (1995) who sees drivers coming from the integrated oil operators themselves and their investor partners, along with the establishment of integrated contractors and integrated logistics contractors. The unusual patterns of investors in North Sea oil developments has created a rather unique pattern of relationships between the major oil operators that would be difficult to find in other industrial sectors. Whereas history has shown that these relationships have led to complicated accounting practices between the operators, the potential is there for a degree of co-operation and integration that would be difficult to imagine within, for example, the manufacturing sector.

The concept of an integrated service concept has been outlined by Latham & Clark (1995) based on a case study of co-ordinated drilling and evaluation of a North Sea exploration well by Baker INTEQ for Clyde Petroleum. The scope of work of the contract was broad including provision of a drilling rig, all direct services, evaluation, testing, boats, helicopters, warehousing, office accommodation and project management. The use of Integrated Teams for the management of these contractual arrangements was highlighted in a case study of six of these contractual arrangements in US, Middle East and UK oil provinces by Farrell & McDermott (1995). The basic characteristics and management structure indicate the use of the 'integrated team' in four cases whilst in the remaining two cases separate client and contractor teams were employed. The four with integrated teams have a management structure headed by a Board or Steering Team made up of senior executives from the client and the contractor organisation.

Supply Chain Systems

Representations of the offshore supply chain are essentially at an early stage of development. Martin (1995) depicts the offshore supply chain as a corridor with a number of underlying processes. Martin sees integration as an optimisation dimension that seeks to improve efficiency through interface reduction or elimination. He also

highlights the importance of supply chain management as being, dependent on how it is defined, typically to be around 20 to 35% of total operating expenditure. Bailey (1996) adapted the Kearney matrix to the offshore supply chain.

Whereas these are generalised representations, work on detailed process mapping of the offshore supply chain has been taking place within offshore operators. Bambridge (1995) has used process mapping as a tool for supply chain re-engineering within BP Exploration. The process is asset specific, due to the recognition of the individual requirements of the various North Sea assets. Bambridge's conclusions on his work to date are that there are many different offshore supply chains and thus several chains will require re-engineering. He identifies the value of determining customers' requirements in the re-engineering process and that solutions will be team-based with importance laid on the alignment of objectives between team members.

The nature of information systems within the offshore industry has been researched by Williams (1996). Williams study is based on 11 companies from the UK oil and gas industry who had either implemented or had considered implementation of an integrated IT system called SAP. SAP AG is a German company founded in 1972 by five ex-IBM engineers. The company has grown into a substantial world-wide IT provider with a company strategy based on the development of "standard applications capable of linking together all of a firm's business activities, fusing them into an integrated whole". Williams survey records that 6 oil majors have selected SAP.

Of the companies using SAP, only certain of them use the system for logistics/supply chain purposes. These include Conoco which includes purchasing and warehousing; Mobil which encompasses material management and procurement; Texaco and Shell Exploration which at the time of survey were configuring for logistics; the ASCo/BPAmoco partnership which include materials management and some distribution and Total which encompasses logistics.

The reasons for selecting SAP were primarily functionality and integration which nearly all respondents regarded as a major strength. Functionality benefits related to the ability to cope with partnership accounting arrangements and material management/procurement. The system allows modular implementation and the two modules that most companies intended to use were financial accounting and material management.

The study also identifies alternative products being used or reviewed within the offshore industry. Alternatives mentioned more than once included PM/3 developed specifically for the UK oil industry by Logica. Those surveyed described it as a good product with good functionality. Its drawbacks were that it was regarded as expensive and lacking integration with financial systems. Due to the small user base there were concerns about the costs of maintenance and development of the system.

Swaine (1995) highlights the importance of information to the growing number of alliances in the offshore industry. Systems designed by one contractor may not interface successfully. This leads to a requirement to establish the information needs of the whole alliance, rather than attempting 'bolt-on' solutions. Swaine also highlights the importance of electronic transmission of information and open access to engineering data facilitating response from downstream functions. He concludes that cross flow and open access to information is paramount to the success of the working of alliances.

Bailey (1995) suggests that the employment of IT in cost reduction programmes associated with Supply Base, Transport and Marine logistics has been marginal due to the incompatibility of operator systems. He concludes that this lack of compatibility hinders the provision of real time on-line access to the physical and transactional status within the supply chain procurement, materials management, logistics and accounting functions. The use of 'legacy' systems of oil operators within alliances, results also in duplication and the retention of vertically rather than horizontally integrated business process support from the information system.

Supply Chain Relationships

The extent of industry-specific literature relating to relationship issues has centred on the development of 'alliances' between oil operators and major contractors. The organisation of an 'alliance' in the offshore oil industry is outlined by Charters (1995). He divides the alliance between so-called "primary" partners in which the operator is represented and beneath this there exists a number of sub-contractors. Charters states that the success or failure of a primary alliance to deliver appropriate business solutions resides with the supply chain.

Carmichael (1995) traces the history of alliancing within the offshore industry, starting with BP's Hyde field and followed by Andrew and Harding. Carmichael notes that alliances have been formed through the use of a single integrated contractor providing a "one stop shop" service throughout the development life cycle of an oilfield and also through pre-formed partnerships not involving integrated contractors. The link between 'alliance' and the integrated team is explained by Smith (1995) related to the previously mentioned development of the Harding field by BP. In this project BP's engineering team was integrated into the design contractor's team as far as was physically possible, including the sharing of offices of BP staff with their contractor counterparts. This 'alliance' was not a risk/reward type contract according to Smith, but rather a willingness of two groups to work together in a co-operative manner to their mutual benefit.

Empirical work on the supply chain relationships in the offshore sector has been undertaken by Beecham (1995). The research was part of a wider PhD study of inter-firm knowledge transfer, based on interviews of senior managers from ten oil companies together with thirteen small (less than 50 staff) firm equipment suppliers and engineering consultants. The study indicated a lack of inter-firm trust, particularly related to managing contractors and concluded that although there was enormous potential to develop an integrated offshore supply chain, supportive mechanisms were lacking.

Support mechanisms such as catalyst groups or facilitating groups such as the Scottish Subsea Technology Group are suggested as a possible way forward.

More detailed and widespread empirical study of alliances and partnerships in the offshore industry has been undertaken by Green (1995). The methodology involved the identification of partnering, alliances or long-term relationships from press releases and trade journals and once identified, interviews were undertaken with managers, both operator and contractor, of specific relationships. Green found that relationships varied from long term supply agreements to highly collaborative 'alliance projects' for field developments. Green has identified about 175 relationships and has completed detailed study of 20 of these, through about 50 interviews with representatives from 6 operators and 19 contractors. Green's work bears out Beecham's (1995) findings that first tier suppliers appear to accept the idea of collaborative working as a good idea, but that second tier suppliers are less positive. Green investigated level of collaboration styles of contracts and incentive structures and partner selection. The broad conclusions are that there are a wide variety of relationships in place in the offshore industry and that they are at differing stages of development. The implications of these findings for supply chain research are clearly related to the relational complexity that is evolving within the industry, leading to a wide network of interactions and influences.

6.3 The CRINE Initiative

The pattern of falling revenues and rising costs in the UKCS offshore industry was highlighted by the DTI report 'Report of the Working Group on UKCS Competitiveness' (DTI, 1993). In parallel, the offshore industry recognised in 1992 that in a continuing low oil price environment, the current portfolio of 230 small but significant oil and gas discoveries listed in the DTI's Brown Book (Development of Oil and Gas Resources of the United Kingdom, 1993) were likely to remain undeveloped unless total capital and operating costs were significantly reduced. This led to an industry-wide initiative named Cost Reduction Initiative for the New Era (CRINE, 1994). The plans were launched at a conference in December 1993, supported jointly by the United Kingdom Offshore

Operators Association (UKOOA) and the DTI and organised by the Institute of Petroleum. In the months leading up to the conference, work groups addressed the various aspects of the cost reduction issue. Industry culture and business practices were identified as the root cause of many of the problems.

The report (CRINE, 1994) notes that distrust and adversarial relationships lead to technical complexity, unnecessary and unbalanced risk of financial exposure, and inadequate communications, education and development. The aims of CRINE (See Table 6.2) were to identify significant cost drivers and to define the ways to lower costs and shorten the development cycle. Industry competitiveness is at the heart of the CRINE Mission Statement: “People working together to create a UK oil and gas industry which is competitive anywhere in the world”. (CRINE, 1999).

<i>CRINE Objective</i>	<i>Priorities</i>
Standardisation	Priority for standardised functional specifications to power generation, gas compression, cranes and pumps.
Document simplification:	Priority in procurement documentation and coding systems permitting reduction in paperwork and the increased use of EDI.
Contractual culture:	Removing adversarial culture and favouring new-style contracts such as alliancing, partnering and risk-reward relationships.
Rationalise regulations;	Certification, Production Consents, Pipeline Works Authorisations, Field Development Programmes.

Table 6.2: CRINE Objectives

Following the CRINE report a number of sub-groups were set up with industry participants and these resulted in a series of publications. “The Common Working Practices” (CRINE, 1996) was a study of the relationships between contractors and

fabricators, establishing common working practices based on existing quality management systems. Together with the Institute of Petroleum, CRINE published “The CRINE Functional Specifications” (CRINE, 1997), which are “a framework to enable the user to develop a unique Functional Specification that meets his precise needs”. Finally “The CRINE Standard Contracts” (CRINE, 1998) were published to “significantly reduce the inefficiencies associated with the repeated drafting and reviewing of contracts”. A conference of procurement managers (“Value and Profit from Supply Chain Management”, 17th November, 1998) was influential in the further development of supply chain concepts within the industry.

The principles of CRINE were re-defined to include many supply chain aspects (See Table 6.3). In particular, aspects such as “trust”, “partnership”, “relationships”, “communication”, “information sharing”, “simplification of design and process”, “align objectives”, “involve suppliers early” are clear indications of the supply chain approach as reviewed in the literature.

1	Work in trust and partnership to eliminate adversarial relationships and minimise the need for inter-company litigation.
2	Communicate, communicate, communicate: strive towards total openness and, more importantly, be completely honest in all internal and external dealings. Share information and experience.
3	Work smart – actively seek radical solutions through simplification of design and process. Find new ways of working in co-operation to add value. Improve individual performance.
4	Align objectives and share rewards the length of the supply chain. Involve suppliers at the earliest opportunity.
5	Continuously challenge established practices, welcome the unorthodox and the innovative, and accelerate the introduction of new technology.

Table 6.3: CRINE Supply Chain Aspects

The CRINE (1999) Report produced 42 recommendations. A number of these take a macro approach including “pan-industry planning” [No 8] related to “batching of work”

[No 9] to reduce discontinuous demand, “pan-industry logistics initiatives” [No 26], “shared inventory” [No 30], “ a shared seismic data repository” [No 37], “common industry part numbering” [No 40] and the use of “common data warehousing formats” [No 41].

Of the micro recommendations there is once again a close alignment with the material in the earlier literature review. The recommendations are classified in Table 7.4 according to the format of the classification of relevant supply chain research in chapter 1.2.

<i>Supply Chain Systems and Structures</i>	<i>Supply Chain Relationships and Infrastructure</i>
“Ongoing Programmes of supplier development” [No 2]	“Extending the application of the Alliance concept down the supply chain to create confederations of mutually dependent suppliers in the same sub-system” [No 20]
“Early supplier involvement” [No3 & No 12]”	“Long term contractual relationships” [No 21]
“Alignment of objectives by total cost incentive-related, or life-of-filed contracts” [No4]	“Fair risk allocation” [No 22]
“Focal points for supplier suggestions and customer feedback” [No 6]	“Cascading of incentives further down the supply chain” [No 23]
“Individual targets for re-usability and percentage reductions in existing specifications and/or part numbers” [No 13]	“use of formalised multi-functional teams in the context of projects” [No 33]
“Greater standardisation” [No 14] and “standardised process across the complete procurement cycle” [No 26]	
“Greater modularistion” [No 15]	

Table 6.4: Classification of CRINE Principles

With regard to relationships the report survey found that providers were selected primarily for “technical capability, quoted process, part performance and lead time”. Least valued criteria included “trust, continuous improvement, and multi-functional assessment”. Also supplier relationships were still perceived “to be the primary

responsibility of the purchasing department". A consistent theme of the survey findings was the "lack of a mechanism for providers to make suggestions to their customers". The report concluded that in many cases design was performed before suppliers were even known, precluding any involvement of the supply base. Also "early supplier involvement was regularly mentioned as having major potential benefits".

Over-engineering was cited as "endemic across the industry and recognised as a driver of both cost and lead-time". The use of re-usability or percentage reduction targets was seen as a solution. The industry view that due to the large "installed base of projects" it is too late for standardisation to make a significant impact was challenged by the report. Individual respondents were quoted as estimating considerable cost-savings possible through standardisation, including reductions in inventory holdings and maintenance costs due to non-interchangability of spares.

A structural aspect for implementing long term relationships was the use of the "Framework Agreement". This was defined as "an outline contractual framework agreeing terms, scope of coverage, basis of pricing, usually year-on-year improvement targets and expected medium-term volumes of work". The tendency for risk to be offset by "risk and warranty clauses being cascaded down the supply chain" was highlighted in the report. The benefits of "greater functional integration into teams" was highlighted by report respondents.

6.4 The Oil and Gas Industry Task Force Report

Building on the work of CRINE and co-ordinated by the Department of Trade and Industry (DTI) an Oil and Gas Industry Task Force was established under the chairmanship of John Battle, the then Minister for Energy and Industry. This included 17 senior representatives from a broad spectrum of industry including oil companies, suppliers, trade unions and key government departments. The report was introduced by Stephen Byers, Secretary of State for Trade and Industry in September 1999 (DTI, 1999). This was cascaded through a series of workgroups and sub-groups. A number of

workgroups cite supply chain issues as key to “a sustainable future for the UK offshore oil and gas industry” and these are summarised in Table 6.5.

<i>Workgroup Report</i>	<i>Supply Chain Issues</i>
Competitiveness	“The establishment of LOGIC (Leading Oil and Gas Industry Competitiveness), an industry body to develop and promote supply chain management principles and collaboration throughout the industry” [DTI (1999) p 5]
Regulation & Licensing	“working relationships – simplified commercial relationships”, and “standardisation of approaches to documentation and commercial practices” [DTI (1999) p 11]
Innovation & Technology	“collaboration between technology users to ensure that benefits of applying new technologies are shared” and “technology development and the issues of the industry supply chain cannot be separated” [DTI (1999) p 18/19].

Table 6.5: Oil & Gas Industry Task Force Workgroups – Supply Chain Issues

6.5 The LOGIC Supply Chain Optimisation Programme

As noted in above, a key outcome of the Oil and Gas Task Force was the establishment of LOGIC (Leading Oil and gas Industry Competitiveness). The initial output of LOGIC has been the development of a programme called “Optimising Supply Chains”, which includes a methodology for supply chain improvement. A range of relatively standard consultancy tools has been assembled as a basis for assessing and developing a supply chain strategy. A key aspect of the methodology is the use of the “Procurement Targeting Matrix”. Within this matrix the high risk/high procurement value quadrant relates to the capital equipment supply environment regarded as “critical”. The strategy suggested for this sector is to “form alliances with providers”, the tactics are to “increase the role of selected providers” and the action points relate to the provision of a “close relationship”, “provider process management”, “contingency plans”, “analysis of market/competition” and “use functional specifications”. The potential options in the LOGIC methodology

(LOGIC, 1999, p 47) are classified in Table 6.6 according to the format of the classification of relevant supply chain research in chapter 1.2.

<i>Supply Chain Systems and Structures</i>	<i>Supply Chain Relationships and Infrastructure</i>
“removing costly non-value adding activities” [LOGIC (1999) p 47]	“supply base management – relationship between customers and providers” [LOGIC (1999) p 47]
“striving for functional specifications, simplifying specifications and using industry standards” [LOGIC (1999) p 47]	“the development of close relations between providers and customers, especially in the post-contract award” [LOGIC (1999) p48]
	“for incentives to work trust is required and should be aligned to clear business objectives and plans” [LOGIC (1999) p 48]

Table 6.6: Classification of LOGIC Principles

6.6 The Generic Nature of the Capital Equipment Supply Chain

The recent contribution by Lamming (2000) provides helpful justification of the importance of studies of different types of supply environments. In order that studies such as this one might contribute to wider generalisation, it is important that the generic nature of the supply chain under study is defined. A justification of this study has been the lack of information on the behaviour of supply chains in non-repetitive environments. By providing a clear definition and classification of the supply chain under study, tentative comparison can be made with the extensive writings on repetitive chains.

Capital Equipment manufacture can readily be classified as producing industrial products broadly classified as being within the engineering industry. Sweeney and Szwejczewski (1996) provide a helpful conceptual framework, based on customer service criteria and manufacturing process design. Their work was based on data from the Cranfield School of Management Best Factory Awards. Companies grouped in quadrant 2 (Innovator) had new rather than traditional process design and high customer service criteria. Within this

group Sweeney et al included a number of capital equipment manufacturers where “each manufactured product required an innovation to a standardised product design”. In the Reorganiser sector product performance, delivery speed and manufacturing flexibility are key criteria. This would mainly be the domain of the engineer-to-order capital equipment under study in this research. The majority of companies in quadrant 4 (Reorganiser) were assemble-to-order companies and these would profile most clearly as non-repetitive supply chains.

In the Innovator quadrant the key criteria relate to product performance, delivery speed and new product development and this profiles with the more complex and innovative products in a non-repetitive supply chain. In these products there may be individual conceptual design involved in each product order. In oilfield capital equipment, this would typically relate to areas such as control systems where there is a considerable amount of conceptual software design.

Manufacturers in quadrants 1 and 3 tended to make more often to stock and would profile with the repetitive supply chains more commonly studied within the supply chain literature. In quadrants 1 and 3 delivery reliability and price were more significant criteria. The capital equipment manufacturer would thus be expected to produce customised products to order, whereas typically the repetitive supply chain produces standard products to stock.

Bartezzaghi et al (1994) provide a process taxonomy for lead time modelling that has a similar structure to the Sweeney et al (1994) model. This taxonomy examines *process steadiness* (activities, sequence and organisation) and *object interchangeability* (degree of interchangeability of materials and/or information passing through the process). Bartezzaghi (1994) concludes that make-to-stock manufacturing and physical distribution generally show a high degree of process steadiness and a high degree of object interchangeability (i.e. the possibility to satisfy customers by means of outputs or semi-processed objects not yet assigned). Engineer-to-order products are classified with low object interchangeability, but in a medium position with regard to process steadiness.

Where engineering is not required the extent of object interchangeability increases. Bartezzaghi (1994) then identifies a number of time drivers that have an impact on lead time, including: uncertainty, variety, flow erraticity, demand-capacity ratio and overlapping (degree of parallelisation of sequential activities).

A number of writers have identified time-based features of engineer and make-to-order supply environments. Babu (1999) identifies the characteristics of this environment: “each product is unique in terms of design, manufacturing and technological requirements and precedence constraints.....in all the above cases it is very difficult to predict the customers’ requirements and specifications, so keeping inventory is not possible.....(this) makes the management of long lead time manufacturing systems a more complicated problem” (Babu, 1999, p23). This writer also identifies the fact that often details about product specifications become gradually known. Object specificity can be reduced in this environment by the use of generic assembly drawings. In a case study in the clothing industry, Meijboom (1999) identifies the importance of order penetration/decoupling in make-to-order situations.

Battacharya et al (1996) suggest that shorter lead times produce less ‘turbulence’ in the manufacturing system and provide a classification based on market uncertainty and product complexity. Those cases with high complexity/uncertainty will tend towards new product development models rather than production-type models. Kritchanchai and MacCarthy (1999) note that in engineer-to-order industries responsiveness is the key, based on highly flexible processes.

6.7 The Difference between Repetitive and Non-repetitive Supply Chains

Based on the literature in 6.6 above the differences between repetitive and non-repetitive supply chains become apparent. These are summarised in Table 6.7. It should be emphasised that in reality there is a spectrum of difference from the highly standardised product, supported by stock, at one end to the new concept design, produced to order, at

the other. This is complicated in repetitive supply chains by Just in Time approaches that approximate towards the make-to-order model. These tend to be achieved, however, in a less variable environment where process steadiness can lead to process and supply chain balance.

	<i>Repetitive Supply Chain</i>	<i>Non-repetitive Supply Chain</i>
Model	Production-type [1]	New Product Development Type [1]
Product Design	Standard [2] Low complexity [1] High object interchangeability [3]	Innovation to standard design [2] High complexity [1] Low object interchangeability [3]
Orientation	Produce to stock [2]	Produce to order [2]
Customer Criteria	Delivery reliability [2] Price [2]	Product performance [2]
Process Criteria	Low unit cost [2] High process steadiness [1]	Process Flexibility [2] Low process steadiness [1]
Production Specification	Known from start of production[4] Predictable requirements [4]	Gradually established [4] Less predictable requirements [4]
[1] Battacharya et al (1996); [2] Sweeney and Szwejczewski (1996); [3] Bartezzaghi et al (1994); [4] Babu (1999)		

Table 6.7: Comparison of Repetitive and Non-repetitive Supply Chains

The importance of procurement lead times in engineer-to-order industries is highlighted by Tersine and Hummingbird (1995). Daugherty and Pittman (1995) note that in custom-engineered control systems, manufacturing lead time can range from ten days to two months largely due to the custom engineering involved and they have discovered that customer tolerance levels regarding order cycle times are decreasing.

The consideration of the control of un-necessary variety proliferation, rather than perhaps variety reduction in make-to-order manufacturers is identified by Ong (1997). This

includes standardisation of parts and feature designs of products assisted by category coding (defining generic function of parts) and preference coding (defining frequency of usage of parts in different products). This links with the consideration of practices that control engineering changes (Huang and Mak, 1999), particularly at the product development stage. A framework for the management of product variety has been produced by Da Silveira (1998) in which the importance of flexibility is highlighted. Gehani (1995) emphasises the importance of 'modular' approaches to improving time responsiveness.

Concurrent Engineering (CE) practice is highlighted as a key contributor to lead time improvement (Jayaram et al, 1999; Kumar et al, 1995; Ahmed et al, 1996; Maylor, 1997; Yan and Jiang, 1999). Vernadat (1999) highlights the importance of integrated teams to the CE process, whilst Yan and Jiang (1999) emphasise the importance of information flow and Jarvis (1999) emphasises cultural issues related to the sharing of information and knowledge as important to improving time-responsiveness in CE. Jarvis (1999) also identifies the importance of Early Supplier Involvement (ESI). In engineer-to-order industries this new product development lead time merges with operational lead time to become a key part of the order lead time. Thus some adaptation of CE practice to this supply environment requires consideration.

6.8 A Conceptual Model of the Influencing factors on Lead Time Performance in the Generic Supply Environment

The classification of relevant research in chapter 1.2 above, together with the literature review in chapters 2-6 was used as a basis for the development of a conceptual model of the influencing factors on lead time performance (see Fig 6.1). This basis was provided with a detailed focus based on the more specific industry related material on the generic supply environment (capital equipment supply to the oil exploration and production industry on the UKCS) as reviewed in this chapter. The model illustrates the potential interaction of supply chain systems (structural) features and supply chain relationship (infrastructural) features and their potential influence on supply chain performance as

defined by lead time performance. Arrows represent potential influences or interaction between influencers, based on the literature review.

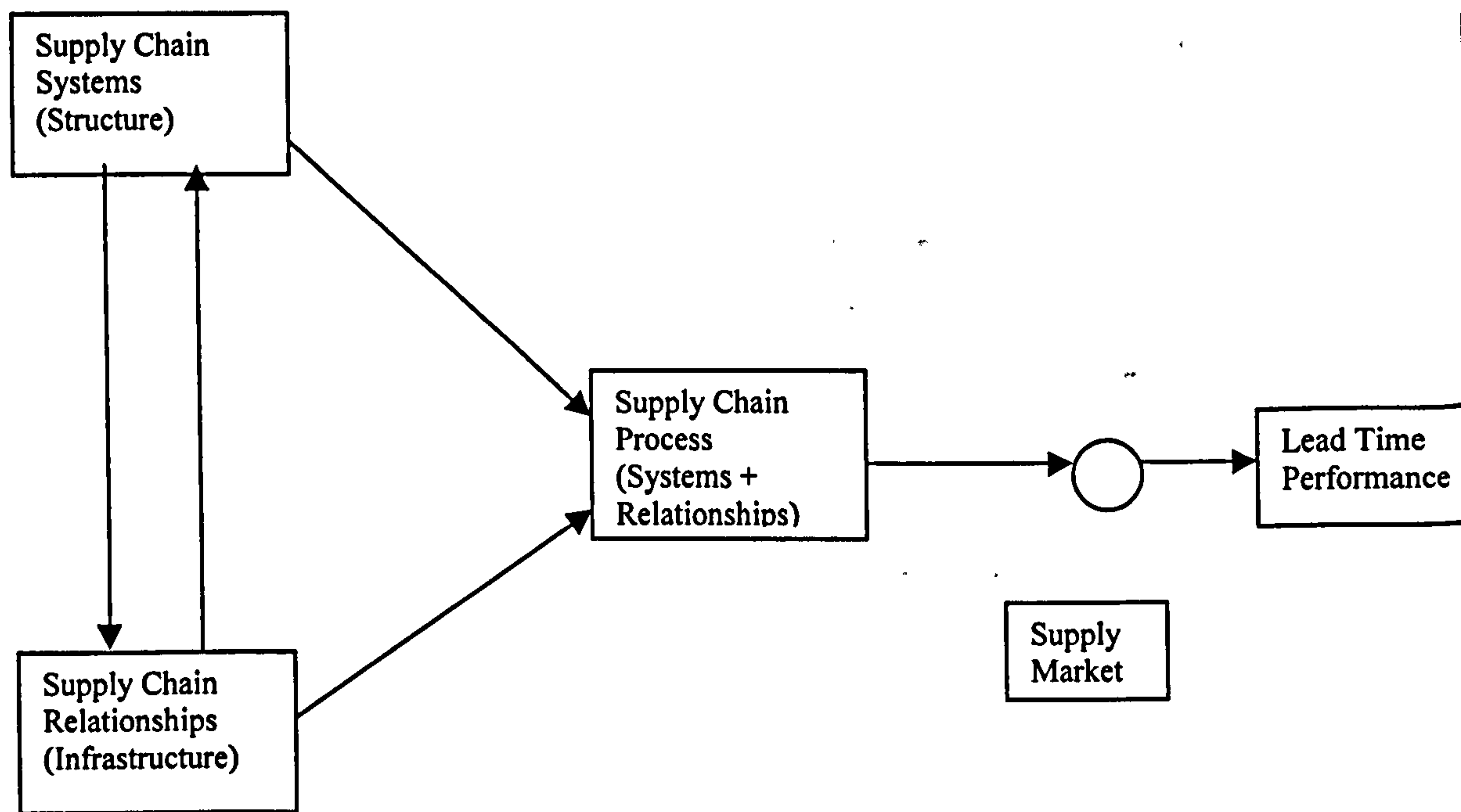


Fig 6.1: Conceptual Model of Influencing Factors on Lead Time Performance for Capital Equipment Supply environment to the offshore oil exploration and production industry

The detailed features that are expected to influence improved lead time performance are summarised in Table 6.8 in line with the Research Questions outlined in Chapter 1. More specific systems/structural factors have been derived from the literature review and focused on three groups of features: [1] Design Standardisation Systems, [2] Information Communication Structures and [3] Contract Structures. Specific relationship/infrastructural influencing factors have been based on the Obligational Contract Relationship (OCR) type, considered within the literature review to have a potentially positive influence on lead time performance. Infrastructural aspects related

broadly to this relationship type and how this translates into an ‘obligational’ communications culture and ‘obligational’ attitudes to design standardisation are considered potential influencers.

<i>Supply Chain Systems (Structure)</i>	<i>Supply Chain Relationships (Infrastructure)</i>
<i>Design Standardisation Systems</i>	<i>Design Standardisation Attitudes</i>
Undertaking Product Standardisation and/or modularisation	Proactive and interested in Design Standardisation <i>cf</i> Inactive and disinterested in Design Standardisation
Using re-usability/%age reduction targets	
Using Functional rather than technical specifications	
<i>Information Communication Structures</i>	<i>Information Communication Culture</i>
Feedback arrangements upstream and downstream in the supply chain	Positive and open culture to sharing information and technical expertise in the supply chain <i>cf</i> Protective and closed culture to sharing information and technical expertise in the supply chain
Direct access to production plans/forecasts upstream and downstream in the supply chain	
<i>Contract Structures</i>	<i>Contract Relationships</i>
Lon-term ‘Frame-type’ Contracts (i.e. long-term commitment within broad trading frameworks) Innovative contracts	Obligational-type Contract Relationships (OCR) <i>cf</i> Arm’s Length Type Contract Relationships (ACR)
Early Supplier Involvement (including multi-functional teams)	
Ongoing Involvement (including development support for suppliers)	

Table 6.8: Influencing Factors on Lead Time Performance

The conceptual model identifies potential interactions between systems (supply chain structure) factors and relationships (supply chain infrastructure). These interactions are more specifically addressed in Table 6.8. For example, there may be a structure that provides direct access by suppliers to production plans and forecasts, but unless there is a

culture of sharing relevant information that involves many staff, the benefits relating to such a system may be hollow and possibly short-lived.

These potential influencing factors and the interaction between shall thus be the focus of the empirical phase of the study. There is one final word of caution in relating cause and effect on the influences on lead time performance. This is the fact that actual (as distinct from relative) lead time performance will be influenced by the supply and demand situation in the supply market. Thus when comparing lead time performance from one period to another this factor must be taken into account. Whereas this factor will be borne in mind, it is proposed that supply market influences should largely be excluded from the study and the assumption made that all data is being collected within the same market situation.

7. RESEARCH METHODOLOGY

7.1 The Development of a Philosophical Basis for the Research

7.1.1 The Contribution of Systems Thinking

In order to understand system behaviour, it is necessary to be able to represent the system itself. The literature review revealed that logistics research has used a series of model types to represent the supply chain: symbolic models, optimisation models and static and dynamic simulation models. A major dilemma for supply chain research, however, comes from the systems theory on which it is based. This dilemma is that understanding of supply chain behaviour is only possible from an holistic perspective. This perspective can be found in the general *Gestalt* principles that 'the whole is greater than the sum of its parts'. Supply Chain Management thus requires an holistic perspective and one in which its system can be regarded as an open system, as noted by Kathawala and Nauo (1989) in a paper related to materials management.

The contribution of the different types of models to the understanding of supply chain behaviour must therefore be judged against their contribution to understanding of total system behaviour. Symbolic models have the benefits of utility in representing the 'whole' (including 'open system' characteristics), but tend to be invalidated due to their abstracted simplicity and lack of empirical underpinning. Optimisation and simulation models, due to their basis in mathematical constructs, take a 'bounded' approach to the supply chain, which has utility in contributing to understanding individual parts of the chain, but fails to evaluate the linking and integrating benefits.

The 'irrational' approach to systems theory provides not only its point of contact with the probabilistic approaches of social science research, but also the realisation that an inductive approach must be used at an early stage in research to cope with these behavioural aspects. Sceptics, such as Gattorna et al (1991) even suggest that "the supply chain is still largely a mythical concept - an admiral goal, perhaps, but one rarely

realised". His criticism of supply chain thinking is based on the danger of interpolation of optimisation thinking, whether dynamic or not, into behavioural situations. He suggests that this had led to failure due to the assumption that members of the chain will *change* their behaviour, rather than observing the "*natural*" behaviour of customers, suppliers and other chain members.

Supply Chain research based on the time concept has tended to lead towards dynamic modelling of the supply chain based on time data, such as the 'Strategic Lead Time' approach of Christopher and Braithwaite (op cit) or the 'Systems Dynamics' approach of the Logistics Dynamics Group at Cardiff University (op cit). Whereas, these studies have substantially added to supply chain understanding they have tended to take a 'rational' view of the supply chain system. Churchman (1970) defines the 'rational' approach to systems theory as one that assumes organisations can advance through scientific based rational thought and by employing systematic scientific method. It is not suggested that the aforementioned approaches take a mechanistic view, but as Ackoff (1979) points out "The optimal solution to a model is *not* an optimal solution of a problem unless the model is a perfect representation of the problem, which it never is". The 'irrational' view of These systems views are reflected in the ideas of 'mechanistic' and 'organic' organisations (Litterer, 1973; Wilkins, 1987) and the consequent contingency approach to organisational design has been extended to the organisation of logistics by Pfohl and Zollner (1987).

In relation to research aim iii (see 1.6 above), the nature of the model to be constructed is a conceptual one and not a systems model. Whereas, the systems-based approach can embrace behavioural issues (for example, in 'Soft Systems' methodology), on balance its approach is viewed as still too mechanistic to capture the richness of the potential influencing factors in this study.

7.1.2 Positivist and Phenomenological Paradigms

New and Payne (1995) highlight that academic research can be regarded as “good” if it has lots of references, follows a logical structure and contains difficult mathematics using a statistical test to a 5 per cent degree of significance. New thus draws on the comments of Ackoff (op cit) that the result of such an approach can be academic research that scores high on “rigour” and “cleverness” but low in connection to “real” problems.

It is interesting to note that a number of researchers establish both a qualitative and a quantitative phase to their work. The Cardiff framework (Naim & Towill, 1994) encompasses both the use of ‘soft’ systems analysis and ‘hard’ systems design. Horscroft and Braithwaite (1990) have a two-stage methodology, starting with large scale analysis and following with the construction of time-based simulation.

New (1995) suggests three paradigms for logistics research: [1] Managers may choose different types of practice. Some of these are “best” and will give optimum performance for the business, but may have to be adapted to different situations; [2] Performance is driven independently by both practice and the environment; and [3] The environment determines practice, only appropriate practices survive. New concludes that although logistics is a difficult area for relevant empirical research, progress may be possible if the range of methodologies expands to match the greater scope of the holistic interpretations of logistics.

Thus the traditional positivist approach in operational and logistics research is currently being challenged. This indicates that consideration should be made of the use of the inductive approach in this research area. Ragin & Becker (1992) link the inductive in case research to two orientations: the orientation of Realism, (i.e. cases are found inductively and pieced together) and that of Constructivism (i.e. cases are gradually imposed on empirical evidence as they take place in the course of research). This perception of reality as a social and psychological construct concurs with the views of

New and the benefits derived from the ability of case research to relate to human complexity in context. The orientation adopted within the study was one of “realism”.

In comparison with another framework for Logistics research by Mentzer and Kahn (1995), New and Payne (1995) argue that hypothesis testing does not work well in Supply Chain research due to a major problem in establishing valid and reliable *causal* links. The Supply Chain perspective implies that an organisation’s success is due not only to its own internal practices, but also those of its suppliers and customers. New argues that in this inter-firm environment, valid measures of success may be difficult to untangle. He also notes that “big picture” holistic logistics, where the supply chain is the focus, presents issues that go beyond the technical issues of material and information flow. A problem with this approach is the difficulty of obtaining a research question. A further difficulty is the consideration of the selection of appropriate classes of case. New and Payne (1995) note this as being a major problem for supply chain research due to its boundary-spanning and organisation-spanning nature.

7.1.3 Adopted Philosophical Approach

Moving onwards from the debate above, the adopted ontological position is one in which ‘benchmark’ information about the nature of supply chain processes in a particular supply environment (in this case, the generic capital equipment environment) is explained by recourse to the participants in the actual process: customers and suppliers along the chain. In order to gain holistic understanding, it is contended that it is necessary not just to examine supply chain systems and structures, but also the relationships and infrastructure that influence the systems and work within, or challenge, the structures. The epistemology of the study thus takes the orientation that a form of knowledge, such as actual lead times, can be explained by the choices made by the people that participate in the supply chain process. Thus the behavioural preferences of the participants count as knowledge, although it is in a considerably different form. This is in line with New’s Paradigm 1 (see 7.1.2 above).

Jankowicz (2000, p118) supports the constructivist approach in business and management research: “the approach I would advocate for your work in business and management eschews scepticism and works.....with conviction directly”. Jankowicz thus suggests that the management researcher should avoid searching for ‘truth’ and should focus instead on socially agreed understanding. In the complex interactions of a multi-company supply chain, such an approach, based on inductive rather than deductive reasoning appears the most defensible for this study.

7.2 Review of Methodologies in Supply Chain Research

Methodologies for Supply Chain research are not as well established as in other disciplines due to the relative novelty of the concept. Three main methodologies are evident within empirical studies in logistics and supply chain:

7.2.1 Structured Questionnaires

A seminal article about the state of Logistics research by Mentzer & Kahn (1995) profiles the type of research performed based on the US Journal of Business Logistics. Apart from normative articles, the largest category of articles were exploratory studies and only 4% involved hypothesis testing procedures. Mentzer and Kahn went on to analyse the type of methodology used. Even in the apparently more quantitative domain of U.S. research, Mentzer and Kahn found that two thirds of empirical studies employed only descriptive statistics and smaller proportions used advanced data analysis. Mentzer and Kahn conclude that most of logistics research remains at the substantive justification stage and suggest that the discipline must progress to more hypotheses testing studies if it is to become more rigorous. It is suggested that this ‘rigour’ would be achieved by more rigorous data analysis related to demonstration of validity and reliability. Mentzer and Kahn (1995) do not conclude that this requires advanced statistical data analysis techniques per se, although this is implied in their earlier discussion. They are clear,

however, that a substantial shortcoming of the articles reviewed was the failure to discuss validity and reliability, regardless of the analytical technique employed. This survey adopts the New and Payne (1995) approach in using structured surveys as a pre-cursor to detailed Case Research.

7.2.2 Supply Chain Mapping/Simulation

These have been used principally in the investigation of the 'hard' factors of supply chain design. Berry et al (1994) used causal loop models together with simulation. Christopher and Braithwaite (1989) used dynamic simulation modelling, whilst Beesley (1995) uses time-based process mapping within Warwick's Time Compression Programme. Berry's methodology starts with the construction of a basic "reference framework" which is essentially a simplified flow model of the supply chain in the industrial sector under study, in this case the electronics sector. By examination of the various echelons in the chain relative to specific components, such as the printed circuit board, a more detailed schematic diagram of the supply chain is constructed. Up to this stage, the review is essentially descriptive and static. Demand is then introduced into the model at a sub-system level and a causal loop explanation of the behaviour is constructed. Much of the work concentrates on the inadequacy of the flow of information and the impact that this has on system behaviour.

Christopher and Braithwaite (1989) undertake investigation at the level of the case company. A simulation model based on the two variables of throughput efficiency and process efficiency is measured on the basis of time, the two dimensions used in the Scott and Westbrook (1991) pipeline map. The model calculates the throughput cover, expressed in time, across the whole business necessary to service the projected customer demand. Variation can then be introduced to the model, particularly variation in demand and variation in lead time. The effects of these variations can be examined related to inventory cover and customer service performance.

Although mapping approaches have been found to be valid as part of an improvement methodology, this approach was not adopted within this study for two reasons: [1]

detailed mapping and investigation of an individual chain was traded-off against a broader approach involving both upstream and downstream perspectives and the ability to study a number of comparative supply chains; and [2] the focus of the study was centred on the participant's view of influencing factors rather than on the process itself. This avoids the mechanistic approach that can sometimes result from the mapping approach.

7.2.3 Case Research

The work on Supply Chain Relationships by Macbeth and Ferguson (1994) and Macbeth (1994) in the Glasgow Supply Chain Group has been generally case-based. Their original research was based on six major customer companies, some of their direct suppliers and a more widely-based sample from the electronic and mechanical engineering industries, comprising over forty companies in all. Ongoing research included visiting 24 of the English winners of the Management Today Best Factory Award.

The work on Lean Supply by the International Motor Vehicle Program (IMVP) of the Massachusetts Institute of Technology (Womack et al, 1990) and followed up by the work on Lean Supply by Lamming (1993) was based on a research approach based upon personal interviews with individuals on both sides of the relationship. Lamming comments that the interview method was regarded as a more appropriate method than a postal survey. Employing face-to-face interviews meant that factors could be extensively discussed and developed gradually, whereas a postal survey would have left more interpretation to the researcher. Lamming (1993) used early interviews to construct a model tracking 9 factors over 3 phases and towards a proposed fourth phase. The model was then tested and refined by further interviews, initially within the UK automotive industry and later in Europe and North America.

In this study, the whole environment is regarded as a Case. Its definition is based on a classification of supply type: that of capital equipment. Using a further classification based on product complexity, informed from the supplier survey, 2 units of analysis were developed based on [1] Complex and [2] Less Complex assembled products.

7.3 Evaluating Case Research Methodology

Ragin and Becker (1992) define Case Research as an empirical enquiry which: [1] investigates a contemporary phenomenon within its real life context; [2] *when* the boundaries between the phenomenon and the context are not clearly evident; *and* [3] multiple sources of evidence are used.

Cases involve a small sample size, but can use within it multiple sources of data. The shortcomings in the case study method lie in the particularity of the circumstances of cases selected and the consequent inability to provide a valid link with theory or enable further generalisation. The benefits of the method include its strong connection with reality and its relevance to the analysis of cause and effect within a problem context. The test of validity in case study research is related to the production of an iterative research design using multiple cases and cross-case comparison to provide generalisation and relate to theory.

The case study approach is not the exclusive territory of qualitative research. Quantitative data can be used within the case study design, but should be regarded as descriptive or benchmark data, rather than data to which statistical significance is attached. The use of lead-time data is thus compatible with the research design.

Thus this study relates to a single case environment: capital equipment supply in the offshore oil exploration and production industry on the UK continental shelf. The boundaries of the case are thus threefold: the generic supply environment, the industry

and the geographical boundary. Within the case design, different research methods will be employed to construct the case study.

Greenwood (1994) presents a stages model for case research where he centres on the importance of issues in case research being generalised to theoretical propositions. He also confirms that “it is essential that full theory assertion rests on multi-cases, which demand testing throughout classes of cases for plausibility. A plausible explanation can become theory through confirmation by additional cases. Nevertheless, single cases can be found which question its assertions.” (Greenwood, 1994). This approach concurs with that of Yin (1994).

Aspects of both the Ragin & Becker (1992) and Greenwood (1994) approaches are relevant to this study. As a single case environment, it is intended to use multiple sources of evidence (Ragin & Becker, 1992) in an adaptation of the New and Payne (1995) mixed methodology. As part of this ‘mix’ individual cases shall be studied and the Greenwood (1994) model of generalisation becomes more useful at this stage. Whereas Greenwood (1994) uses hypotheses, the inductive orientation adopted has led to the development of research questions and propositions. The evidence from the individual Cases are thus used to address the research questions and by doing so develop propositions related to the underlying theory. These propositions are then tested for validity by cross-case comparison. Using a classification of supply types, tentative theory can be built or existing theory amended.

7.4 Adopted Methodology

This review of methodologies used in Supply Chain research appears to indicate that, at its current stage of development, there is no clear and accepted methodology that, if adopted, would be regarded as mainstream and accepted as rigorous by the academic community.

If the premise is accepted that benefits in supply chain management result from the improved operation of the supply chain *as a whole*, this leads the researcher into considering a study methodology that captures holistic data. Case Research methodology permits this holistic view (Ragin & Becker, 1992) and has been adopted within this study.

Case Research design permits the use of both quantitative and qualitative research methods within a case research design. New postulates that mixed methodologies are perhaps the most valid approach to gain real understanding of the supply chain. This way, survey data can inform initial conceptual models, based on existing theories and these can be tested in the field using further in-depth cases. The compatibility of lead time data (regarded as descriptive or benchmark data, rather than data to which statistical significance is attached) to the research design is a key aspect of the adopted methodology.

7.5 The Generic Case Environment

The researcher identified that much of the empirical work that has been carried out on supply chain improvement has been based on research in repetitive ‘make-to-stock’ manufacturing industry. It appeared, therefore, that a contribution could be made to supply chain understanding from additional empirical work on less repetitive ‘make-to-order’ or ‘design/make-to-order’ industries.

The use of a supply environment as a case has provenance in Macbeth and Ferguson (1994), Lamming (1993) and Berry et al (1994). The Capital Equipment supply chain was selected as a generic type and within this the Capital Equipment Supply Chain to the offshore oil exploration and production industry on the UK Continental Shelf was selected as a case supply environment. Its selection was due to an ability to access the industry due to the researcher’s own location in Europe’s oil capital, Aberdeen and previous involvement in the industry. The research methodology has been designed to use “multiple sources of evidence” (Ragin & Becker, 1992) to construct a generalisation of the influencing factors on lead time performance in this generic environment. From an

orientation standpoint, the study shall be discussed based on the downstream and upstream supply chains from the capital equipment manufacturers.

Relative to the Doctorate, it is important to select appropriate classes of cases in order to progress with operational practicality to the case iteration phase. The number of cases relative to the classes is likely to be less than would ideally be preferable, again due to the limitations of resource available to a Doctoral student. The use of multiple sources of evidence and chains of evidence suggested by Yin (1994) will assist validity.

7.6 Methodological Contribution

The study makes a methodological contribution to supply chain research in two ways: [1] the development of the Supply Chain Trace-back Technique, and [2] the use of Telephone Survey Methodology.

Supply Chain Trace-back

The significant difference of this research from previous studies is the examination of not one customer-supplier relationship, but a number of these along the chain. To operationalise this, an approach based on a systematic trace-back has been developed. The method is based on an adaptation of the Berry et al (1994) concept of a 'key active component' – Berry used the printed circuit board in a study of electronic industry supply chains. This idea was merged with the identification of a component at the next level down in the chain that was the most significant in relation to lead time. This would be an item on the 'critical path', which is termed a 'pacing' item, in that it determines the pace of supply along the chain. The approach is not dissimilar to an 'end to end' audit of a process, but with the external orientation provided by the supply chain.

A further innovation was made in the introduction of a sampling frame of three key 'pacing' items at each level of the chain. If this is applied at each level in the supply chain, this approach rapidly produces a very large number of potential respondents and thus may have to be adapted in some circumstances. However, it has a practical

application in that any single trace-back could easily result in a refusal to interview. Although taking the next pacer is not ideal, it at least provides the opportunity to maintain the trace-back. The methodology for such an approach clearly requires to be iterative: it is only from the discovery of data at one level that you have the information to go onwards to the next level, and so on. It would thus be impossible to use conventional postal survey methods as a methodology.

It was originally envisaged that the appropriate methodology would be the use of semi-structured interviews and this is the method that was used at the early stages of the study. This approach ran into practical difficulties, regarding the enfolding geographical dispersion of the supply chain. Although many of the initial suppliers were easily accessible to the researcher's base in Aberdeen, as supply chains are traced back, suppliers emerge in various parts of the central belt of Scotland, the Midlands of England and so on. The initial solution to this problem was to group suppliers in areas and attempt to visit each of these areas in turn. Unfortunately, the iterative nature of the trace-back makes this extremely complicated and this is compounded by the practical difficulties of key respondents not being available at the time you have decided to visit the area. To further compound the problem, certain of the supply chains exhibited an international dimension. These difficulties required the researcher to consider an alternative to the on-site semi-structured interview. As the nature of the interview and iterative method had to be preserved, the use of Telephone Survey appeared to be the most practical alternative.

An evaluation of Telephone Survey Methodology

Telephone Survey Technique has been substantially used in the social sciences and in market research. Its use to permit case research within a dispersed supply chain environment is, to the author's knowledge, relatively innovative. The most important advantage of the use of the telephone survey is the ability to cope with the geographical dispersion of the suppliers, without the requirement of a face-to-face interview. The method can also permit the use of probing and follow-on questions, which is a useful part

of interview techniques. The method can permit the use of pre-interview contact, in the same way as would be required when making a face-to-face interview appointment. Frey (1983) undertakes a comparison between telephone interviews and face-to-face interviews, based on a number of criteria of which the following appear relevant to this study: costs, data quality, item response rate, and questionnaire length.

With regard to costs, clearly the mail survey is the least costly method, but this has already been ruled out as unsuitable for the proposed study. Telephone survey costs will relate to the geographical distance and the length of the survey interview. Frey notes that as geographical dispersion of the sample increases, the cost differential between the methods also increases. The effect of interviewer distortion (question wording; probing; recording) is possible in face-to-face as well as telephone interviews. Other data quality issues such as 'socially desirable response' have been found not to vary between methods according to Frey and it has been found that 'item non-response' is reduced when only verbal clues are given, as in the telephone survey. It is not uncommon for face-to-face interviews to be as long as 60-90 minutes in length, permitting the establishment of rapport and the ability to probe in depth. For some time telephone interviews have been criticised by their apparent inability to conduct more lengthy interviews (Simon, 1978 in Frey, 1983). However Frey quotes a number of researchers who have successfully utilised more lengthy interviews, without a high incidence of early terminations (Rogers, 1976; Dillman, 1987; Jordan, 1980 in Frey, 1983). Balancing these factors, it was concluded that a telephone survey would be practical and cost-effective related to the dispersion of the survey population; that data quality would not be severely compromised by the method; and that, although interview length is likely to be shorter, it should be possible to conduct interviews of a suitable length to obtain the necessary data. In this study, in-depth interviews were undertaken which had in excess of 70 questions and took around 45 minutes to complete (see Appendix E).

Telephone Survey Design

The aspects that require to be addressed in the design of a telephone survey are: Pre-interview contact; introductory message; question ordering and probing.

With regard to pre-interview contact Frey (1983) has suggested that this approach has been shown to depress refusal rates and improve data quality. Pre-interview contact by letter has the benefit of not only reducing the element of surprise, but also provides an authentication of the survey and will clearly distinguish the research from disguised sales activities. Where practical, pre-interview contact by letter was undertaken. In an iterative (trace-back) survey, however, the length of time required to lapse for the use of a letter by mail was found to be cumbersome. Fax and e-mail were thus used as a faster alternative that maintain the same authentication endorsement. The use of pre-interview contact by telephone was also necessary in order to set up an appointment time for the interview. This technique has not, according to Frey, improved the compliance rate compared to undertaking a single call. The method used was that respondents were asked if they are able to undertake the interview on first call and failing this an appointment was made for a call-back.

Where pre-advice by fax or e-mail was undertaken, the introductory message normally required in a telephone interview was curtailed. Frey suggests that interviewees often do not 'hear' the bulk of the introductory message, as they are too busy contemplating whether or not to participate in the survey. The written pre-advice has the same purpose as a covering letter in a mail survey, i.e. to provide information on: the purpose of the interview; the kind of information that will be requested; the conditions of confidentiality; the estimated length of interview and finally the benefits of participating.

The requirements for question ordering and probing are essentially no different to a face-to-face survey, although the risks of early termination are higher. Techniques such as starting with fairly easily answered questions and working up to those that require more thought is thus important. The ability to establish rapport is more difficult with the

telephone interview and this difficulty was exacerbated in international contexts, requiring a high level of inter-personal skills from the interviewer. The identification of probing questions in advance is also important in the more limited time-scale of a telephone survey.

7.7 Detailed Research Methods

Preliminary Interviews

A preliminary survey consisting of semi-structured interviews of Supply Chain Managers of 5 Offshore Oil Operators was undertaken (see Appendix A). In a declining North Sea reservoir, future exploration is likely to locate only much smaller fields. The problem for the industry is thus to be able to bring these fields into production in much shorter time frames than previously. Only by achieving this, shall the return on the capital investment (realised once the oil flows) be competitive with lower-cost oil provinces. Thus the aim of the exploratory phase was to identify the key supply environments that are critical to reducing lead times in offshore projects.

A consensus was established from the preliminary survey that the Offshore Supply Chain could be disaggregated into a number of sub-systems. Initial discussions identified three coherent supply environments supporting the initial Drilling of wells, the Production of oil and the Maintenance of the offshore platforms. As research progressed, it became clear that the Drilling supply environment had two distinct components: firstly, the actual Drilling of the well and secondly, the construction of the well which is called Well Engineering. The sub-systems were thus expanded to four, as follows:

- Maintenance sub-system
- Production sub-system
- Drilling sub-system
- Well Engineering sub-system

Firstly, the maintenance sub-system was eliminated from the study. Where stocks are held they relate to 'insurance' spares and beyond this the main supply lines relate to non-strategic consumables. Within Production and Drilling sub-systems there are also many non-strategic supply items such as production chemicals and drilling fluids. An investigation of the drilling sub-system revealed that much of the equipment was mainly operated on a hired basis and thus was an issue for service logistics rather than the material supply chain. Thus the main sub-system of strategic importance from a lead time standpoint for the offshore industry was thus identified as the Well Engineering sub-system.

Integration Survey

On the basis of the information provided at the exploratory interviews, a structured survey was undertaken to key supply chain respondents in the main 10 oil operating companies (see Appendix B). This provided a customer perspective on the state of integration of the capital equipment supply chain. This instrument was designed to address research Objective (i) (see 1.8 above). The rest of the research instruments were designed to address the remainder of the research objectives.

Supplier Mail Survey

A structured mail survey was sent to a sample of assemblers (systems integrators), sub-assemblers and component suppliers (See Appendix C). The aim of the survey was to provide information on the following: [1] Benchmark lead times for different supply environments; [2] Data on the nature of the product and the approach to product/process design; [3] Data on supply chain systems/structures; and [4] Data on the type of supply chain relationships in place. 12 useful responses were obtained from assemblers, 9 useful responses from sub-assemblers and 5 useful responses from component suppliers, representing a 36% response rate. Questionnaires were coded and follow-up undertaken by fax and e-mail.

Secondary Interviews

A series of 8 secondary interviews (see Appendix D) then took place with project managers and well engineers in 4 oil operators and 2 contractors, experienced in offshore projects. Within Well Engineering, the critical products were then identified and classified. Supply of capital equipment was identified as the key area where respondents saw the strategic importance of lead times as important. The study thus focused on the supply of capital equipment to the industry. This enabled the critical products to be identified and subsequently classified. Within the Well Engineering sub-system, Wellhead Xmas Trees and Well Completion Equipment were identified as both strategically important and key long lead time items.

Case Research

The supply environment was sub-divided into two sub-environment cases: [1] Complex Assembled Product and [2] Less Complex Assembled Products. Three case companies were studied in each of these sub-environments.

The Complex Assembled Products Case sub-environment provides a unit of analysis that is based on [1] Equipment value >£1m; [2] Sub-assembly complexity (at least 5 major sub-assemblies involving different processes); and [3] Component complexity (>500 components in the finished product). Three Case Companies, manufacturers of Wellhead Equipment, were selected as producing products that met these criteria.

The Less Complex Assembled Products Case environment provides a unit of analysis that is based on [1] Equipment value <£1m; [2] Low sub-assembly complexity (less than 5 major sub-assemblies involving different processes); and [3] Lower component complexity (<500 components in the finished product). Three Case Companies, manufacturers of Well Completion Equipment, were selected as producing products that met these criteria.

7.8 Design of Research Instruments

Two research instruments were used within the Detailed Research Methods, namely, the semi-structured interview and the structured survey. The design of the individual instruments is explained within this section.

7.8.1 Preliminary Interviews

Preliminary interviews were essentially unstructured. Their purpose was to identify the key areas of supply within the case environment that were significant from a lead time point of view.

7.8.2 Integration Survey

This postal survey was based on an adaptation of measures of integration from Armistead and Mapes (1993), Larson, 1994, McGinnis and Kohn, (1990), Stevens, (1989) and Williamson et al (1990). It was structured to measure [1] Supply Chain Organisation; [2] Supply Chain Information Systems; [3] Supply Chain Developments; [5] Indicators of Supply Chain Integration; and [6] Supply Chain Attitudes. The questionnaire was designed using mainly Likert-style scales where respondents were asked to grade their agreement/disagreement to a range of statements (see Appendix B).

7.8.3 Supplier Mail Survey

The supplier mail survey was structured in 6 sections (see Appendix C). The categorical data classification was undertaken by an adaptation of the Cranfield University Best Factory Audit (see Sweeney and Szwejczewski, 1996). The other sections were based on key aspects of the literature review. The structure and underpinning theory for the sections are in line with literature review summaries in 1.4.3 (Systems and Structure) and 1.4.4 (Relationships and Infrastructure).

[Section 1] This section was designed to provide categorical information on the nature of the plant and its ownership.

[Section 2] This section was designed to produce a categorisation of the nature of the product. In order to avoid generality, respondents were asked to answer the question based on the product produced with the largest output. This section included a measure of product complexity.

[Section 3] This section was designed to investigate the nature of the lead times for the sample product and the influencing factors on short, average and long lead times. Question 3.6 was designed to provide a measure of flexibility.

[Section 4] This section was designed to investigate the nature of information communication from both upstream and downstream perspectives.

[Section 5] This section was designed to measure the nature of upstream and downstream supplier relationships. This section was based on an adaptation of the Sako (1992) questions designed to profile with Arms-length (ACR-type) or Obligational (OCR-type) contract relationship types. The adaptation provided a straight choice between a series of twinned statements, one of which profiled ACR and the other OCR. Respondents were asked to select one statement from each pair. To avoid respondents identifying and selecting a “good” response, the statements were randomised and respondents were told this on the questionnaire.

[Section 6] This section asked respondents to provide some general information, in a semi-structured form, about the process related to the sample product.

The questionnaire was provided with an introductory page of explanation, including a definition of lead time “the time from receipt of a customer order to the time of receipt of the equipment by the customer”. A confidentiality statement was provided, but questionnaires were coded to permit follow-up. Follow-up was undertaken by fax and e-mail, but this did not result in any more useful responses and thus the 36 useful responses from 100 represented the initial responses only. Non-response bias could not be determined for this reason.

7.8.4 Secondary Interviews

Secondary interviews were focused on the identification of significant ‘pacers’ within the environment and the reasons for lead times from a customer perspective (see Appendix D).

7.8.5 Semi-structured Interviews used in Case Research

The semi-structured interviews undertaken within the Case Research phase consisted on an in-depth investigation of 79 questions in total (see Appendix E). As in the structured questionnaire these questions were based on a sample product in order to be as specific as possible. This was identified at the start of the interviews, based on information from the secondary interviews. Within the environment it was the product that was most significant from a lead time standpoint based on a balance between time and production volume. In other words, a product that might have the longest lead time in a product portfolio, but was not produced in significant volume would be rejected in favour of a sample product that had significant impact from both a volume and lead time point of view. Where there was no significant difference in lead time between product types, the product with highest volume was selected. There were some difficulties with this design in practice, in that the answers could be different in relation to different customers. The interview had the flexibility to record these differences. The questions were first based on the nature of lead times for the sample product and then on different influencing factors as defined from the literature review.

Sample ‘pacer’ components to be traced back were selected on the basis of the three most significant from a lead time point of view.

7.9 Case Research Triangulation and Analysis Method

Within each case, around 7 to 10 respondents were interviewed from three perspectives: the manufacturer, the downstream customer and the upstream pacer suppliers (see Appendix F). Within the practicalities of access provided by the manufacturers it was

attempted to obtain interviews from operations/manufacturing managers, purchasing/materials managers and sales/project managers within each case company. At least three customer respondents were interviewed in each case from purchasing and well engineering perspectives within oil operators and contractors. In the case of the upstream suppliers it was only practical to interview one supplier contact and this was normally the contact provided by the manufacturer. Interviews were individually conducted, transcribed and analysed in the case research.

Detailed case analyses are provided for each individual case. Cross-case comparisons are then drawn for each sub-environment case and finally conclusions are drawn for the complete case environment.

Finally the case research is compared with the evidence provided by the Integration Survey of customers and the Structured Mail Survey of suppliers to address the research propositions.

7.10 Summary

The adopted ontological position is one in which 'benchmark' information about the nature of supply chain processes in a particular supply environment (in this case, the generic capital equipment environment) is explained by recourse to the participants in the actual process: customers and suppliers along the chain.

The epistemology of the study thus takes the orientation that a form of knowledge, such as actual lead times, can be explained by the choices made by the people that participate in the supply chain process. Thus the behavioural preferences of the participants count as knowledge, although it is in a considerably different form.

Aspects of both the Ragin & Becker (1992) and Greenwood (1994) approaches are relevant to this study. As a single case environment, multiple sources of evidence were used (Ragin & Becker, 1992) in an adaptation of the New and Payne (1995) mixed

methodology. Instead of the use of hypotheses, however, the inductive orientation adopted led to the development of research questions and propositions. This way, survey data informed initial conceptual models, based on existing theories and these were tested in the field using further in-depth cases and validated through cross-case comparisons.

The study relates to a single case environment: capital equipment supply in the offshore oil exploration and production industry on the UK continental shelf. The use of a supply environment as a case has provenance in Macbeth and Ferguson (1994), Lamming (1993) and Berry et al (1994). Within the case design, different research methods were employed to construct the case study. It was structured into two phases. Phase 1 (Exploratory) involved identifying the key areas of strategic interest related to lead times in the offshore supply chains using semi-structured interviews and a structured survey of oil operators. Phase 2 (Investigation) involved two instruments. Firstly, a structured mail survey was sent to a sample of assemblers (system integrators), sub-assemblers and component suppliers. Secondly, semi-structured interviews were undertaken within the identified supply environments.

Detailed case analyses are provided for each individual case. Cross-case comparisons are then drawn for each sub-environment case and finally conclusions are drawn for the complete case environment. Finally the case research is compared with the evidence provided by the Integration Survey of customers and the Structured Mail Survey of suppliers to address the research propositions.

Relative to the Doctorate, it is thus important to select appropriate classes of cases in order to progress with operational practicality to the case iteration phase. The number of cases relative to the classes is likely to be less than would ideally be preferable, again due to the limitations of resource available to a Doctorate student.

The significant difference of this research from previous studies is the examination of not one customer-supplier relationship, but both upstream and downstream relationships. To operationalise this, an approach based on a systematic trace-back was developed.

8 THE STATE OF INTEGRATION OF THE OFFSHORE SUPPLY CHAIN – THE CUSTOMER PERSPECTIVE: Integration Survey

8.1 Theoretical Basis for Integration Survey

The theory of integration of the supply chain was analysed within Chapter 4. The paradigm that organisations progress along a staged development towards the goal of integration is well supported by the literature. The Stevens (1989) model is often used to illustrate these stages. Stevens defines the characteristics of supply chain development onwards from a baseline non-integrated position. The functional integration within Steven's Stage 2 may include the application of time phased planning using MRP, but orders are still "thrown over the wall" from production to materials management - the two functions are effectively 'de-coupled' from each other. This use of inventory to de-couple processes from each other and permit internal resource productivity within the process is well documented within operations management literature. Stage 3 internal integration is characterised by full systems visibility, in this case from purchasing through to distribution. Stage 4 sees this integration extended outwith the organisation to suppliers and customers: supported by EDI, this stage does not just represent a change in scope, but also a change in attitude relative to the sharing of information.

In an attempt to clarify the state of integration of supply chain management in the UKCS oil sector from the customer's perspective, a survey was sent to key respondents in 10 UKCS operators. These represent the customers of the capital equipment manufacturers and they are all multi-national oil companies. The choice of respondent was based on the individual that was originally identified by the operator to undertake an initial interview with the researcher. In some cases this was a supply chain manager or equivalent, in others it was a key member of a functional activity such as materials management.

The survey was based on the literature review in Chapter 4 and in particular the three themes: [1] the use of information communications systems; [2] the existence of co-ordinating mechanisms; and [3] the existence of co-operative relationships. The literature on which these themes were based is reviewed in 4.5 above (McGinnis and Kohn, 1990;

Armistead and Mapes, 1993; Stevens, 1989; Larson, 1994). The survey was structured to investigate the following features of integration:

- Supply Chain Organisation
- Supply Chain Information Systems
- Supply Chain Developments
- Indicators of Supply Chain Integration
- Supply Chain Attitudes

8.2 Supply Chain Organisation

Eight of the companies had a senior manager responsible for the supply chain whilst two did not. This manager, in some cases, did not have the title of supply chain manager and there were clearly differences in the coherence of the supply chain organisation for which these managers were responsible. Six of the managers were at a level of reporting responsibility two levels below the Chief Executive Officer of the company responsible for UKCS and two were three levels below the CEO.

Responsibility of Supply Chain Managers

If the supply chain were being regarded as an important integrating mechanism for oil operators, it would be expected that the supply chain organisation would be involved in the medium term planning of principal business activities. Respondents were thus asked to indicate involvement in the key planning activities involved in offshore activity: drilling programmes, platform maintenance and construction projects. The results for the involvement of the supply chain department are shown in Table 8.1.

50% of the eight operators which have a supply chain manager's position (or equivalent) within their organisation thus indicate that this manager (or immediate management team) have a substantial involvement in the planning process for Drilling and Construction Programmes, but only 12.5% have a substantial involvement in ongoing activities such as Platform Maintenance. Perhaps as interesting in the figures related to the extent of involvement, is the indication that a minority of respondents have no involvement in the planning of these programmes. A lack of involvement would appear

Responsibility of SCM's	Substantial (%)	Minor (%)	None (%)
Drilling Programmes	50	12.5	37.5
Platform Maintenance	12.5	50	37.5
Construction	50	25	25
Other	62.5	12.5	25

Table 8.1:Responsibility of SCM's

to indicate a lack of strategic involvement of the supply chain manager within the business. The strategic involvement of the supply chain manager thus appears to be rather mixed, with considerable differences between one organisation and another.

Respondents were asked which section of the company was responsible for the medium term planning of the management of these activities. The sections selected were based on the typical arrangements discovered in preliminary interviews with the companies, as follows: 1. Supply Chain Department; 2. Purchasing Department; 3. Inventory/Materials Department; 4. Logistics Department; 5. Logistics Contractor; 6. Contracts Department; 7. None of these

The overall results on the basis of aggregating the scores for all the 10 activities are shown in Fig.8.1.

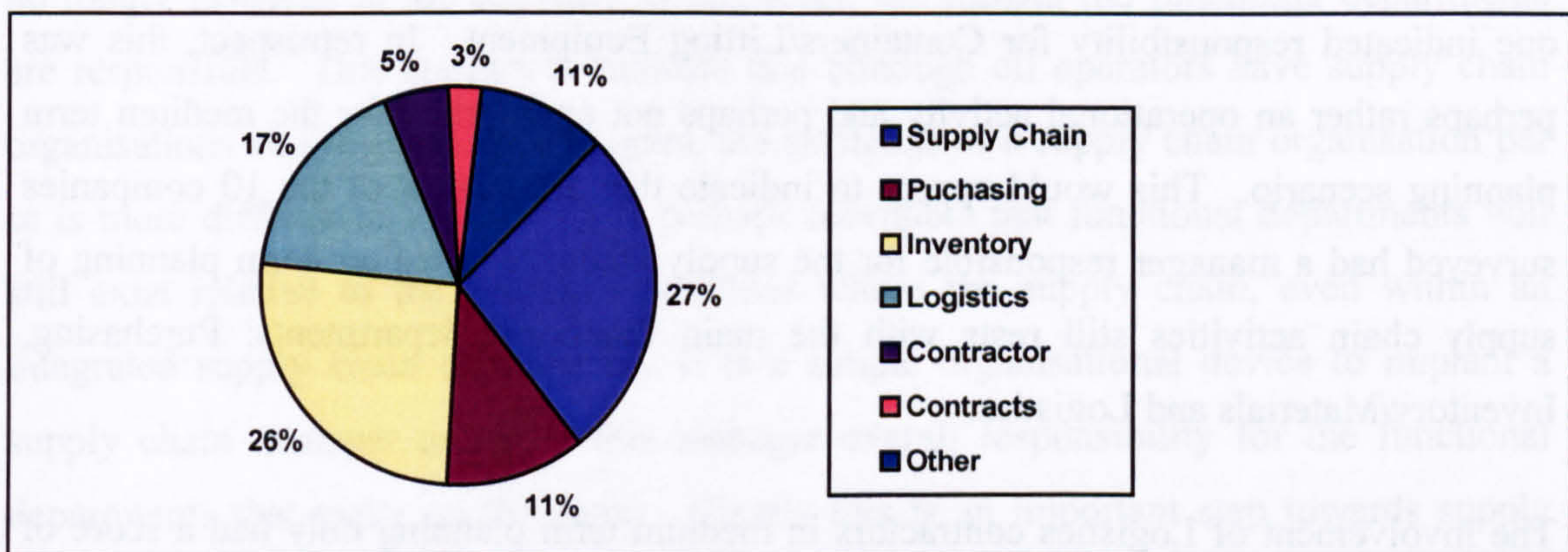


Fig.8.1: Medium Term Planning of Supply Chain Activities

The Supply Chain Department provides the highest overall score of responsibility for 27% of medium term planning activities. The department with the next highest score was

that of the Inventory/Materials department with a score of 26.1%, followed by the Logistics department with 17.2%. In Offshore Oil, the Logistics Department is usually involved only with outbound logistics activities. The list of activities is not equally profiled between those activities that would normally be expected to be dealt with by these particular departments. Activities 1 and 2 would normally be dealt with by Logistics; 3,4,5,and 6 would normally be dealt with by Inventory/Materials; activities 7 and 8 would normally be dealt with by Purchasing and activities 9 and 10 by Supply Chain Departments. To remove this possible weighting bias, the activities were aggregated into four measures for the three main functional areas and for the Supply Chain Dept. The profile is broadly similar, although the importance of Inventory/Material is slightly diminished and this was probably overstated in the previous analysis.

The largest response that none of the departments were involved in an activity was for 'Deciding Stock Holding Levels'. This issue appears to be very much still the responsibility of user departments, rather than being within the scope of the players within the supply chain. Three respondents consistently indicated Supply Chain Department responsibility for the majority of the 10 supply chain activities, although only one indicated responsibility for Containers/Lifting Equipment. In retrospect, this was perhaps rather an operational activity and perhaps not appropriate for the medium term planning scenario. This would appear to indicate that although 8 of the 10 companies surveyed had a manager responsible for the supply chain, the medium-term planning of supply chain activities still rests with the main functional departments: Purchasing, Inventory/Materials and Logistics.

The involvement of Logistics contractors in medium term planning only had a score of 5.7% and this mainly related to Road Freight Transportation, Chartering Marine Vessels, Warehousing and Containers/Lifting Equipment. This is not altogether surprising, as it is principally within these logistical activities that dedicated and shared-user logistics contracts currently exist. Clearly, the scores for Contract Logistics will vary dependent on the whether this option is used by the oil operator concerned. It is thus inappropriate to judge the extent of outsourcing of Logistics from this survey. If Logistics Department

scores are added to Logistics Contractor, a figure of 24.5% is obtained, placing this functional area in almost equal position to the Supply Chain department and thus indicating that it is individually the most significant function department responsible for medium term planning of the supply chain. This is not altogether an expected result, as the degree of professional development of supply chain organisation in the industry has tended to come from the procurement rather than the distribution end of the chain. One activity that provided a higher score for Logistics was the score for Performance Monitoring. The involvement of Contract Departments in the activities was low in significance at 3.4% overall.

Respondents were then asked about the responsibility for Day-to-day Supply Chain activities. Once again a list of supply chain activities was drawn up, based on information obtained from initial interviews.

The list is as follows: 1. Arranging road transportation; 2. Arranging collections from suppliers; 3. Marine vessel routing; 4. Allocating freight to vessels; 5. Warehousing; 6. Open storage; 7. Containers/lifting equipment; 8. Stock control; 9. Processing orders; from offshore/user departments; 10. Placing purchase orders.

The overall position for day-to-day activities shows that the Supply Chain Department is no longer involved in the activities at this level, but instead the functional departments are responsible. This appears to indicate that although oil operators have supply chain organisations and responsible managers, the existence of a supply chain organisation per se is more difficult to identify. It is perhaps inevitable that functional departments will still exist relative to the specialist activities within the supply chain, even within an integrated supply chain organisation. It is a simple organisational device to implant a supply chain manager and give this manager overall responsibility for the functional departments that make up the chain. Clearly this is an important step towards supply chain integration, but does not in itself mean that integration is advancing or will even take place. The extent to which this organisational form promotes integration, requires further investigation. The categorical analysis of the data below provides some clues. The relative importance of the functional departments is shown in Fig 8.2.

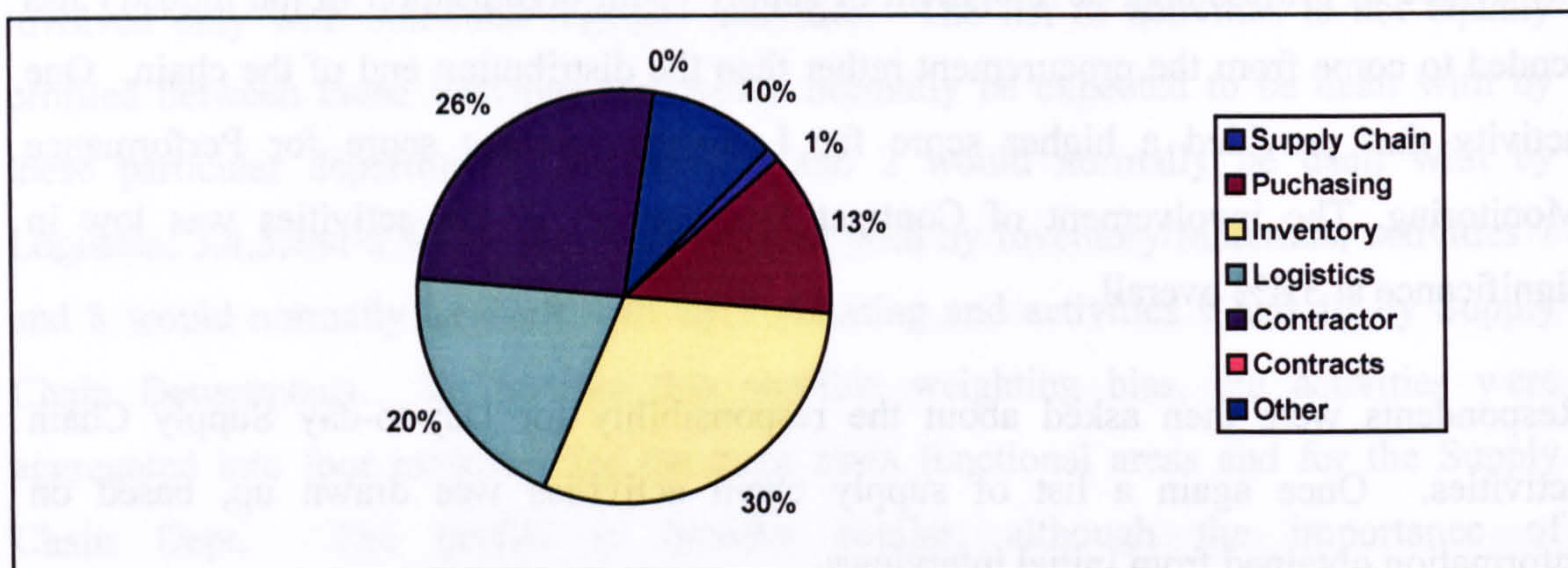


Fig.8.2: Day-to-day Operation of Supply Chain Activities

The scores for day-to day activities indicate that the Inventory/Materials department has the highest score with 30% overall, but Logistics departments and Contractors, if combined, score 46%, whilst Purchasing score 13%.

Purchasing Departments

Purchasing Departments virtually only score for activities 9 and 10 relative to the processing and placing of orders, where they are almost wholly responsible for these activities.

Inventory/Materials Departments

The activity, not surprisingly, that most respondents indicate as a responsibility for this department is Stock Control with 65% of responses. 50% of respondents also indicated that Warehousing was the responsibility of this department, which is in line with normal organisation for the offshore sector. For those who did not allocate responsibility for Warehousing to this department, 30% allocated it to Logistics Contractors and 10% to the Logistics Department. There is an identical profile relative to the responsibility for open Storage. In 25% of responses this department was also responsible for arranging Road Transportation and in 30% of respondents for arranging collections from suppliers.

Logistics Departments/Contractors

Taking Logistics departments and Contractors together, respondents were agreed mostly on this department's involvement in arranging Road Transportation. 75% of respondents indicated that this department was responsible for this activity. Similarly, 70% indicated responsibility for arranging the actual collections themselves. 80% of respondents indicated this department was responsible for Marine vessel routing and 55% for containers/lifting equipment. Responsibility for Warehousing and Open Storage was more finely balanced with 40% of respondents indicating responsibility for these activities to Logistics compared with 50% allocating responsibility to Inventory/Materials Depts. In these activities there was a clear difference between Logistics departments and Contractors, where the 40% for Logistics was built up of 30% responsibility to Contractors, with only 10% to in-house Logistics departments. For the other logistical activities the breakdown between Logistics Contractor and Logistics Departments was around 50% for each, i.e. in activities 1-4 around 40% of respondents indicated these activities the responsibility of Logistics departments, around 40% allocated the responsibility to Logistics Contractors and the remainder allocated the responsibility elsewhere. Marine Vessel Routing was the main activity to be allocated elsewhere. Some operators had separate marine contracts with specialist shipping agencies separate from their logistics contracts.

8.3 Outsourcing of Supply Chain Activities

Respondents were asked about the current and likely development of outsourcing of supply chain activities to logistics contractors (Fig 8.3). Four respondents outsourced warehousing/transportation activities, 3 outsourced offshore marine distribution, and 2 utilised a logistics contractor for purchasing. In the management of inventory, only one respondent utilised a logistics contractor and within this category one respondent was currently implementing outsourcing and one considered outsourcing likely within two years.

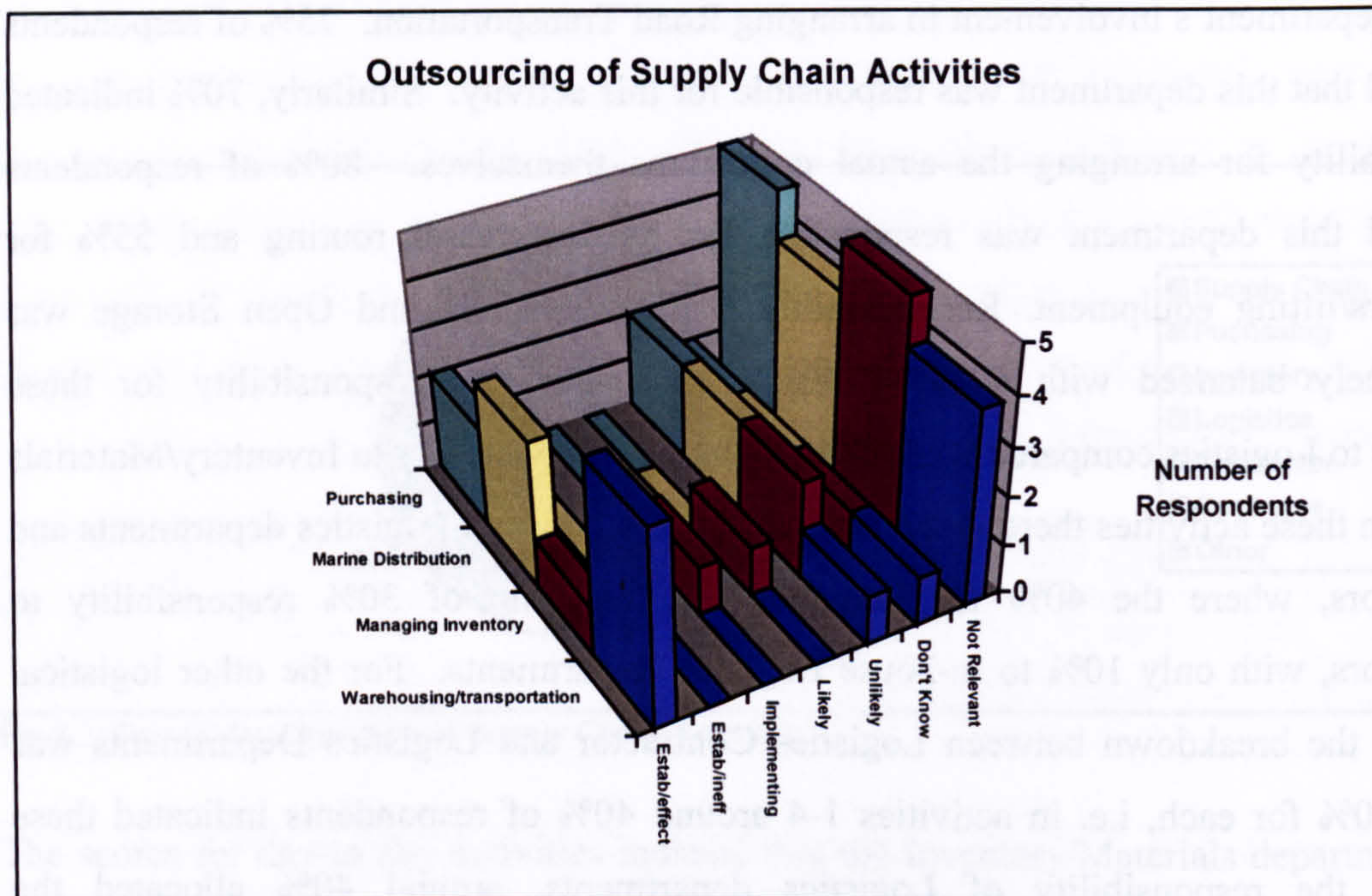


Fig 8.3: Outsourcing of Supply Chain Activities

On all other activities there was little indication of further growth of outsourcing, with a large number of respondents considering outsourcing of these activities as not relevant. The indications are thus that there is a clear divide between those companies that have taken the outsourcing route, and those who are maintaining management in-house. There is no real indication, therefore, of a rolling programme of contract logistics uptake within the sector.

8.4 Supply Chain Developments

Based on initial interviews, 19 programmes and initiatives that might be expected within a company that is undertaking integrated supply chain management were assembled (see Table 8.4). Respondents were then asked about the status of these initiatives in their own organisations, based on the following scale: Established and effective; Established but ineffective; Currently being implemented; Likely within two years; Relevant but unlikely; Not relevant; Don't know.

There was clear agreement about the supply chain developments that were established and effective within the companies and in those companies that did not have these

established, most were currently implementing the developments. Benchmarking of Supply Chain activities was established and effective in 70% of respondents and was being implemented in all but one of the respondents. Strategic long term supply agreements were established or being implemented by all respondents.

Supply base rationalisation in reducing the number of suppliers was established and effective in 55% of cases and currently being implemented by all respondents. Consequently supply base expansion was seen as not relevant by any of the respondents. Ordering by user direct to the supplier was established and effective in 55% of cases and again was currently being implemented in all but one company. Incentive based contracts for service contractors had the same response profile. (Table 8.2).

<i>SUPPLY CHAIN DEVELOPMENTS: Established Programmes</i>	<i>Established & Effective</i>	<i>Currently being Implemented</i>
Benchmarking of Supply Chain Activities	70%	90%
Strategic long-term supply agreements for services	65%	100%
Supply base rationalisation (fewer suppliers)	55%	100%
Incentive-based contracts for service contractors	55%	90%
Ordering by user direct to supplier	55%	90%

Table 8.2: Established Developments

Looking forward, the developments most likely within the next two years include Total Cost of Ownership Analysis, Incentive Based Contracts for Logistics contractors and material suppliers (See Table 8.3). The growth of total cost of ownership analysis

<i>SUPPLY CHAIN DEVELOPMENTS: Future Developments</i>	<i>Likely within 2 years</i>
Total Cost of Ownership Analysis	40%
Incentive-based Contracts for Logistics Contractors	40%
Incentive-based Contracts for Material Suppliers	40%

Table 8.3: Future Developments

profiles with information from initial interviews and material in offshore conferences embracing this concept within the industry. The growth of incentivisation within contracts was discussed in Chapter 6 related to the growth of partnering and alliances

within the industry and profiles with the increasing interest in supply chain performance measurement. Perhaps surprisingly, in comparison with Armistead and Mapes’ work on the UK’s top manufacturers, the development of other improvement mechanisms such as Total Quality Management, ISO 9000 and Investors in People had a very mixed response from the oil and gas industry (see Table 8.4).

Unlikely Developments	<i>Established & Effective</i>	<i>Currently being Implemented</i>	<i>Relevant but Unlikely</i>	<i>Not Relevant</i>
Total Quality Management	20%	30%	40%	10%
BS/EN/ISO 9000	20%	0%	30%	50%
Investors in People	30%	0%	20%	30%

Table 8.4: Supply Chain Developments

If the responses for ‘established and effective’, ‘currently being implemented’ and likely within 2 years’ are aggregated and then re-ordered in level of response it can be seen that a large number of supply chain related programmes and initiatives are likely to be in place within two years (See Table 8.5).

<i>DEVELOPMENT</i>	<i>Agg. Score</i>
Strategic long term agreements for material	100%
Supply Base rationalisation	100%
Strategic long term agreements for services	100%
Partnership arrangements with service contractors	100%
Partnership arrangements with material suppliers	90%
Ordering by user direct to supplier	90%
Benchmarking of supply chain activities	90%
Just-in-time purchasing/deliveries from suppliers	80%
Supplier holding consignment stock in supplier’s premises	80%
Supplier involved in company project teams	80%
Incentive-based contracts for logistics contractors	80%
I. Incentive-based contracts for material suppliers	70%
Total Cost of ownership Analysis	70%
Total Quality Management	50%
Investors in People	30%
BS/EN/ISO 9000	20%
Supply base expansion	0%
Other	0%

Table 8.5: Aggregate scores

8.5 Supply Chain Information Systems

All respondents had supply chain information networks, the majority of which were standard packages and the balance included custom made and customised standard packages (see Fig 8.4). Although some companies operate custom-made solutions, there is clearly indications of the use of standard software, which concurs with the survey work by Williams (op cit) related to the adoption of SAP. Four respondents categorised their current information system as a 'fully integrated standard package' and a further one as a customised version of such a package. These packages were SAP and Logica/PM3. Other respondents had custom-made solutions to their information needs, two of which were integrated systems and one of which was non-integrated.

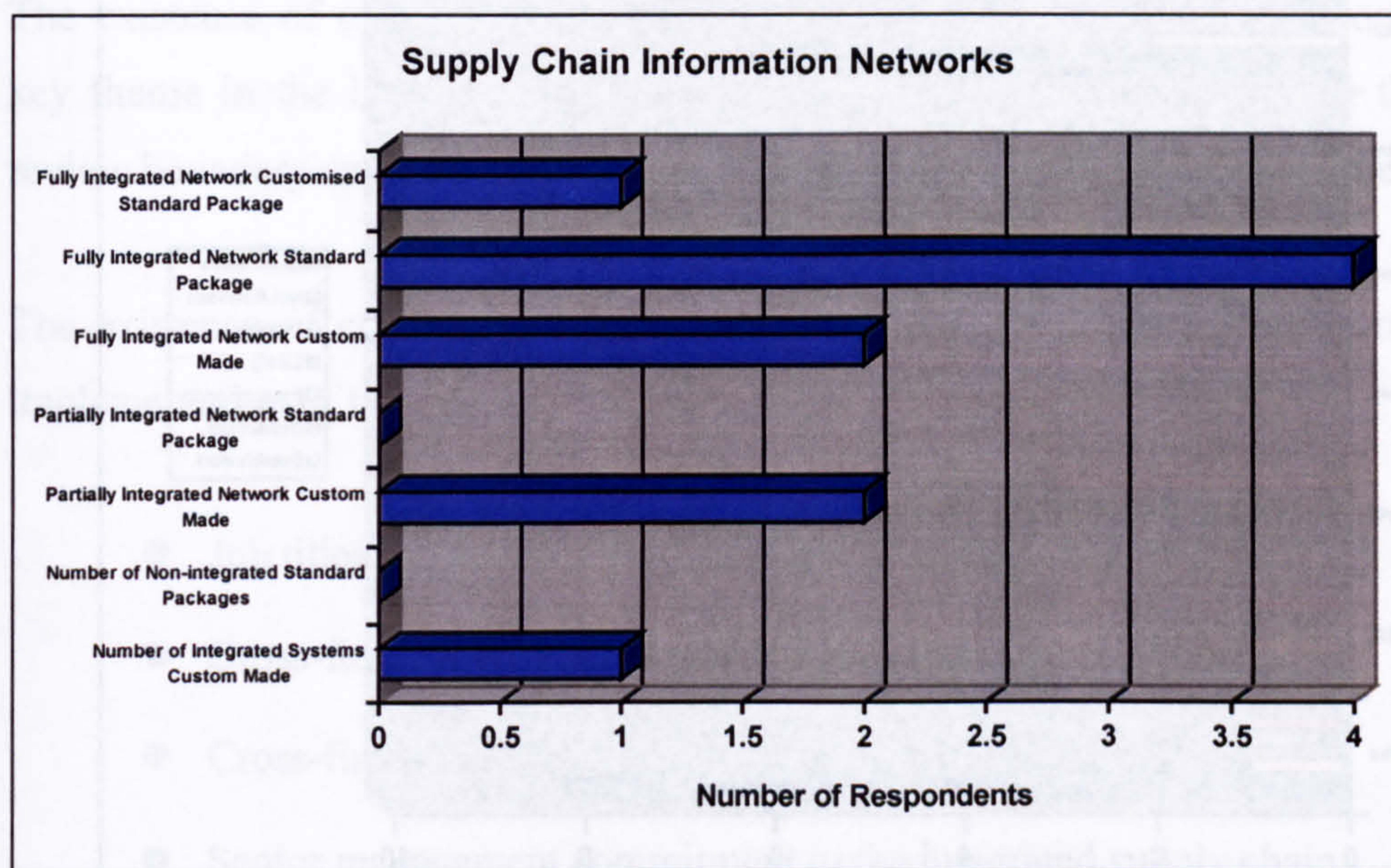


Fig 8.4: Supply Chain Information Networks

However, the interfacing of the information networks with all supply chain activities was far from complete. In 80% of cases the system interfaced with purchasing and in 60% of cases the system linked purchasing, inventory and logistics. Information systems interfaced with accounting in 70% of cases (see Fig 8.5). 80% of companies operated EDI via fax to suppliers and 50% operated computer to computer EDI. None of the companies currently operated Bar-coding either in warehousing or for offshore

distribution and only 30% saw implementation of Bar-coding likely within the next two years.

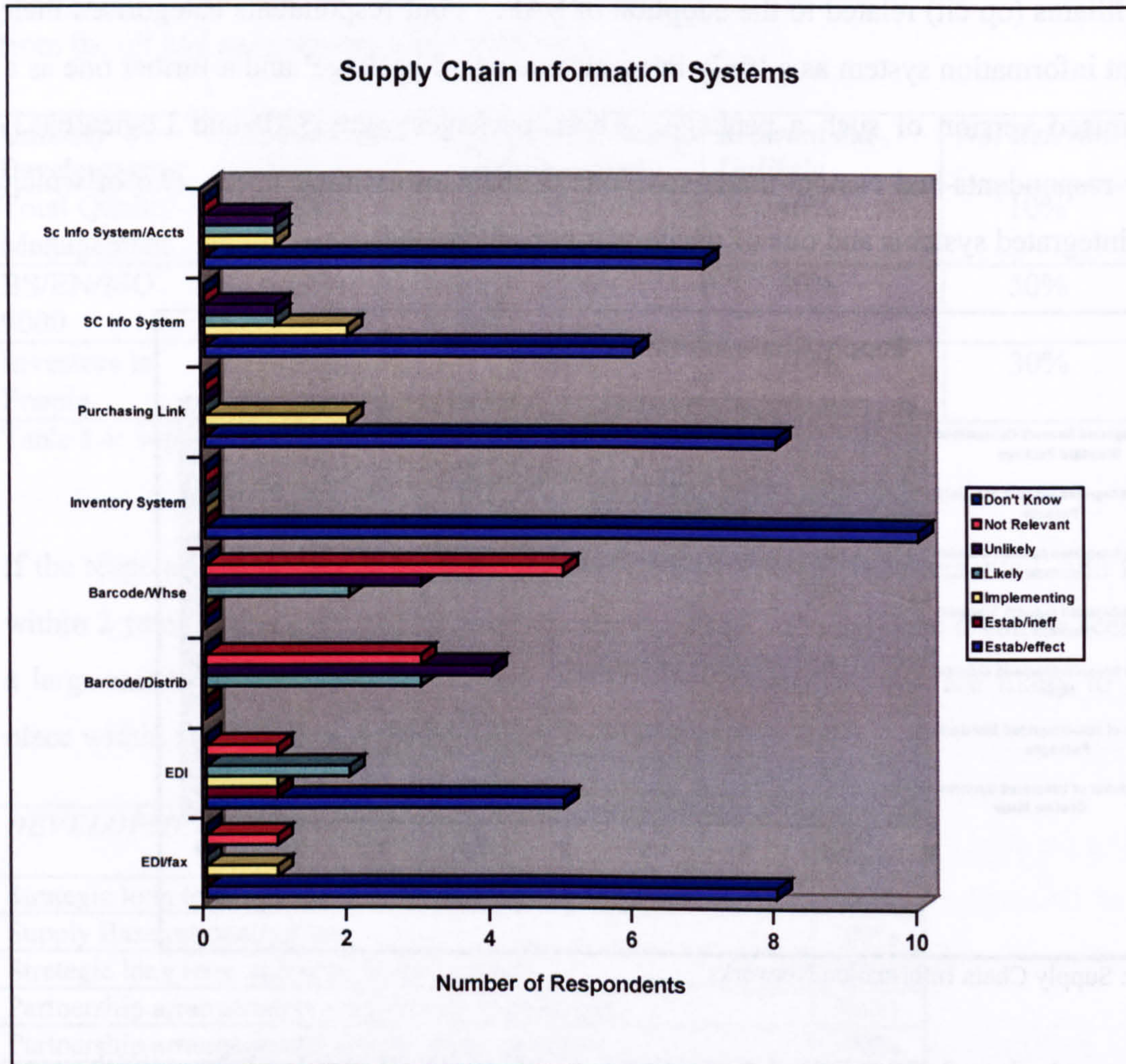


Fig 8.5: Supply Chain Information Systems

8.6 Supply Chain Integration

Twelve indicators of supply chain integration were selected based on cross-functionality, information access internal/external and shared ownership of information.

Respondents were then asked about the status of these indicators relative to their own organisations, based on the following scale:

- Established and effective
- Established but ineffective
- Currently being implemented
- Likely within two years
- Relevant but unlikely
- Not relevant
- Don't know

Cross-functionality

The existence of organisational structures across traditional functional boundaries is a key theme in the literature surrounding supply chain integration. From the literature review boundary-spanning and cross-functionality has been a recurring theme.

The existence of cross-functionality was investigated by enquiring as to the extent of implementation of the following:

- Job titles cross-function (e.g. Supply Chain Manager)
- Cross-functional supply chain/project teams
- Cross-functional supply chain training programmes
- Senior management commitment to the integrated supply chain
- Supply Chain performance measurement

The overall cross-functionality scores were that 32% of companies had cross-functional indicators in place and effective, with 4% indicating that these were in place but ineffective and 21% indicating that cross-functionality was currently being implemented, 15% likely within 2 years. The scores for the measures are shown in Fig 8.6. The indicator of 'cross functional supply chain training programmes' was not established within any of the respondents, although it was currently being implemented or likely

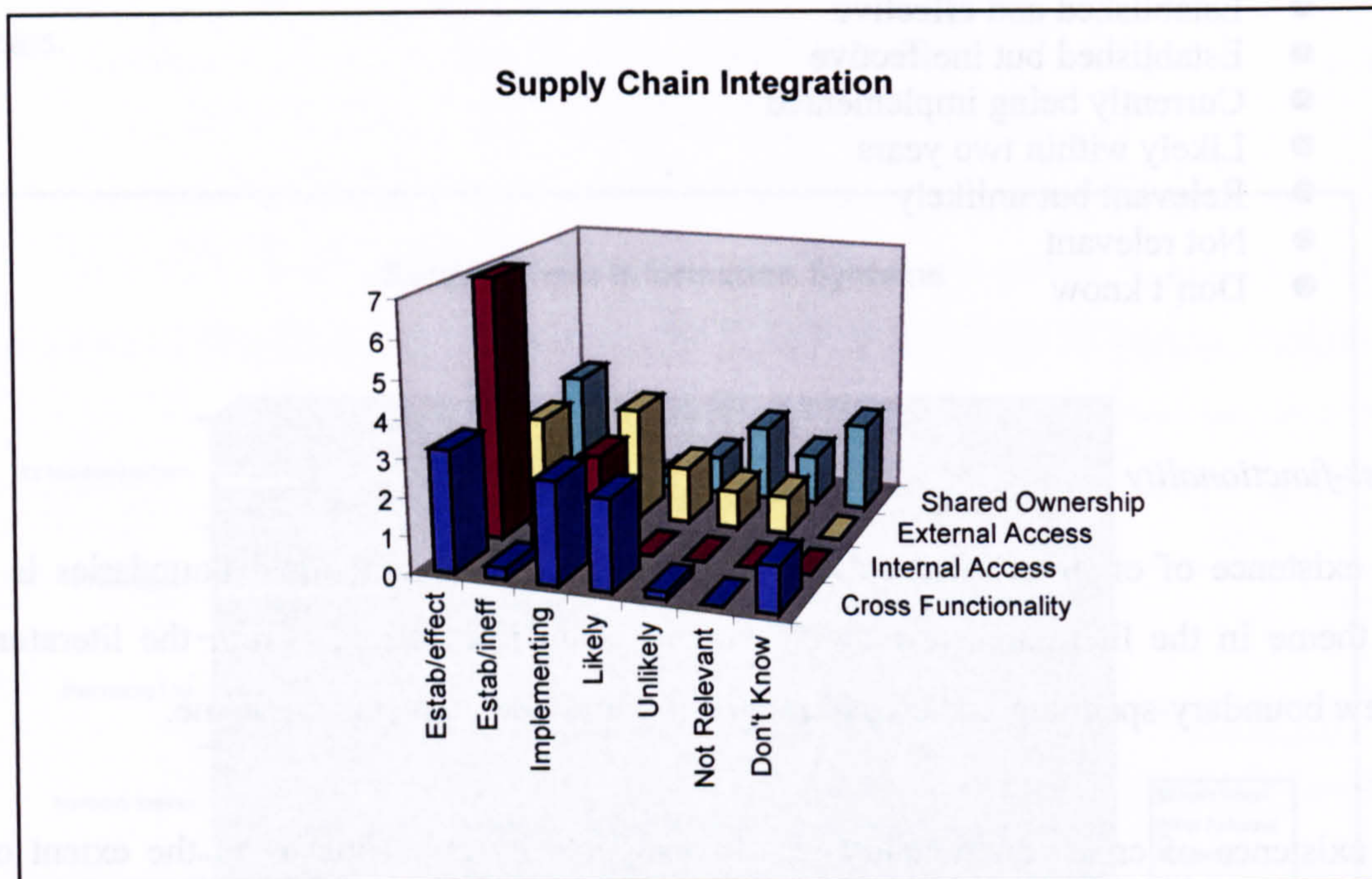


Fig 8.6: Supply Chain Integration Factors

within 2 years in 70 % of cases. Half of the respondents had a job title of Supply Chain Manager (or similar) and 40% expected that this would be in place within two years. 40% judged senior management committed to the integrated supply chain. Supply chain performance measurement was established or being implemented in 70% of cases and likely within two years in a further 20%.

Internal access to Information

The ability to access information throughout the chain by those having an involvement within organisations is another key theme of writers on the subject of supply chain integration. Christopher (1992) talks about the ability of organisations to replace inventory by information as a key theme in supply chain improvement. The idea of visibility throughout the pipeline provided by integrated information systems is also a point made by Farmer and van Amstel (1991). The consideration as to whether information systems are a driver of supply chain integration and improvement or an

enabler is also a point of debate. Bowersox and Daugherty (1995) conclude that information technology has significantly impacted logistics strategy practices and organisational structure choices. Schary and Coakley (1991) explain the impact of information technology on the shape of the logistics organisation, particularly related to network capability and access and related behaviours.

The extent of internal access to information was measured by asking about the following: [1] Integrated information systems and [2] Information access for end users. These measures showed strong positive scores with 47.5% of respondents indicating that these were in place and effective, 7.5% indicated established but ineffective and 27.5% currently implementing and a further 7.5% likely within 2 years. This is clearly in line with information on the increased adoption of software packages such as SAP within the industry, as noted above.

External Access to Information

Clearly a real supply chain organisation will also extend these information systems outwith the boundaries of the organisation to suppliers. This was measured by enquiring about: [1] Information access for material suppliers; and [2] Information access for service contractors.

As would be perhaps expected, the adoption of external access was less marked than that for internal access, but 80% of respondents indicated that they had established or were likely to establish external access within 2 years.

Shared Ownership of Information

The technical ability to access information by those external to the organisation is one thing. Sharing the information in such a way that suppliers can make use of it to improve the operation of the chain is another. Finally, shared ownership of schedules related to the main activities of drilling, maintenance and production was investigated. Here there was a clear divergence of view. 30 % of respondents had these shared arrangements in

place, but there was minimal indication that others were moving to put shared information in place and 58% considered either relevant but unlikely, not relevant or didn't have a view.

In summary the indications of supply chain integration are these: information access potential is strong internally and is being extended externally. Indicators of cross-functional supply chain activities are growing and more are likely within two years. Shared ownership of information is more problematical. For 30% these activities were viewed as being established and effective, particularly relative to drilling and maintenance, but it is only a minority that are currently implementing these initiatives, others see them as relevant but unlikely and many just don't know. Perhaps this is an indicator that the Oil and Gas industry can cope with technical and systems change, but has more difficulties with attitude changes

8.7 Future Indications of Supply Chain Integration

Ten statements were provided to respondents as indicators of integration. Respondents were asked the extent of their agreement with the statements on a Likert-type score as follows:

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree
- Don't know

There were scores indicating agreement on seven of the ten indicators (See Table 8.6). The area where there was most agreement was that sharing of resources between operators would be a growing feature. There was also agreement that there would be increasing co-ordination between logistics/supply chain and other departments and that co-ordination of the supply chain is increasingly part of the overall strategic planning

process. There was also agreement that there would be increased emphasis on Electronic Data Interchange with suppliers and other parties. Respondents agreed that there would be a growth in the sharing of information with material suppliers although the score was slightly less strong than with service contractors. There was also agreement on the expectation of the development of a 'shared vision' between company and supplier and a weaker agreement about increased emphasis on integrated information systems. It is not clear whether this slightly lower score for information systems emphasis is due to the substantial advances in integrated solutions already in place or due the perception that information systems will be a less important emphasis.

<i>FUTURE INDICATIONS</i>	<i>5=strongly agree>1=strongly disagree</i>
Sharing of Resources between operators	4.6
Co-ordination of activities with other departments	4.5
Co-ordination of supply chain increasingly part of overall strategic planning	4.3
Growth in sharing of information with service contractors	4.2
Increased emphasis on Electronic Data Interchange with suppliers and others	4.2
Growth in sharing of information with material suppliers	4.1
Expect 'shared vision' to be developed between company and supplier	4.0
Increased emphasis on integrated information systems	3.9
Partnering with service contractors will improve supply chain efficiency in future	3.3
Growth in outsourcing of logistics/supply chain activities	2.8

Table 8.6: Future Indications of Supply Chain Integration

At the other end of the scale there tended to be disagreement in the growth of outsourcing of logistics/supply chain activities (See Fig 8.7). Respondents were neutral on the impact of partnering with service contractors on supply chain efficiency. This is an interesting result, as it perhaps indicates the possible dichotomy between the benefits to be derived from partnering and the possible downsides for the dis-integration of the chain. However, it is the strong overall scores that is the main pattern to emerge which would indicate positive indications for further integration of the offshore supply chain.

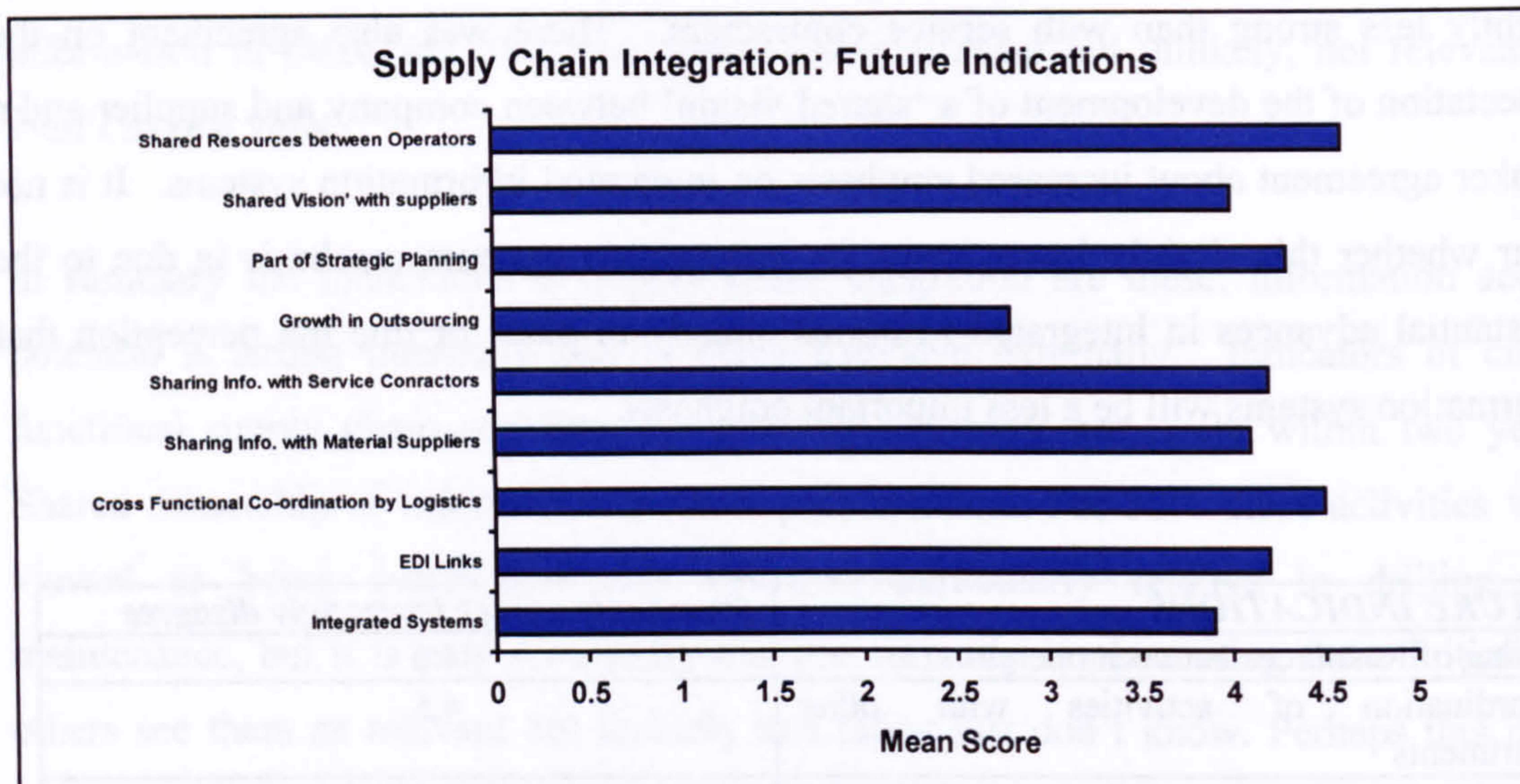


Fig 8.7: Supply Chain Integration – future indications

8.8 Supply Chain Attitudes

The same format of using agreement or disagreement to statements was used to investigate the state of supply chain attitudes for UKCS operators. The statements were all indicators of positive supply chain attitudes. The problem with any questionnaire of this type is that respondents will tend to accept positive attitudes as being an 'acceptable' answer and thus more positive scores are recorded than would be realistically the case. Most responses are showing weak agreement, but if the possible bias above is taken into account, perhaps they could be regarded as rather neutral in relation to the development of supply chain attitudes (see Fig 8.8).

The most positive response was for the sharing of marine distribution resources with other operators, where seven respondents strongly agreed and the remaining two agreed. This indicates the unusual situation of the upstream oil industry related to its distance from markets, which has previously been discussed. The growth of marine resource sharing initiatives such as Marine Team (Johnston, op cit) would thus appear to be leading to more formal and informal resource sharing arrangements.

The next most positive response was for the sharing of forecasts/plans/call-offs with suppliers, where three respondents strongly agreed, two agreed and the remaining two were neutral. Strong positive scores were also recorded for active help to suppliers to improve quality, sharing of warehouse resources with other operators and agreement that partnering arrangements with service contractors will improve supply chain performance. Weaker scores were obtained for the following: detailed feedback on supplier performance; active assistance to suppliers to reduce costs; sharing of detailed cost information with suppliers; sharing data on inventory levels with suppliers; encouragement of co-operation with other operators to use the same supplier.

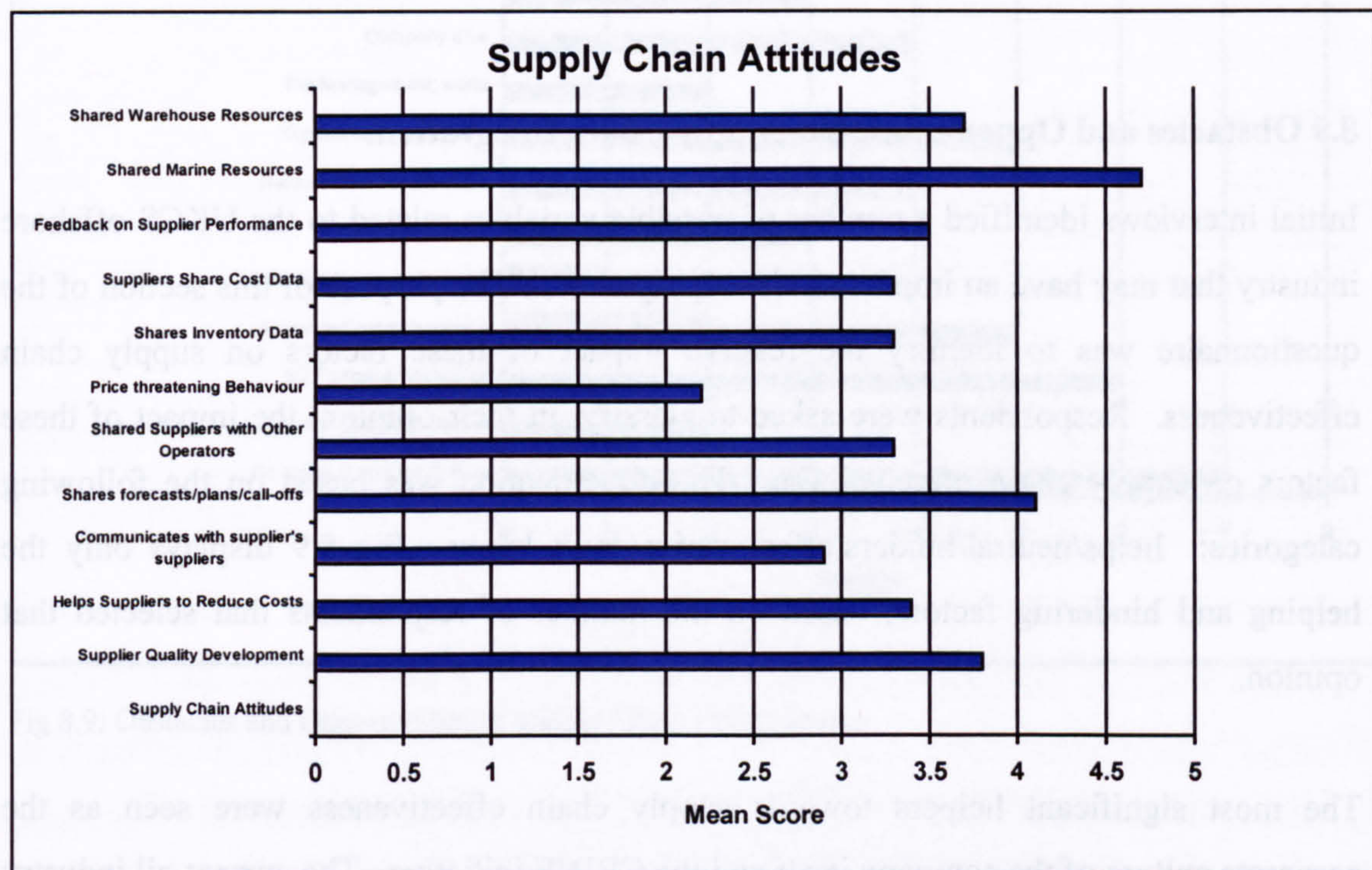


Fig 8.8: Supply Chain Attitudes

Disagreement was recorded on the communication with suppliers' suppliers, indicating that relationships still tend to be with first tier suppliers only. Relative to this question, five operators disagreed with the statement, but on the other hand one operator strongly

agrees and two agreed, leaving one as neutral. There thus appears to be a mixed pattern on supply chain development past first tier suppliers, but clearly not a totally negative situation. There was one statement in which a negative response would indicate relationship attitudes in place and this was the use of the threat of withdrawing business to secure low prices from suppliers. By reversing the negativity score a mean score of 3.5 is obtained indicating a weak positive attitude. Interestingly, two respondents agreed that their organisation used this threatening behaviour.

8.9 Obstacles and Opportunities to Supply Chain Integration

Initial interviews identified a number of possible variables related to the UKCS offshore industry that may have an impact on the supply chain. The purpose of this section of the questionnaire was to identify the relative impact of these factors on supply chain effectiveness. Respondents were asked to classify, in their opinion, the impact of these factors on supply chain effectiveness. The classification was based on the following categories: helps/neutral/hinders/effect varies/don't know. Fig 8.9 displays only the helping and hindering factors, based on the number of respondents that selected that opinion.

The most significant helpers towards supply chain effectiveness were seen as the corporate culture of the company itself and the CRINE initiative. The current oil industry economic atmosphere, information systems and supply chain performance measures were also seen as helpful. Whereas 50% saw top management in the UKCS as a helpful influence, top management world-wide were seen as neutral. Features such as company size, organisational structure and the corporate culture of suppliers were seen as features where the effect varies.

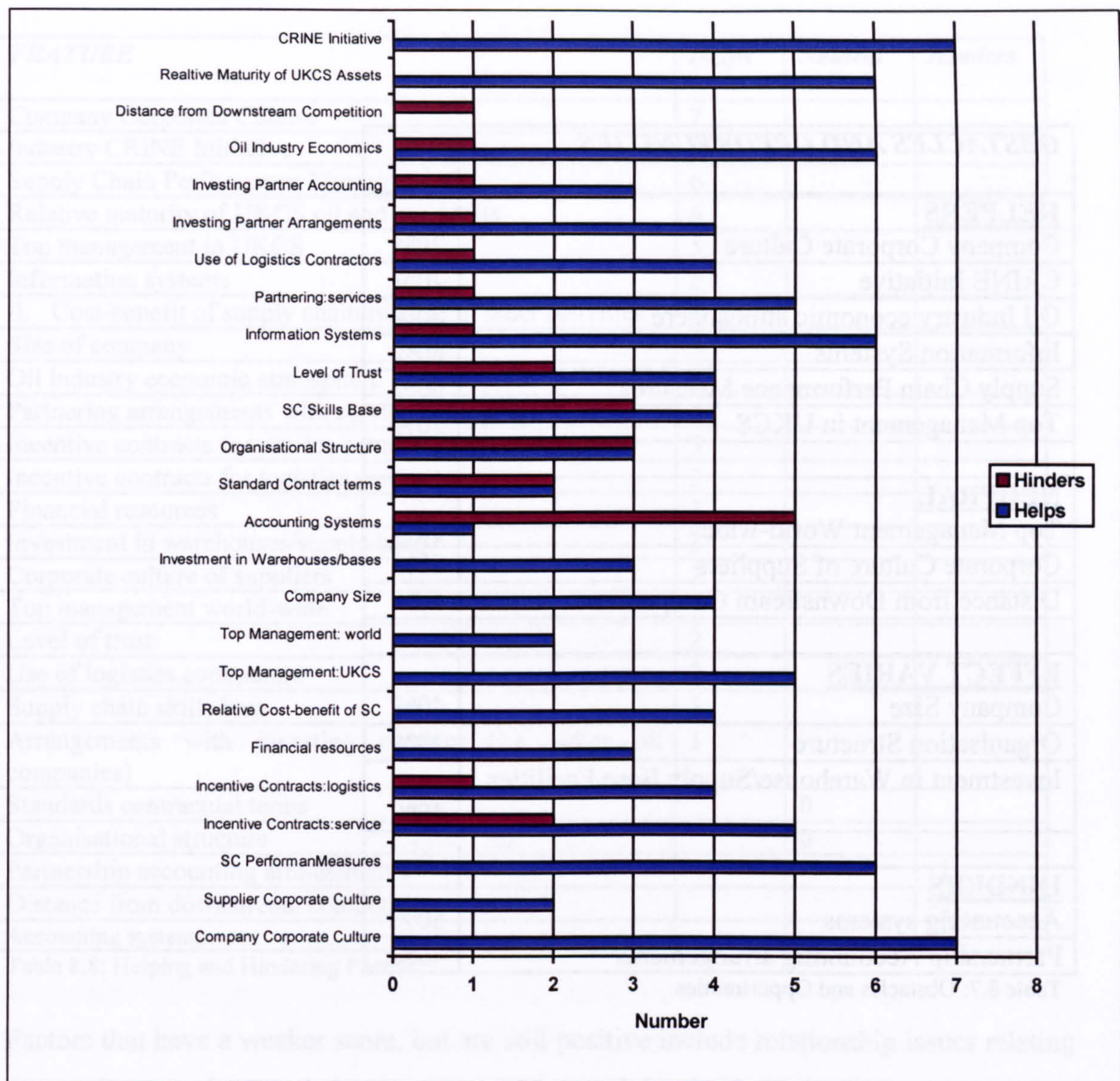


Fig 8.9: Obstacles and Opportunities to Supply Chain Development

The features that were seen to hinder the effectiveness of the supply chain were accounting systems and partnership accounting arrangements (see Table 8.7).

<i>OBSTACLES AND OPPORTUNITIES</i>	
<u>HELPERS</u>	
Company Corporate Culture	70%
CRINE Initiative	70%
Oil Industry economic atmosphere	60%
Information Systems	60%
Supply Chain Performance Measures	60%
Top Management in UKCS	50%
<u>NEUTRAL</u>	
Top Management World-wide	60%
Corporate Culture of Suppliers	40%
Distance from Downstream Competition	40%
<u>EFFECT VARIES</u>	
Company Size	40%
Organisation Structure	40%
Investment in Warehouse/Supply Base Facilities	40%
<u>HINDERS</u>	
Accounting systems	50%
Partnership Accounting arrangements	40%

Table 8.7: Obstacles and Opportunities

The data was also analysed on the basis of allocating a 'helps' response with +1 score, 'neutral' with 0 score and 'hinders' with -1 score. The results profiled on this basis are presented in Table 8.8. Overall there are thus a greater number of factors helping supply chain effectiveness rather than hindering. Some key management factors show positive scores such as company corporate culture, top management in the UKCS and supply chain performance measures. Factors related to the business environment also score positively: the relative maturity of the UKCS oil and gas assets is seen as a helper towards presumably a realisation of the need for the effective supply chain as is the industry CRINE initiative (explained in Chapter 5). In this mature environment the relative cost-benefit of supply chain activities are regarded as helpers as is the economic atmosphere within the industry.

FEATURE	Helps	Neutral	Hinders
Company Corporate Culture	7		
Industry CRINE Initiative	7		
Supply Chain Performance Measures	6		
Relative maturity of UKCS oil and gas assets	6		
Top management in UKCS	5		
Information systems	5		
II. Cost-benefit of supply chain relative to other activities	4		
Size of company	4		
Oil industry economic atmosphere	4		
Partnering arrangements with service contractors	4		
Incentive contracts for service contractors (not logistics)	3		
Incentive contracts for logistics contractors	3		
Financial resources	3		
Investment in warehouses/supply bases	3		
Corporate culture of suppliers	2		
Top management world-wide	2		
Level of trust	2		
Use of logistics contractors	2		
Supply chain skills base	1		
Arrangements with investing partners (i.e. other oil companies)	1		
Standards contractual terms		0	
Organisational structure		0	
Partnership accounting arrangements			-1
Distance from downstream competition			-2
Accounting systems			-4

Table 8.8: Helping and Hindering Factors

Factors that have a weaker score, but are still positive include relationship issues relating to suppliers, including their corporate culture and level of trust. Some management factors also have a weak positive score such as top management world-wide, the supply chain skills base and arrangements with investing partners. Neutral factors are standard contractual terms and organisational structure. Perhaps surprisingly, related to the emphasis of CRINE on standard terms, respondents do not consider this a helper towards supply chain effectiveness. The neutral response on organisation structure is perhaps more understandable, due to the differing forms within the industry.

Negative factors occur in management issues, particularly related to accounting systems and the need for these systems to deal with accountability related to the investing partners

within any particular offshore asset. Distance from downstream competition is perceived as a hindering factor relative to supply chain effectiveness. Again this is a surprising perception, as the ability to co-operate between operators, including the sharing of resources was perceived by the researcher as being permitted by the relative distance of the upstream oil industry from the downstream market. Perhaps respondents consider that the service levels required by the supply chain would highlight it as more important, in sections of the industry nearer the ultimate customer, whereas upstream the demands of engineering outweigh the supply chain in terms of relative importance.

8.10 Summary of Findings

This research instrument was designed to provide a customer perspective of the state of integration of the offshore oil exploration and production supply chain.

With regard to Armistead and Mapes (1993) four areas of integration measurement, there is considerable evidence of growth of cross-functionality. There was positive evidence of the use of integrated information systems internally within customers' organisations and there was some evidence of these systems extending externally to suppliers. The use of standard Enterprise Resource Planning (ERP-type) systems such as SAP had increased the pace of change in this area. Whereas supply chain visibility is well on the way to be technically possible, evidence of attitudes in the sharing of this information, particularly with those external to the organisation is more sparse. Where it did exist, it tended to be at a rather broad level (such as drilling activity plans) rather than detailed schedule information that would be useful to suppliers for their own scheduling. In comparison with Armistead and Mapes (1993) findings in the manufacturing environment, the offshore oil and gas industry is much more divided about the link with other improvement mechanisms such as Total Quality Management or Investors in People. If the industry is to gain benefits from Supply Chain Management this is a concern, as Larson (1994) indicated that the indicators of co-operative sentiment required for functional integration are also the major concepts of TQM.

The survey indicated that all customers had strategic long-term agreements with suppliers and had undertaken substantial supply base rationalisation. Customer attitudes showed weak levels of agreement to their use of detailed feedback to suppliers about performance. There were also weak scores for customers providing active assistance to suppliers to reduce costs or the sharing of cost information with suppliers. Customers did not agree that they communicated further upstream from the first tier supplier to the 'supplier's supplier'.

Perceptions of customers about the future is that it will bring increased co-operation between operators, particularly in the sharing of supply chain resources, most evident in marine distribution. Opinion is more divided in the future growth of outsourcing of logistics/supply chain activities and the impact of service partnering on supply chain performance. Customers perceive drivers for supply chain integration to be present in the corporate culture of the operators, the CRINE initiative (CRINE, 1994) and the economic atmosphere within the industry, whilst accountancy systems are seen as the main obstacle.

Clearly then, the current state of supply chain integration in the oil and gas industry is one that has shown rapid and continuing advance in the integrating mechanisms of organisational structure and information systems. The barriers to supply chain integration appear to be cultural and attitudinal rather than technical.

9. INFLUENCING FACTORS ON LEAD TIME PERFORMANCE
Structured Mail Survey

The structured mail survey was sent to a representative sample of Assemblers (systems integrators), Sub-assemblers and Component Suppliers. The sample represented the main identified suppliers to the supply environment. The aim of the survey was to provide information on the following: [1] Lead times for the capital equipment supply environment that are representative and would provide a benchmark for the environment; [2] Data on the nature of the product and the approach to product/process design; [3] Data on supply chain systems/structures; and [4] Data on the type of supply chain relationships.

9.1 Nature of Supply Chain Tiers and Lead Time Performance

Questionnaire responses were classified on the basis of Assemblers, Sub-assemblers and Component Suppliers (see Table 9.1). Assemblers, which can be regarded as system integrators and profile with the category “Complex Assembled Products” and Sub-assemblers relate to “Less Complex Assembled Products”. In addition, this classification is congruent with the levels in the supply chain: 1st tier, 2nd tier and 3rd tier suppliers. The nature of the different categorical variables was broadly as expected, apart from one company in the Component Supplier category, which was a larger player than any of the others. When this case is extracted from the data (shown in brackets in Table 9.1), the number of plants and number of employees returns more closely to what would be expected.

	<i>Assemblers (System Integrators)</i>	<i>Sub-assemblers</i>	<i>Component Suppliers</i>
Ownership	92% public (n=11); 8% private (n=1)	33% public (n=3) 67% private (n=6)	40% public (n=2) 80% private (n=3)
Nationality	25% UK (n=3) 58% USA (n= 7) 17% EU (n=2)	67% UK (n=6) 22% USA (n=2) 11% EU (n=1)	60% UK (n=3) 40% USA (n=2)
Plants (average)	115	20	31 (3)
Size (average)	16,855 sq. ft	154,312 sq. ft	4,460 sq. ft
Employed (average)	185	84	92 (42)
Product Cost (average)	£1,497,500	£13,578	£1,693

Table 9.1 Categorical Data Grouped by Tier

Respondents were asked to classify the nature of their product relative to a four-part classification that was used by the Cranfield University “Best Factory Audit” (Sweeney et al, 1996). In the case of Assemblers 67% of their products were classified as of ‘unique customer specific design’, whilst all other categories were around 10%” (see Fig 9.1). The most prominent category for Sub-assemblers was “sales catalogue items with customer choice options” (32%), with other categories around 20%. Many of these suppliers could be regarded as Original Equipment Manufacturers (OEM’s) to the Assemblers and the extent of customer choice options indicates a lack of standardisation within the oilfield supply environment. Component Suppliers recorded “customer specific design to repeat orders” as the most common type of order with 38% of sales, sales catalogue items were 31% and unique designs accounted for 23%.

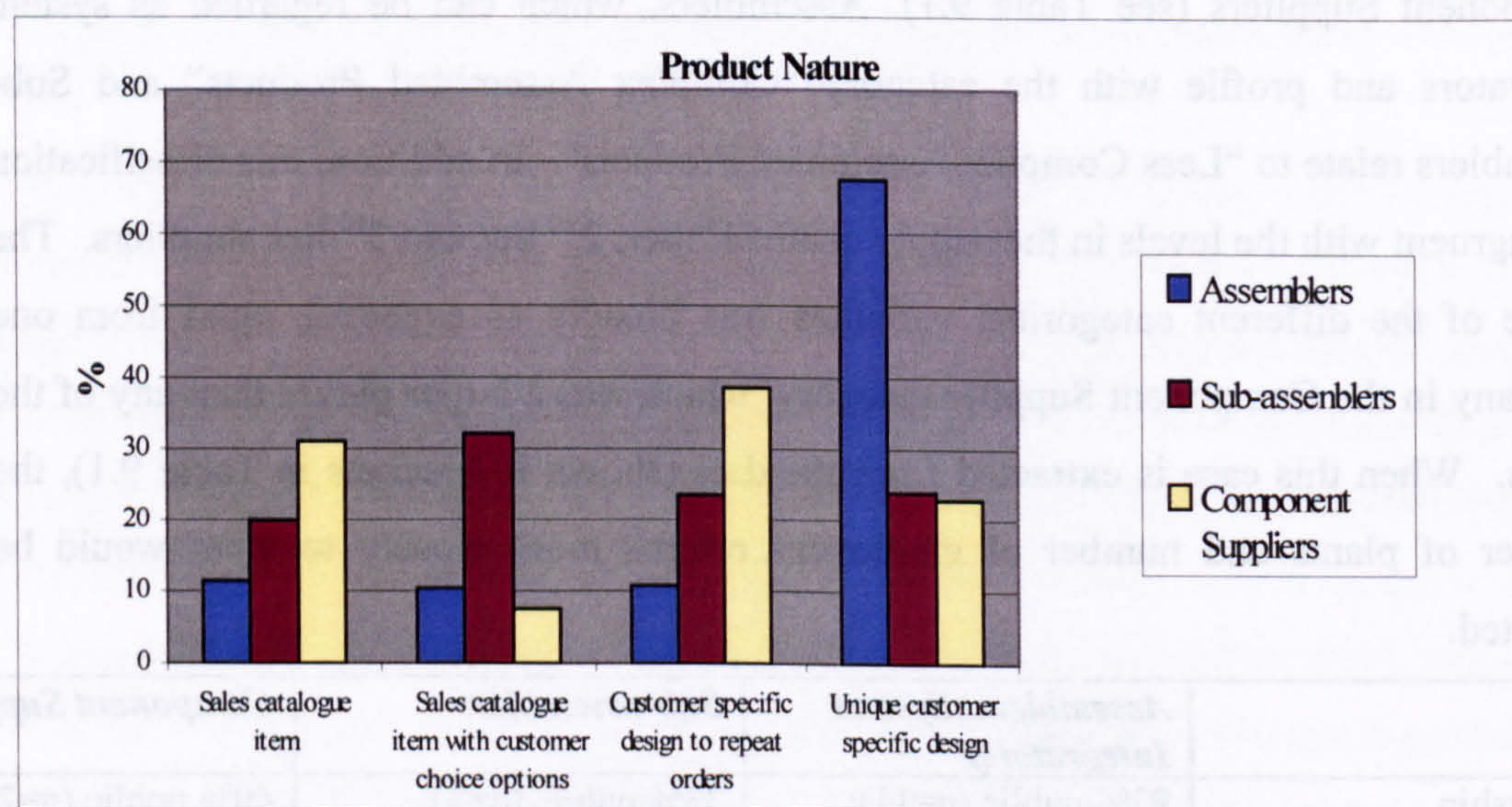


Fig 9.1: Product Nature

To provide further information about the supply environments a complexity profile was compiled, again adapted from the Cranfield University “Best Factory Audit”. Throughout all the categories and particularly with regard to the ‘average number of components in the finished product’ the most significant difference can be seen for Assemblers that have a substantially higher complexity profile than the other categories (see Table 9.2). The profile for the other two categories is consistent with expectations, with the least complexity relating to component suppliers as would be expected. There

was an inconsistency with the data for ‘number of components in finished product’ for component suppliers, where one respondent recorded 250 components. When the data for this unusual case is excluded, a figure of 7 is found on average instead of 55. It would appear that the inconsistency relates to different coupling threads and fittings in the case of the ‘unusual’ component supplier.

	<i>Assemblers</i>	<i>Sub-assemblers</i>	<i>Component Suppliers</i>
No. of raw material components	191	17	3
No. of bought-in components/sub-assemblies	364	25	7
No. of components/sub-assemblies manufactured	226	40	4
No. of components in finished product	1867	66	55 (7)

Table 9.2: Product Complexity Profile

The benchmark lead times for the different supplier categories are broadly as would be expected with longest lead times relating to the most complex products and shortest to the least complex (see Table 9.3).

	<i>Assemblers (System Integrators)</i>	<i>Sub-assemblers</i>	<i>Component Suppliers</i>
Shortest Lead Time	1-3 months	< 1 month	< 1 month
Average Lead Time	3-6 months	1-3 months	< 1 month
Longest Lead Time	9-12 months	3-6 months	1-3 months
Reduction in Lead Time	83% record reduction	100% record reduction	100% record reduction

Table 9.3: Lead Time Performance

9.2 Importance of Customer Service Criteria

Respondents were requested to rank customer service criteria in terms of importance (see Table 9.4). For the assemblers and the sub-assemblers “product features or performance” were ranked as most important. In the case of assemblers this was followed by

“reliability of delivery or service level”, followed by price. These categories were inverted for sub-assemblers who ranked price as more important than delivery reliability. Both 1st and 2nd tier suppliers rated “after sales service” and “brand image/reputation” as their least important criteria, although once again the order was reversed between the two categories.

<i>Assemblers (System Integrators)</i>	<i>Sub-assemblers</i>	<i>Component Suppliers</i>
Product features or Performance	Product features or Performance	Reliability of Delivery Date or Service Level
Reliability of Delivery Date or Service Level	Price	Product features or Performance
Price	Reliability of Delivery Date or Service Level	Quoted Delivery Lead Time
Quoted Delivery Lead Time	Quoted Delivery Lead Time	Price
After Sales Service	Brand Image/reputation	Brand Image/reputation
Brand Image/reputation	After Sales Service	

Table 9.4: Ranked Customer Criteria

Component suppliers ranked “reliability of delivery date or service level” as their most important criterion. Interestingly, all categories ranked “quoted delivery lead time” lower than “reliability of delivery date”, indicating that they perceived delivery reliability more important than delivery speed.

9.3 Influencing Factors on Lead Time Performance

Where orders achieved a short lead time, contributing factors to this performance were investigated based on asking respondents to rank the importance of a list of criteria. For Assemblers “specification received on time from customer” and “specification not altered since time of order” were perceived as the most important criteria (see Table 9.5). This would be a logical conclusion based on the ‘design to order’ nature of their products.

Rank	Assemblers (System Integrators)	Sub-assemblers	Component Suppliers
1	Specification received on time from customer [C]	Components held in stock [S]	Specification received on time from customer [C]
2	Customer specification not altered since time of order [C]	Short lead times at raw material suppliers [S]	Customer specification not altered since time of order [C]
3	Components held in stock [C]	Specification received on time from customer [C]	Short lead times at raw material suppliers [S]
4	Short lead times at raw material suppliers [S]	Standard catalogue item ordered by customer [C]	Standard catalogue item ordered by customer [C]
5	Capacity easily available at component suppliers [S]	Customer specification not altered since time of order [C]	Capacity easily available at component suppliers [S]
6	Other	Capacity easily available at component suppliers [S]	Low rework time
7	Low rework time	Other	Components held in stock [S]
8	Standard catalogue item ordered by customer [C]	Low rework time	Other

Table 9.5: Contributing factors to SHORT Lead Times

The next important contributor was perceived as “components held in stock”. These were all seen as more important than effects further down the supply chain, such as “short raw material lead times “ or “capacity easily available at component suppliers”. Interestingly, the pattern for component suppliers profiled closer to that of assemblers than that of sub-assemblers, although “short lead times at raw material suppliers” and “standard catalogue item” were perceived as more important, which would appear to be consistent with a 3rd tier supply environment. If the three downstream criteria related to the customer (marked [C] in Table 9.5) are compared with the upstream supplier criteria (marked [S] in Table 9.5), the ranked score for Assemblers is [C] = 16 and [S] = 15, indicating that downstream customer influences are marginally more important than upstream supplier influences. Component suppliers show a similar pattern: [C] = 17 and [S] = 15. The

situation is reversed for Sub-assemblers, [C]= 15 and [S] = 18, who see upstream supplier influences as more important.

When contributing factors to long lead times are examined, once again customer influences are perceived to be more important than upstream supply chain influences (see Table 9.6). When the criteria are referenced against downstream (marked [C] in Table 9.6) and upstream criteria (marked [S] in Table 9.6) the downstream influences predominate for all supply tiers and are stronger than for the perceived influencing factors on short lead times. The ranked scores are as follows: Assemblers [C] = 21, [S] = 12; Sub-assemblers [C] = 21; [S] = 11; Component Suppliers [C] = 19; [S] = 14. In the case of both long and short lead times, internal delays caused by re-work are not perceived as an important influencing factor.

<i>Assemblers (System Integrators)</i>	<i>Sub-assemblers</i>	<i>Component Suppliers</i>
Special design required by customer [C]	Changes in customer specification [C]	Special design required by customer [C]
Delay in decisions on specification from customer [C]	Special design required by customer [C]	Long lead times at raw material suppliers [S]
Changes in customer specification [C]	Delay in decisions on specification from customer [C]	Delay in decisions on specification from customer [C]
Inability to stock special components [S]	Long lead times at raw material suppliers [S]	Changes in customer specification [C]
Long lead times at raw material suppliers [S]	Inability to stock special components [S]	Inability to book capacity at component suppliers [S]
Inability to book capacity at component suppliers [S]	Other	Inability to stock special components [S]
High re-work time	Inability to book capacity at component suppliers [S]	High re-work time
Other	High re-work time	

Table 9.6: Contributing factors to LONG Lead Times

9.4 Nature of Supply Chain Systems and Structures

The nature of supply chain systems and structures was investigated for all suppliers and for the individual categories. Fig 9.2 ranks the categories for all supply tiers based on the level of agreement to a range of statements related to the nature of communication from customers to the supplier. Across the categories, the highest level of agreement was that “customers provide feedback on delivery performance”, “customers involve us in their appraisal of us as a supplier” and “customer transmit technical specifications in a timely manner”. The highest level of disagreement related to “customers provide information on their costs” and “customers involve us in regular team meetings”.

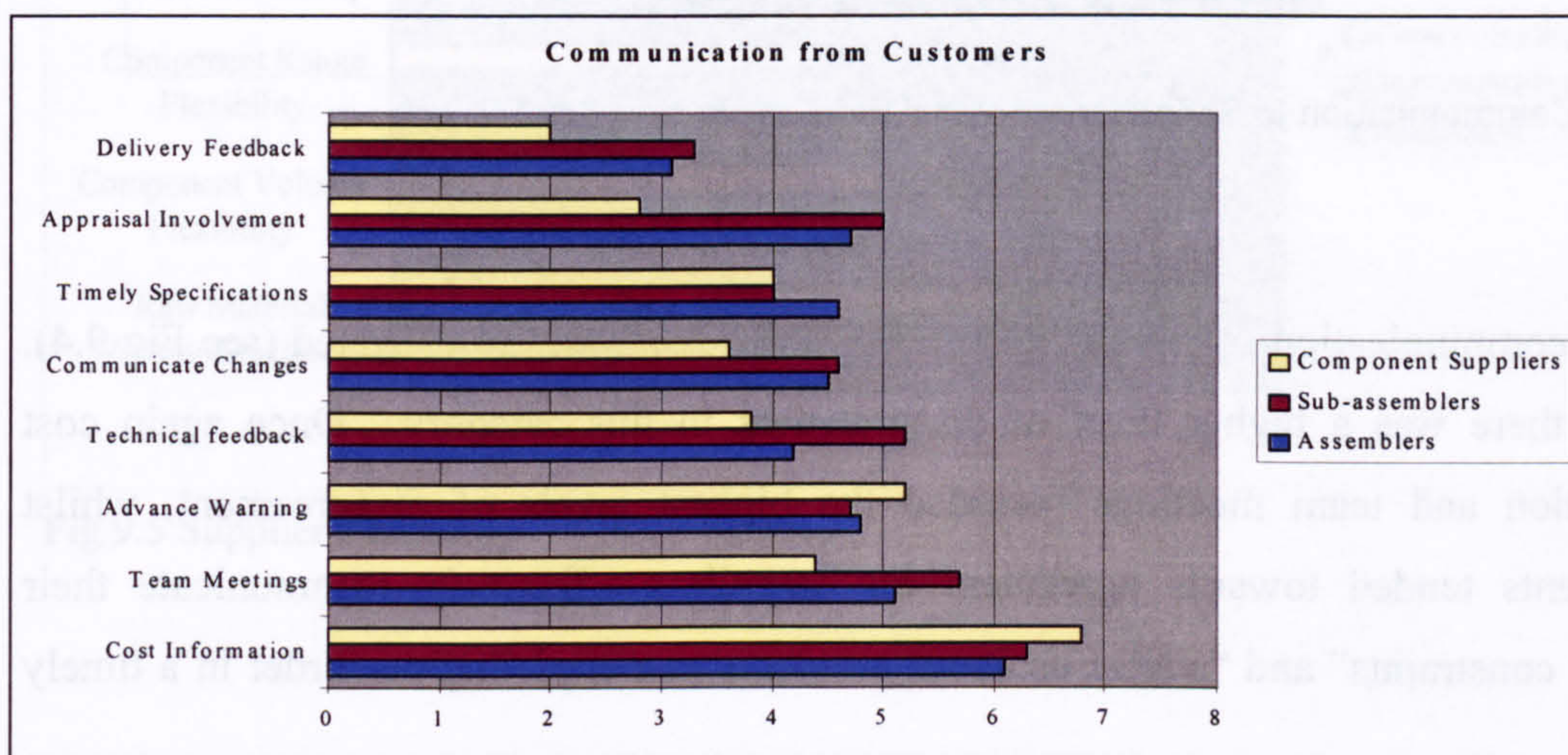


Fig 9.2 Communication from Customers

With regard to communication ‘to’ suppliers (see Fig 9.3) over all categories there was a higher level of agreement to the statements than for communication from customers. Respondents had a high level of agreement that they provided suppliers with feedback on their delivery performance, advised changes to specifications in a timely manner and provided suppliers with feedback on their technical performance. Respondents were neutral on providing advance warning of potential orders, transmitting technical specifications to suppliers in a timely manner and involving suppliers in team meetings. There was disagreement that cost information was provided to suppliers.

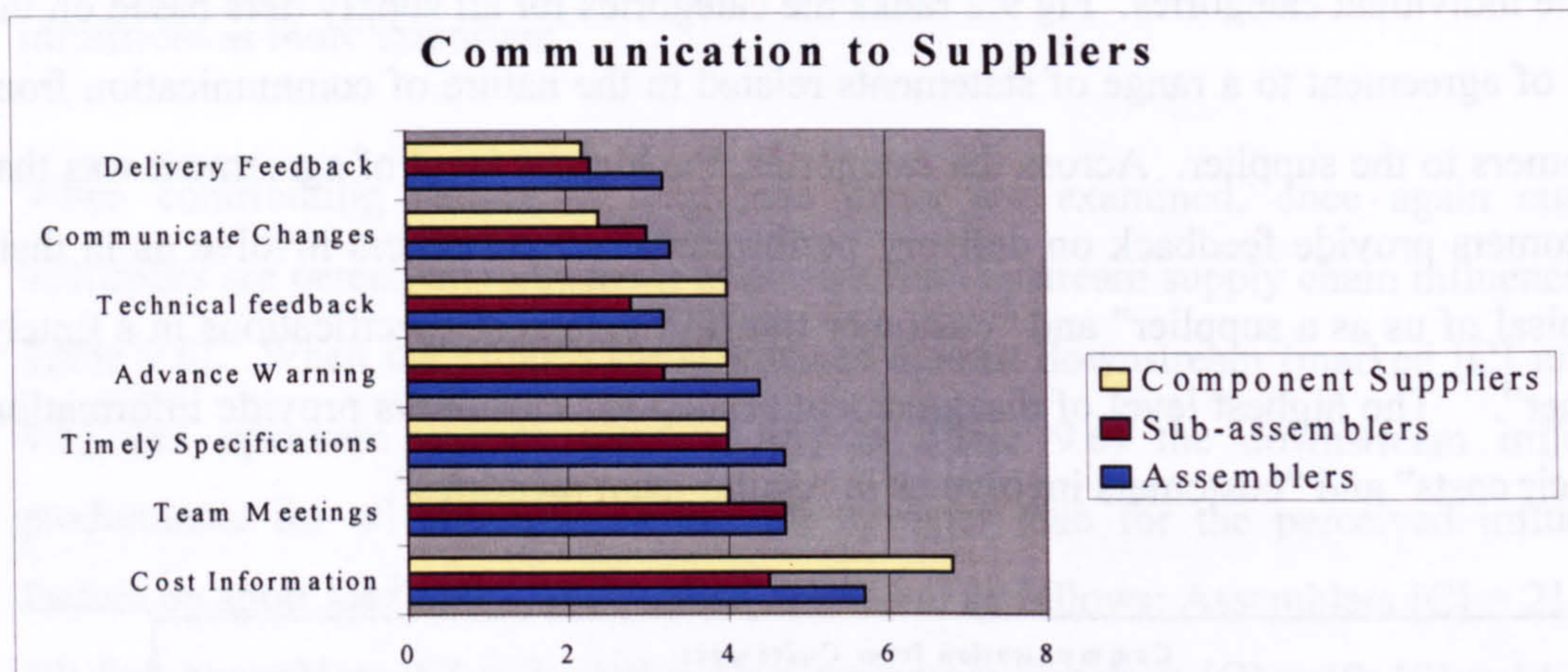


Fig 9.3: Communication to Suppliers

Finally, communication from suppliers to the respondents was investigated (see Fig 9.4). Overall there was a higher level of disagreement in this category. Once again cost information and team meetings recorded the highest levels of disagreement, whilst respondents tended towards agreement on “suppliers effectively communicate their capacity constraints” and “advise us about problems in completing our order in a timely way”.

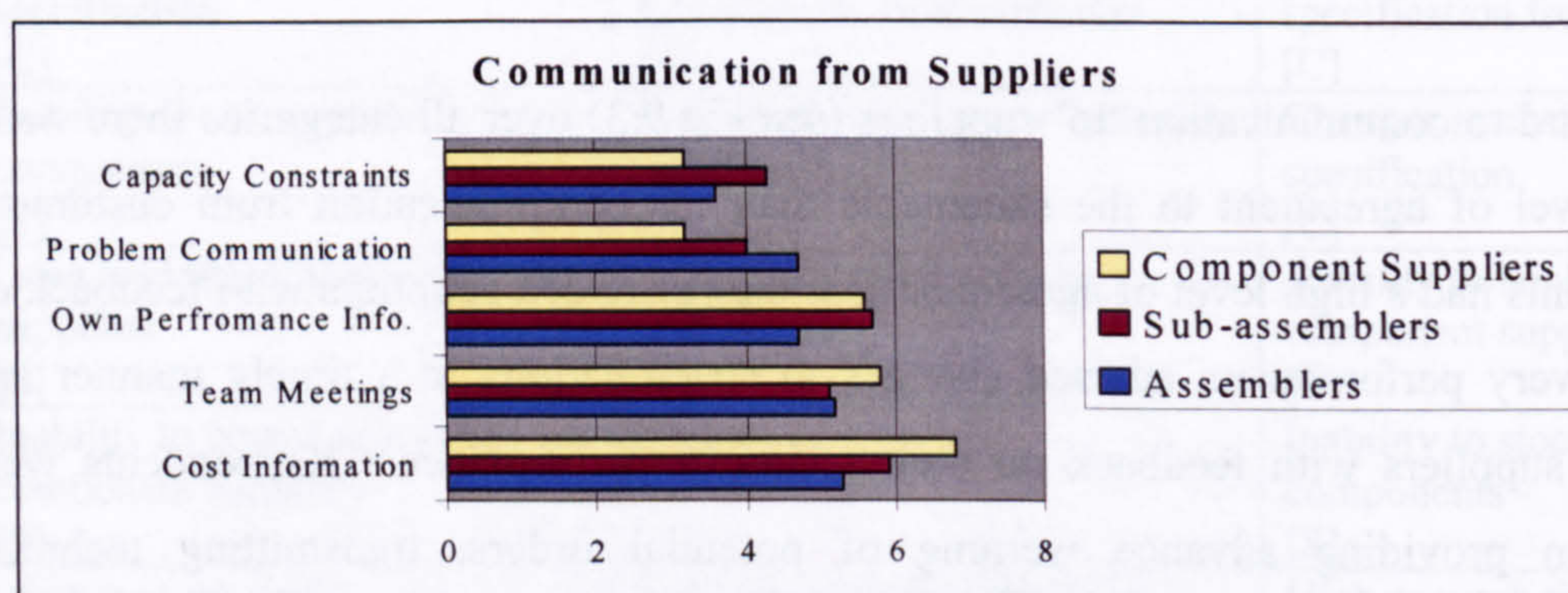


Fig 9.4: Communication from Suppliers

A further possible influencer on lead times was investigated: the influence of flexibility. Five categories of flexibility were investigated. Agility was defined in a narrow fashion as the “ability of suppliers to significantly reduce the lead times of critical path (pacing) items in an urgent case” (see Fig 9.5). There was agreement from assemblers and

component suppliers related to this criterion, but a more neutral position for sub-assemblers. Volume and range flexibility was investigated relative to component and raw material flexibility. Opinions tended to be neutral related to these other types of flexibility. There was a greater agreement that suppliers exhibited flexibility for component suppliers than other categories.

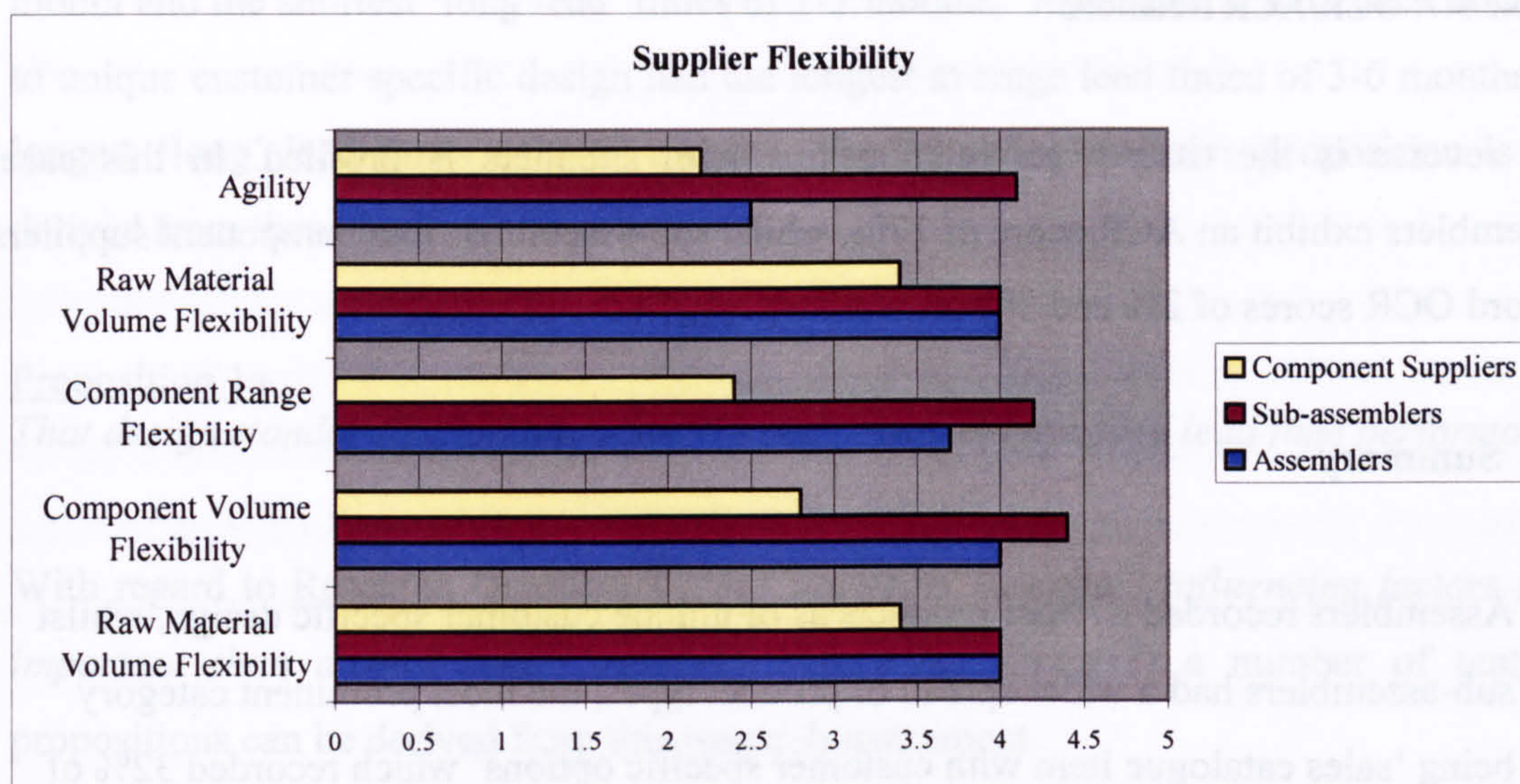


Fig 9.5 Supplier Flexibility

9.5 Nature of Supply Chain Relationships

The nature of supply chain relationships was profiled relative to Sako's ACR/OCR relationship types (see table 9.7). For relationships with customers, Assemblers recorded an OCR score of 15% and sub-assemblers a lower OCR score of 5%. Component Suppliers recorded an ACR score of 9%. This indicates that relationships tend more towards the ACR in lower supply tiers, which is in line with expectations. Interestingly,

	<i>Assemblers (System Integrators)</i>	<i>Sub-assemblers</i>	<i>Component Suppliers</i>
Relationship with Customers	15% OCR	5% OCR	9%ACR
Relationship with Suppliers	17% ACR	2% OCR	3% OCR

Table 9.7: OCR/ACR Relations

the reverse is the case when relationships with suppliers is profiled. In this case, assemblers exhibit an ACR score of 17%, whilst sub-assemblers and component suppliers record OCR scores of 2% and 3% respectively.

9.6 Summary

- Assemblers recorded 67% of products as of unique customer specific design, whilst sub-assemblers had a wider spread of product types, the most prominent category being ‘sales catalogue item with customer specific options’ which recorded 32% of responses.
- Product complexity and benchmark lead times clearly differentiated the different categories of manufacturer
- Product features or performance was regarded as the most important customer service criterion for assemblers and sub-assemblers
- Customer influences related to on-time and unaltered specifications are ranked as more important than upstream supplier influences in relation to the achievement of short lead times.
- With regard to long lead times, downstream influences are once again seen as most important, particularly those related to special rather than standard designs.
- Communication systems and structures tended to be related to feedback on delivery and supplier performance, rather than sharing information on costs or advance warning of orders.
- Assemblers recorded a positive OCR score for relationships with customers but a positive ACR score for supplier relationships. Sub-assemblers downstream and upstream relationships exhibited a low OCR score in both cases.

9.7 Implications for Research Questions

With regard to Research Question No 1 (*How does design standardisation influence lead times?*) the survey confirms, as would be expected, that there is a relationship between product complexity and lead time performance. Component suppliers with only 22% of orders to unique customer specific design had the lowest 'average' lead times of <1 month and the shortest 'long lead' times of 1-3 months. Assemblers, with 68% of orders to unique customer specific design had the longest average lead times of 3-6 months and longest 'long' lead times of 9-12 months. The following tentative proposition is thus derived from these findings:

Proposition 1a

That design standardisation has a positive influence on improved lead time performance.

With regard to Research Question 2 (*Are upstream (supplier) influencing factors more important than downstream (customer) influencing factors?*) a number of tentative propositions can be derived from this research instrument.

There is evidence of a difference in perception of the importance of customer service criteria at different tiers in the supply chain. There is also evidence of a difference between the upstream and downstream influencing factors related to systems/structures and relationships/infrastructure.

Proposition 2a

That influencing factors on lead time performance are perceived as different at different supply tiers in the supply chain.

Proposition 2b

That downstream (customer) factors are perceived in most cases as more important influencing factors on lead time performance than upstream (supplier) influences.

Proposition 2c

That downstream (customer) factors are perceived in all cases as more important influencing factors on LONG lead times.

With regard to Research Question No 3 the survey only examined the nature of communication systems and structures in order to inform the case research phase. The results indicate the highest level of disagreement on both upstream and downstream communication related to the use of team meetings and providing information on costs. This information provides some indication of communications systems and culture problems in the capital equipment supply chain which require further investigation within the case research phase. Supply chain relationships were scored on an adaptation of the Sako (1992) OCR-ACR relationship profile.

With regard to Research Question 4b (*How does the type of supply chain relationship influence lead time performance?*) the survey provides no clear evidence of a relationship between OCR-type relationships and lead time performance. In retrospect, it may have been possible to measure an effect if a better measure had been made of lead time improvement. Another interpretation worthy of further testing is that OCR-type relations alone cannot influence lead time improvements and other factors also require to be present. On this basis two propositions have been derived which require further testing in the case research phase:

Proposition No 4a

That obligational (OCR-type) supply chain relationships alone may not influence lead time performance.

Proposition No 4b

That obligational (OCR-type) supply chain relationships downstream in a supply chain do not necessarily translate to the same form upstream.

10. INFLUENCING FACTORS ON LEAD TIME PERFORMANCE: Case Research

The overall generic case supply environment under study was defined in 2.5 above: capital equipment supply to the UK offshore oil production and exploration industry. This has been sub-divided into two sub-environment cases: [1] Complex Assembled Products (>£1m sales value) and [2] Less Complex Assembled Products (<£1m sales value). The division was based on the information from the structured mail survey (see 9.1 above) and informed by the secondary interviews (see 2.8.4). Three case companies were studied in each of these sub-environments. In Secondary Interviews with customers, respondents indicated that all Case Companies had reduced lead times in the past two years. The aim of the case research was thus to identify which factors were perceived as influencing this improvement. Where there are differences in the extent of the lead time improvement between cases, the aim of the case research was to identify reasons for the differences.

The cases are individually analysed using the analytical structure derived from the literature review and the model explained in Chapter 6: [1] Supply Chain Systems and Structure (Design Standardisation Systems; Information Communications Structures; and Contract Structures); and [2] Supply Chain Systems and Infrastructure (Design Standardisation Attitudes; Information Communications Culture; and Contract Relationships).

Detailed case analyses are provided for each individual case and the particular implications of case findings on Research Questions are examined on a case by case basis and tentative propositions derived. As further cases are examined, the propositions are amended and elaborated in the light of additional comparative evidence. Cross-case comparisons are then drawn for each sub-environment unit of analysis and finally conclusions are drawn for the complete case environment. In Chapter 11, these conclusions are analysed together with the evidence of the Integration Survey (Chapter 8)

and the Structured Mail Survey (Chapter 9) to address the Research Questions and further refine the Propositions.

10.1 Complex Assembled Products (Cases A, B and C)

The Complex Assembled Products Case sub-environment provides a unit of analysis that is based on [1] Equipment value >£1m; [2] Sub-assembly complexity (at least 5 major sub-assemblies involving different processes); and [3] Component complexity (>500 components in the finished product). Three Case Companies, manufacturers of Wellhead Equipment, were selected as producing products that met these criteria.

10.2 Case A

Case A is a manufacturer of wellhead capital equipment for both surface and sub-surface environments. The company is a substantial international supplier of products and systems for oil production. Their product range includes production trees through to complete riser systems. The company also ranks as one of the world's largest suppliers of sub-sea production systems.

The business embraces more than 20 manufacturing and service facilities in 11 countries. The company has a corporate objective of: unsurpassed customer satisfaction achieved by dedicated customer focus. The company designs, manufactures and assembles capital oil production equipment. Equipment is normally supplied in small quantities, each being specific to an individual oil development project.

For the subsea production range, a maximum total throughput of around 50 assemblies per annum are produced. The case company's operations are based on MRP-type planning and control systems. The equipment manufactured are essentially assemblies of hydraulically and mechanically operated valves, configured to control fluids during production and also to enable safe access to the downhole production equipment during maintenance activities. Production runs are low due to a large number of possible permutations due to [1] Process Requirements: valve configuration, valve sizes, pipework sizes, process fluid type, pressure rating; [2] External Interface Requirements: interfaces with other types of equipment; and [3] Customer Preferences: specific materials, surface coatings, identification markings. In addition to this there are differences in the regulations, for example, between UK and Norwegian oil sectors. There were 10 key respondents interviewed in this case. These included customers within operators and contractors and supply chain managers and manufacturing project managers (see Table 10.1).

Respondent	Supply Chain Perspective	Functional Perspective
CA1	Customer of Manufacturer A	Purchasing Manager Customer
CA2	Customer of Manufacturer A	Wellhead Purchasing Manager
CA3	Customer of Manufacturer A	Wellhead Engineer
CA4	Customer of Manufacturer A	Drilling Manager
MA5	Wellhead Manufacturer A	Sales Project Manager
MA6	Wellhead Manufacturer A	Supply Chain Manager
MA7	Wellhead Manufacturer A	Sales Project Manager
SA8	Supplier of Choke Valves	Sales Manager
SA9	Supplier of Fabricated Frames	Managing Director
SA10	Supplier of Actuators	Divisional Manager

Table 10.1: Key Respondents for Case A

10.2.1 Lead Time Performance

The average lead time for the product in Case A was 6 months and there had been an improvement within the last two years from a previous average of 12 months. Manufacturer A has a target of 4 months average lead time. The shortest lead time was 45 days. This was achieved due to standardisation of product with the resultant ability to manufacture in small batches of around 5. Longest lead times were 9 months and this was due to the requirements for special designs from customers. Some of these were regarded by Case A respondents as unnecessary specialisation (and given the derogatory term “bells and whistles” by a number of respondents).

With regard to the upstream supply chain, the most important pacing component was the choke valve, with an overall lead time of 29 weeks. Standardisation was again an issue: *“If they bought the same choke twice, the delivery time can be reduced to 12 weeks. The extra time is due to redesign time each time as the customers interfere”* [Supply Chain Manager MA6]. The valve block is the second most significant pacer, with machining

time of 4-5 weeks on top of procurement time. Procurement time has been substantially reduced due to the use of a standard forging that is produced on a regular kanban-type flow. The downside is that standardisation means more machining time to deal with individual configurations. The third most important pacing component was that of forged and bent pipe which had a lead time of 20 weeks. During the currency of the study, however, this pacer had been eliminated. Again, improvements to lead times had been achieved by single sourcing and *“talking directly to the bender who have reduced lead times to 3 weeks by holding pipe stock”* [Supply Chain Manager MA6] This is evidence of the major step-change improvements possible in the upstream supply chain. Having eliminated this pacer, the fabrication of frames was the next most significant at 16 weeks. During the currency of the study, a further main source supplier was in discussions with the manufacturer. This resulted in investment by the supplier, with assistance from the Local Enterprise Company, in process equipment that would eliminate a sub-contracted process. It was expected that this improvement would reduce lead time by 4 weeks.

10.2.2 Influence of Supply Chain Systems (Structures)

Design Standardisation Systems

Design standardisation issues due to the difference in design practices between different oil operators, not just at the equipment stage but due to differences in approach to oil well design. Even within companies there is a lack of well design standardisation, although some operators have made a conscious effort to standardise: *“There are difficulties in operator co-operation due to different standard practices and different well design.”* [Customer CA4] *“Two major customers have a problem in sharing a riser pack.”* [Manufacturer Sales Project Manager MA7] *“One customer has limited itself to 3 workover systems.”* [Manufacturer Sales Project Manager MA7] *“Alliances can cause complexity, due to them coming up with their own ‘spin’ to justify themselves.”* [Customer CA2]

Lack of standardisation is further compounded when it comes to the specifications for capital oilwell equipment: *They are all different - there are not even common colours.*" [Customer CA4] *"Lack of standardisation makes sharing difficult."* [Manufacturer Supply Chain Manager MA6] *"There is a total lack of standardisation."* [Manufacturer Supply Chain Manager MA6] *"If you get one PO you are lucky if you get another one the same."* [Manufacturer Supply Chain Manager MA6]

The respondents recorded some attempts at a modular approach to design and production. The importance of interfaces between different manufacturers equipment was raised as a key issue that required design modifications to 'cross-over' between one manufacturer and another: *"Have based design (90%) + bolt-on components. Modularity is limited in the base case. We avoid cross-overs (from one manufacturer to another)."* [Customer CA3] *"About 75/80% are standard modules but some 'tweaking' is required for certain reservoirs. Technical interfaces are a problem."* [Drilling Manager CA4] *"Interfaces are an important issue e.g. with control systems."* [Manufacturer Sales Project Manager MA5]

The relationship between standardisation (or the lack of it) and the ability to hold finished goods and component inventories was frequently raised as an important issue: *"Previously there was 6 months for forging, but this didn't in any way relate to process time. We have now agreed to hold a standard shape of raw material in stock. Nothing is standard. Last year 17 systems became 52 systems this year. With regard to variety there are too many people dabbling."* [Manufacturer Sales Project Manager MA5]. The relationship between standardisation and the ability of Manufacturer A to commit to stock of pacing components was seen as a key factor in the improvement of lead times: *"The main valve block is a major issue. Standardisation of this component is an issue. Stock turnover is low."* [Customer CA1] *"Inventory turns are too low."* [Manufacturer Sales Project Manager MA7] *"On long lead items there may be some decisions to hold ourselves."* [Manufacturer Supply Chain Manager MA6]

The contribution of variation control (or the lack of it) was noted by respondents, most of whom perceived it as a cost rather than a lead time issue: *"The true cost of variation is now costed."* [Manufacturer Sales Project Manager MA5] *"Changes are also an issue. What justification is given by oil companies for changes? In a repeat order from an oil company we had 1,000 formal communications resulting in £2m of variations on a £6m order."* [Manufacturer Sales Project Manager MA5] *"Variation control - this is the last thing they want to do. They modify after the order. We have to stop, establish the cost variation and then continue. There is a lot of time and effort required to process variations."* [Manufacturer Sales Project Manager MA5]

Information Communications Structures

The use of meetings and team-based approaches to information communication, including 'implant' teams in suppliers' premises, was highlighted by respondents as contributing to improved lead time performance: *"We 'swap' teams and go to suppliers' site and walk through the problem."* [Manufacturer Supply Chain Manager MA2] *"We establish a team each time and create interface documents from procurement to well engineers (but dedicated to a manufacturer's system) - to project managers at the manufacturers."* [Customer CA4] *"We take suppliers in to talk about their bid."* [Customer CA3]

The problem of internal information communication between projects being undertaken by the same customer was highlighted as important and a reason for lack of improvement from one project to the next. This 'silo' mentality is clearly a problem in a decentralised organisation structure that does not have adequate cross-team or intra-project communication structures: *"Individual assets were fragmented and went out to the market as 10/12 companies. We have limited access to SME's and these silos didn't transfer knowledge or lessons learned."* [Customer CA5]

Contract Structures

External time delays were noted due to the consortium influences within oilfield operations and the regulatory environment: *"Partner approvals are necessary for existing arrangements"*. [Purchasing Manager CA1] *"Previous arrangements meant specification about 18/19 months ahead of need. 5/6 months of this was related to EC Legislation and 10/12 months on manufacturing"*. [Wellhead Purchasing Manager CA2] *"EU legislation causes increase in lead times which are around 6-13 months."* [Customer CA1]

The contribution of 'frame-type' agreements and the use of single-sourcing, to the ability to work with capital equipment suppliers on lead time reduction was commented on by respondents: *"We have framework agreement for Xmas Trees."* [Customer CA1] *"80/90% on frame contracts, but can't cover everything. We use single source or call-off against the frame agreement."* [Customer CA3] *"Frame contracts go to one contractor to ensure fewer interfaces and spares."* [Customer CA4]

The ability for these contract structures to further influence lead time improvements by permitting stocking of components was identified and interestingly customers were prepared to underwrite the costs of the stockholding: *"Contract with our customer is to hold all pacing items to achieve a 6 month delivery."* [Manufacturer Sales Project Manager MA5] *"There has been a lot of work done on lead time reduction worldwide from Houston. It has led to stocking agreements."* [Manufacturer Sales Project Manager MA5] *"Discussed constraints with Manufacturer A. Raw material stuck out as an issue. New tenders require vendors to carry certain levels of raw material."* [Customer CA3]

10.2.3 Influence of Supply Chain Relationships (Infrastructure)

Information Communication Culture

The 'project' structure of the way that the offshore industry does business which was criticised above as having poor intra-project communication, in turn appears to have

fostered a 'silo-type' communications culture: *"Project managers have 20/30 projects and £140m throughput. They tend to be single-minded, strong-willed and the organisation is functional."* [Manufacturer Sales Project Manager MA5]

Communication culture throughout the capital equipment supply chain was seen as not supporting the possible structural improvements: *"We tend to think limited capacity and supplier rules to an extent. There is a high cost in delays due to systems being fully loaded."* [Manufacturer Supply Chain Manager MA2] *"Approved vendors can tell us forecasts, but its difficult due to the oil company situation."* [Manufacturer Sales Project Manager MA5] *"There has been a framework to standardise at a high level, but they have not told the suppliers that they should have stocking agreements."* [Customer CA2]

Contract Relationships

Evidence of a lack of trust and a lack of 'obligational (OCR-type)' relationships downstream with customers was evident from respondents: *"Operators have a lack of customer loyalty. They always go back to the table, related to bids."* [Manufacturer Supply Chain Manager MA6] *"Operators want it for less, but quicker."* [Manufacturer Supply Chain Manager MA6] In some cases, however, a much more OCR-type approach is in evidence in the upstream relationship: *"Presently working with Manufacturer A on spares including consignment stock process"* [Customer CA3]

The difference between manufactures in their supply chain relationships was commented on by one customer: *"Manufacturer A embraced the supply chain concept, including working with sub-suppliers. Manufacturer C is a sales-type organisation, good at packages, but lack of depth drive to control sub-suppliers."* [Customer CA4] It is interesting to note, therefore, that Manufacture A has a supply chain manger who has had exposure from other industries: *"I came 6 months ago from the electronics industry. There is such a difference between oil and electronics. The reason is simple - they don't have relationships with the supplier - they don't manage them. They place a PO and beat them up when it goes wrong."* [Manufacturer Supply Chain Manager MA6]

Downstream relationships exhibit ACR-type forms with lack of trust in manufacturer's internal quality assurance systems and continued use of 'policing' checks by customers: *"We have to deal with operating companies' requirements for testing."* [Manufacturer Sales Project Manager MA7] *"We have to put people in at all stages of the manufacture. Tight tolerances are often specified but are un-necessary."* [Customer CA4] *"We need to re-check and test and then re-test offshore and again on the sea-bed."* [Customer CA3]

Upstream relationships from the manufacturer also exhibit ACR-type practices, with little evidence of reducing the supplier base and working with suppliers: *"We have 41 approved shops and yet we use 100. We insist on materials being delivered 4 weeks before they are necessary."* [Manufacturer Supply Chain Manager MA6] *"There is resistance in working with suppliers. It does not give overnight results, it takes trust."* [Manufacturer Supply Chain Manager MA6]

10.2.4 Summary of Case A Findings

Manufacturer A has the best lead time performance in the Complex Assembled Products Supply Sub-environment and has ambitious targets for even more improvements. Customer appear to view the company as having more of an understanding of supply chain issues and it was the only case company that had a supply chain manager in post. This manager had experience outwith the oil sector and appeared to have been instrumental in pro-active improvements in the upstream supply chain.

Although Manufacturer A had a number of pacer components still contributing to non-value added time within the overall lead time, there was considerable evidence that they had undertaken a process of systematically identifying and removing critical pacers (nb. a pacer component is an upstream component that affects the overall lead time). Most of these improvements had been undertaken with the assistance of single-source supply arrangements together with considerable mutual problem solving between manufacturer and supplier. It is also clear from this case that the ability of the manufacturer to

undertake these upstream improvements was very dependent on changes in downstream structures and culture with regard to the customer.

Internal to the customer, non-value added time due to decisions and authorisations had been previously created due to two main reasons: [1] awaiting partner approvals and [2] delays waiting for advertising and tendering under EC procurement rules. The use of long-term frame-type agreements has eliminated this non-value-added time within the lead time.

Within the structure provided by these frame agreements, the use of functional specifications has permitted certain of Manufacturer A's customers to enter into a dialogue with Manufacturer A as a single source supplier. This has, in turn, permitted the manufacturer to propose more standardised design solutions.

Having achieved a larger volume of more standardised product, Manufacturer A has then been able to work on improvements to its upstream supply chain. In particular, one customer has been prepared to underwrite the cost of holding stock of the principal pacing component: the valve block forging. This has been a major contributor to lead time reduction. Manufacturer A has cascaded this co-operative approach to its upstream supply chain through the mechanism of 'core supplier groups' where multi-functional teams are used to examine and reduce or eliminate lead time problems.

Although these structural aspects are in place, there is still considerable evidence that the culture to make them work successfully is far from perfect. ACR-type contract relations are still in evidence in both downstream and upstream supply chains. Lack of trust continues to be evidenced in the continuance of QA policing by customers, contributing to internal delays due to waiting for sign-offs at various stages of manufacture.

10.2.5 Implications of Case A Findings on Research Questions

With regard to Research Question No 1 (*How does design standardisation affect lead times?*), there is evidence of one customer who has accepted a standard design for the primary 'pacer', the valve block forging. This has led to a stocking agreement for this 'pacer', the inventory-holding cost of which has been underwritten by the customer. Thus whereas the literature review centred on the impact of standardisation on the design phase of the lead time, the evidence from this case indicates a more significant influence on lead times related to the solution of lead time problems with upstream 'pacers'. This permits the development of a further tentative Proposition No 1.1a: *That design standardisation leads to an ability to influence lead time improvement through the strategic stocking of 'pacing' components.*

The findings of Case A have particular implications for Research Questions 1 and 2.1. With regard to Research Question No 2 (*Are upstream (supplier) influencing factors more important than downstream (customer) influencing factors?*). Preliminary and Secondary Interviews with customers revealed that Case A products were regarded as a significant 'pacer' on offshore oil projects and that the main reason for long lead times was due to long lead times in 'pacer' supply components upstream. Case A bears out the significance of upstream pacers, particularly the valve block forging. However, when perceptions of what has influenced the reduction in lead time for this primary 'pacer' and secondary and tertiary 'pacers' is examined within the Case, the importance of the downstream customer is highlighted as significant. Those customers for whom the greatest lead time performance improvement has been achieved, are those who have engaged the manufacturer in long-term trading arrangements. In Case A this has led to the development of similar long-term, single-sourcing arrangements with upstream suppliers. Thus the evidence from Case A upholds Proposition 2b, developed from the survey research: *That downstream (customer) factors are perceived in most cases as more important influencing factors on lead time performance than upstream (supplier) factors.*

10.3 Case B

Case B is a manufacturer of capital wellhead equipment for both surface and sub-surface environments. The company supplies oil and gas exploration and production equipment for land and offshore applications. Headquartered in the USA, it has manufacturing and service facilities in the USA, Europe and Asia. The product types and volumes are broadly compatible with Case A.

There were 11 key respondents interviewed in this case. These included customers within operators and contractors and materials managers, operations manager, purchasing manager and manufacturing project manager (see Table 10.2).

Respondent	Supply Chain Perspective	Functional Perspective
CB1	Customer of Manufacturer B	Purchasing Supervisor
CB2	Customer of Manufacturer B	Supply Chain Manager
CB3	Customer of Manufacturer B	Supplies Manager
CB4	Customer of Manufacturer B	Strategic Purchasing Manager
CB5	Customer of Manufacturer B	Project Manager
CB6	Customer of Manufacturer B	Project Manager
MB7	Wellhead Xmas Tree Manufacturer B	Sales Project Manager
MB8	Wellhead Xmas Tree Manufacturer B	Materials Manager
MB9	Wellhead Xmas Tree Manufacturer B	Materials Manager
MB10	Wellhead Xmas Tree Manufacturer B	Operations Manager
MB11	Wellhead Xmas Tree Manufacturer B	Purchasing Manager
SB12	Choke Supplier	Oil Products Manager
SB13	Forgings Supplier	Project Sales Manager
SB14	OEM Valve Supplier	Operations Manager

Table 10.2: Key Respondents for Case B

10.3.1 Lead Time Performance

The average lead time for the sample product in Case B was 8/9 months. This had shown a reduction in the last two years from 12-14 months. The shortest time was 60 days on a call-off type arrangement. This customer accepted a standard proven systems design that resulted in less re-work in the internal process. With regard to the upstream supply chain, the call-off arrangement also permitted ability to stock materials – in particular long lead time items such as block forgings. These were being fed through from the supplier on a regular schedule. Standard sub-assembly design also contributed to the improved lead time performance. The longest lead time was 12-14 months due to Research and Development (R&D) work necessary on more specialised designs. A further contributor to long lead times was the need for different interfaces to suit different configurations. This was particularly evident in re-furbishment projects where there may be need to interface with much older equipment.

The most significant pacing component was the valve block forging, which had a lead time of 10-14 weeks or 14-18 weeks if the design required substantial welding. These lead times could be reduced by the use of a stock billets. The second most important pacer was Choke Valves that had a lead time of 20-24 weeks – but as there was more standardisation of this commodity it could often be ordered ahead of the valve block. The third most important pacer was OEM Valves that had a lead time of 10 weeks.

10.3.2 Influence of Supply Chain Systems (Structures)

Design Standardisation Systems

Customer BC1 saw standardisation as a major contributor to a 22-32 weeks lead time. BC1 said “*Standardisation is a problem*” and that “*Suppliers make variants.*” He did note, however, that “*our own engineers and our own designs don’t help standardisation.*” He also stated that his company was currently in discussion with two other operators about standardisation. His view was that “*There are benefits to the*

supplier on standardisation". Customer BC4 stated that "Reasons for extensive lead times are changes in design". He related these changes to a lack of standardisation: "It is very seldom standard equipment. We try to standardise, but fail" Customer BC2 perceived "There has been a move away from company propriety standards and towards functional specs. from detailed engineering specs".

Customer BC4 was aware of attitudes in lower supply tiers and highlighted the attitude of forgings suppliers: *"Mills don't worry about capacity until they start rolling".* Manufacturer Sales Manager BM7, confirmed the lack of standardisation: *"80% of UK production is non-catalogue."* BM7 commented that lack of standardisation also extended to the manufacturing process: *"Certain customers have a qualified welding process which means we can't make it at another plant."* [Manufacturer Sales Manager BM7]. The particular importance of lead times to the smaller field developments was highlighted: *"Customers expectations of lead times are that they should be lower. The reason is that smaller fields don't give time to sit and plan. Founding to commission is now 2 years compared to 8-10 years previously."* [Manufacturing Sales Manager BM7]

There was evidence from the manufacturer's perspective of a move by customers towards the use of functional specifications. In the case of some customers this had permitted the manufacturer to standardise the product. *"They are now prepared to provide functional specs. They are not as prescriptive as before and will accept more of the standard product."* [Manufacturing Sales Manager BM7] This product standardisation then led to further standardisation in the material content, with evidence of modularity: *"There was a standard Bill of Materials for the main block."* [Manufacturing Sales Manager BM7] Modularity has been developed with a further customer: *"Instead of a T-shaped forging we have a forged bar with a bolt-on forged bar. This may reduce the need for large forgings."* [Manufacturer Sales Manager BM7] Wider standardisation, such as pan-industry specifications are also evident, but in fairly limited areas: *"We have a completion connector which has an industry profile."* [Manufacturer Sales Manager BM7]

The impact of this standardisation on lead times was clear: *"Standard sub-sea tree 7/10 months; specials 12 months +."* [Manufacturing Sales Manager BM7]. Difficulties related to the operation of Computer-Aided Design (CAD) and its link to Computer-Aided Manufacturing (CAM) was seen as holding back modular approaches and the creation of parts 'families': *"We require to draw in 3-D which takes time and creates families and deals with change. After 3 years it is still not working."* [Manufacturer Sales Manager BM7]. The ability to use inventory to reduce lead times clearly related to the extent of standardisation: *"There are 5 types of raw blocks for forgings, which are bought on forecast. We have a 30% speculative holding. 80% is ordered on firm demand, 20% is forecasted. We have a safety stock on standard components and we are considering more of this to reduce lead times to 20 weeks for certain types."* [Manufacturing Materials Manager BM9]

Information Communications Structures

The existence of a structure of meeting was confirmed by respondents confirmed that *"Pre-award meetings take place to build up understanding"*. [Customer BC2] *"(Meetings take place) mainly prior to award, but that they were mainly based on quality and technical issues. We undertake meeting with our suppliers on a 12 month supply this would be at least monthly."* [Customer BC5] The communication at early stages of projects was evident, but it was questionable as to whether it took the form of Early Supplier Involvement (ESI): *"We provide information the project schedule and explain why it is important to meet the time. Suppliers give presentations (dog and pony shows) and we communicate with project newsletters"*. [Customer BC6]. There was evidence of Ongoing Supplier Involvement (OSI) with a structure of meetings continuing throughout the supply period: *"We undertake meeting with our suppliers - on a 12 month supply this would be at least monthly, but it depends on the package and the level of interfaces. We discuss progress, design change and costs related to the changes."* [Customer BC5] The information exchanged at these meeting included: *"Feedback on performance, via meetings and on close out. We provide future project information."* [Customer BC6].

Information flow at the downstream end of the supply chain, from the customer to within the manufacturer, had a rather traditional form and there was little evidence of 'transparency' or information penetrating the organisation to a de-coupling point: *"Information comes from marketing. We are presently formalising this based on a monthly report, but previously it was ad hoc."* [Manufacturing Materials Manager BM9]

Upstream information flow from the manufacturer to the supplier had a mixture of forms: *"Capacity is reviewed monthly. We inform suppliers by booking capacity. We look at a 3 year period and book x hours per month. There is a commitment date by which if we don't use the capacity it can be used for something else. There are different relationships. At low level subcontract milling there is no real information communication."* [Manufacturing Materials Manager BM9]. Information flow from suppliers also appeared to have some considerable 'blockages' within the manufacturer's own organisation: *"I'm not directly involved in this, but the system has due dates. I am not copied on it and it is not well communicated."* [Manufacturing Materials Manager BM9]. Communication problems were highlighted by respondents: *"Forgemasters were making to drawings + or - thousands of an inch for their machining tolerances. But there was a 1/4 to 1/2 inch machining allowance. We didn't realise this until talking with the supplier."* [Manufacturer Sales Manager BM7]

Contract Structures

External factors contributing to lead time included consortium influences (due to investing partners) and government approvals. *"Decision-making speed is slow because of the partners involvement."* [Customer BC4] *"Partner approval can also cause delays"*. [Customer BC5] *"We often have purchase orders waiting for government approval of the development"*. [Customer BC5] *"Time pressures come from the DTI Development Agreement for the oilfield and shareholders pressure for first oil."* [Customer BC4]. These delays at the pre-contract causes time pressures on the design and manufacturing process: *"If you had unlimited time you would complete the design, 'nest' the design (i.e. look at ways of cutting costs) - you could cut costs by 20%. Instead,*

manufacturing starts before design is complete and construction starts before manufacturing is finished". [Customer BC4]

The nature of sourcing and the contracts that support it were seen as influencing factors on lead times by respondents, in particular the benefits of framework-type agreements was mentioned: *"There is not a lot of sole sourcing - it requires higher authorisation. But we do have frame agreement on 5 year terms."* [Customer BC5] When asked why multiple sources were used the respondent replied *"No obvious reason apart from legislation, agreements between parties, specialist requirements and lack of repetitive supply."* [Manufacturing Materials Manager BM9]. The Benefit in the use of framework agreements to improve lead times was confirmed: *"Framework agreements within EU procurement legislation assist in reducing time"*. [Customer BC6]. There is also evidence of the contribution of these agreements to permit standardisation and modularisation: *"We have a 'frame' agreement with a Norwegian operator for 86 trees. There is a universal raw block. Although this has to be bigger to accommodate all models (by about 1-2 ft of raw material)."* [Manufacturer Sales Manager BM7]. Although interested in participation in 'framework-type' agreements with customer Manufacturer B does not transfer these approaches further down the supply chain, but instead adopts an ACR-type approach: *"We tend to insist on 2 or 3 quotes for significant quotes, say \$10,000."* [Manufacturing Materials Manager BM9]

Traditional contract bidding of the Arm's Length Contractual (ACR-type) also takes place, however: *"Engineering contractors have a couple of bids."* [Manufacturer Sales Manager BM7] *"Conoco uses a qualified supplier list which reduces things to a manageable number and then we bid."* [Customer BC6]

10.3.3 Influence of Supply Chain Relationships (Infrastructure)

Design Standardisation Attitudes

The impact of standardisation attitudes on the supply chain was compared with other provinces by one respondent: *"Even apparent standard items such as pipe have*

'Company specific' test procedures and QA requirements." [Customer BC4]. The problem of change and uncertainty was highlighted by respondents: *"There are changes all along the way: discovery/ detailed appraisal/concepts/detailed design/execution. Another uncertainty factor is sizing"*. [Customer BC2] *"There is a base scope for inputs and outputs, but in the last project these were changed. In design, the manufacturer is best, but there are always inputs from the operator and the engineering contractor."* [Customer BC6] Although this respondent clearly had a more 'hands-off' view and appeared to see a fuller role for the manufacturer in the design process, he still expressed the fear: *"You can leave a supplier alone, but there is a danger that you get a problem at the testing stage"*. [Customer BC6]

Information Communication Culture

Lack of continuity from one project to another was mentioned by a number of respondents: *"There are continuity problems due to project nature of the work. Leads to a lack of organisational mentoring and to 're-inventing the wheel'"*. [Customer BC6]

Contract Relationships

The importance of Obligational-type (ACR) supply chain relationships to lead time performance was seen as important by respondents: *"For key lead time items you need a relationship"* [Customer BC2] *"In the Aquila project group they met and sorted out between them what they would manufacture, based on the machines they had - capability."* [Manufacturing Materials Manager BM9]. Strategic Purchasing Manager BC4 had the view that current contracts did not really foster relationships of an ACR type *"Incentive-based contracts is not real partnering. There may be sharing of savings but little risk sharing."* He also indicated a lack of a long-term view: *"There is a lack of long-term business planning."* [Strategic Purchasing Manager BC4]

Project Managers had a fairly task-related rather than relationship view as to the appropriate criteria on which to judge a supplier *"Agreement to our terms and conditions.*

Value for money. Life cycle costs, quality, reliability and spares back-up.” [Customer BC6] *“Based on performance record compared to ‘does it break down’. Price competitiveness on life-cycle costs. Delivery on time, that’s obvious.”* [Customer BC5]

A lack of trust in lead time information provided by the manufacturer was exhibited by respondents: *“At the bid stage a delivery requirement is stated. If supplier can’t do it they have to negotiate or we exclude them. If they want the work they’ll say they can do it”*. [Customer BC6]. The lack of an OCR relationship was also exhibited in the attitude to the acceptance of supplier responsibility for Quality Assurance (QA) by: *“We audit their inspection services and QA systems. Then 2/3 times during the package”*. [Customer BC5] In addition to auditing, however, BC5 indicated a lack of trust within the relationship evidenced by the fact that *“We have witness tests, to provide us with the confidence that it will work”* rather than relying on the QA systems that BC5’s company have themselves audited. *“Some suppliers get target prices. We use 3 quotes and like it or lump it.”* [Manufacturing Materials Manager BM9]

The entry into informal commitments prior to contract award was noted as a means of improving lead times. *“Pre-sanction commitments are made for long lead items via the contractor”*. [Customer BC2] *“Sometimes we have to help vendors out with cash flow due to long lead times, e.g. paying 10% upfront.”* [Customer BC4] *“We need to make commitments for major forgings and you need to know their manufacturing cycles. Lead time understanding is critical”*. [Customer BC2]

Respondents commented on clear differences between individual customers’ relationship attitudes: *“Customer X is lean in Aberdeen. They require more from the supplier. They are involved in ‘frame’ agreements (call-off) contracts. They are more informal. Customer Y deal formally and there is little communication with Aberdeen. Customer Z seconded a partner individual from a partner for the project. Each unit wants to make its own money. Customer W has projects in London and operations in Aberdeen which results in in-fighting. But they want to make their mark by having extras - but they don’t want to pay for them.”* [Manufacturer Sales Manager BM7] *“Customer V waffled about*

reward sharing. After this they generated a full spec. and went and bought from Manufacturer C anyway. They squeezed our ideas and then set up a 'frame' with Manufacturer C." [Manufacturer Sales Manager BM7]

The possibility of reducing lead time spent in engineering interfaces has also been recognised by customers of Manufacturer B. Opportunities for customers to co-operate or 'club' together to minimise equipment proliferation has been attempted in some limited areas: *"Shell have traditionally bought from Company A and Company C. Their Vertical Alliance has both companies. They decide to buy from one or the other. This forces the need for interfaces between the different manufacturers' equipment and the possibility of interchange between the two."* [Manufacturer Sales Manager BM7]
"Conoco has a horizontal tree club. Customer bought option and paid money, we could deliver in 30 days with the option of the customer to cancel." [Manufacturer Sales Manager BM7]

10.3.4 Summary of Case B Findings

Manufacturer B had the second best lead time performance in the Complex Assembled Products Sub-environment but its targets for further improvement were less ambitious than Manufacturer A. The company's assembly plant is remote from the main customer base in Aberdeen. This appears to have had an effect in creating communication problems between sales engineers, based in Aberdeen, and manufacturing and supply staff based elsewhere. The company did not have a supply chain manager and there was evidence of materials management and purchasing functions being isolated from each other and from the manufacturing process. There was less evidence of pro-active activities to improve the upstream supply chain than in Case A.

Certain of the customers of Manufacturer B appear to recognise the contribution that standardisation and design change can have on the improvement of lead time performance. There was evidence of some customers becoming less prescriptive and

using functional specifications. Other customers maintain a rigid adherence to controlling the design themselves and providing detailed technical specifications. The difference in lead times between these two types of customer was substantial.

Internal non-value-added time at the customer shows evidence of being reduced by the use of frame agreements. This particularly related to eliminating delays due to partner approvals and EC Procurement legislation.

There was more evidence within this case of a modular approach to design than was in evidence in the other case in this sub-environment. The influence of one major customer in promoting this concept was acknowledged. With long-term frame-type contracts providing volume throughput for this modular design, substantial improvements in lead time were possible. Another customer had accepted the concept of a standardised valve block, which could then be adapted to different sizes and configuration by different levels of machining. In this case machining time was traded-off against improved lead time.

These changes permitted Manufacturer B to make improvements to its upstream supply chain. Raw forging blocks were reduced to 5 standard types, with the manufacturer holding 30% of annual production on a speculative basis. The order flow emanating from the frame agreement then permitted 80% of blocks to be ordered on demand with the balance being supplied from stock. For these customers, this upstream improvement had been the main contributor to the reduction of lead times from averages of 18 months to 6 months.

There was still evidence, however, of relationship problems throughout the supply chain. Respondents from various perspectives portrayed a task-oriented rather than a relationship view. This appeared to be emphasised by the project nature of the work organisation. ACR-type behaviour was in evidence in the continued use of witness tests by customers, rather than relying on the manufacturer's QA. There was still a view that customers continued to 'oversee' manufacturers, although this appeared to be less prevalent for smaller and leaner oil operators.

Opportunities for wider co-operation between operators to reduce interfaces between different suppliers' equipment had been recognised by certain customers, with resultant potential gains in lead time.

10.3.5 Implications of Case B Findings on Research Questions

The findings of Case B have particular implications on Research Question 1 (*How does design standardisation affect lead time performance?*). Case B provides evidence of modular approaches being made to the component design of the principal 'pacer', the valve block forging. In Case A, a single forging design had been developed for a 'family' of trees and was customised by varying degrees of machining. In this case, a modular tree design had been developed, with the use of wing blocks as a means of customisation. This, in turn had permitted an ability to stock this pacer. In Case B the stocking was undertaken on a speculative basis, with inventory-holding costs being borne by the manufacturer. Together with the evidence from Case A, this Case emphasises the importance of focusing the design standardisation effort on upstream 'pacers' and including the alternative approach of modular design of those components. This evidence upholds Proposition 1.1a (*That design standardisation leads to an ability to influence lead time improvement through the strategic stocking of 'pacing' components*) and permits its elaboration to: *That design standardisation/modularization of 'pacing' components lead to an ability to influence lead time performance improvement through the strategic stocking of those 'pacing' components*).

10.4 Case C

Case C is a manufacturer of wellhead equipment for both surface and sub-surface environments. The company regards itself as a market leader in the petroleum and industrial equipment market and sells in more than 100 countries worldwide. The company is a producer of pressure equipment for both land and offshore applications, including subsea. The nature of the equipment produced and its temperature and pressure variants are similar to those outlined in Case A.

There were 7 key respondents in this case including customers, manufacturer's sales, manufacturing and purchasing managers and suppliers of pacer components (see Table 10.3).

<i>Respondent</i>	<i>Supply Chain Perspective</i>	<i>Functional Perspective</i>
CC1	Customer of Manufacturer C	Operator Well Engineer
CC2	Customer of Manufacturer C	Well Services Purchasing Supervisor
CC3	Customer of Manufacturer C	Supplies Manager
MC4	Manufacturer C	Sales Project Manager
MC5	Manufacturer C	Manufacturing Manager
MC6	Manufacturer C	Procurement Manager
SC7	Pipework Supplier	Sales Manager
SC8	Forging Supplier	Oilfield Sales Manager

Table 10.3: Key respondents in Case C

10.4.1 Lead Time Performance

Lead time performance in this case was defined mainly due to the lead time of the first pacing component: the main block forging: *"We can achieve 18 weeks when there are good lead times on forgings."* [Manufacturing Manager MC5] *"Short lead times are possible by having forgings on the ground or purchasing already existing forgings."* [Sales Project Manager MC4]. Manufacturer C improved lead times by booking capacity at suppliers based on the material type, which would define which supplier was capable, but before final design was finalised: *"Capacity is booked with the forgemasters. At this point we know the type of material, but not the shape of the final forging."* [Manufacturing Manager MC5] *"Reason is forgemasters have to get the material and then do the forging. It requires a very large size of billet which is not always easily available."* [Sales Project Manager MC4].

The lack of standardisation was also highlighted with regard to the second most important pacing component - forged and bent pipes which had an average 16 weeks delivery lead time: *"Individual configuration required for each order."* [Sales Project Manager MC4] *"The materials are bought, then forged and then bent to produce a sub-assembly. Super duplex steels can also cause delays."* [Supplier Sales Manager SC7]

With regard to the internal process, differences in lead times were noted due to the extent of welding within the process and the relatively short assembly time relative to total lead time was highlighted: *"Some blocks have no welding and therefore manufacturing lead time is less – around 5 weeks."* [Manufacturing Manager MC5] *"Assembly and test takes 2 weeks but it can be 1 week if necessary. The limitations are related to the availability of test bays and test equipment. Dressing takes 1 week to 10 days, including painting and shipping."* [Manufacturing Manager MC5]. The effect of market volume, both in the supply market and that of the manufacturer itself was seen as having a relative effect on lead times: *"Longest lead time was due to being at peak market volume and there was steel supply problems, linked with capacity difficulties on our own shop floor."* [Sales Project Manager MC4] *"During the last two years average lead times have come down."*

This has been due to reduction in market volume from around 50 orders per year to only 12.” [Sales Project Manager MC4]

10.4.2 Influence of Supply Chain Systems (Structures)

Design Standardisation Systems

The importance of repeatability was emphasised where establishing a flow of the primary pacer is possible, whilst the additional time delays of the production of individual dies was emphasised: *“This is easier on larger projects where there are around 12 blocks of one design. A die is required for each client requirement. This is more difficult for a 2-off.”* [Manufacturing Manager MC5] *“Short times are also possible when there are no changes to the design spec. – but this is unusual.”* [Sales Project Manager MC4]

When more standard repeatable designs are combined with modular approaches, the lead time benefits are even more evident: *“We have developed a spool tree whichis a modular approach with a round tube and simple square forgings. Manufacturing time is similar and assembly and test the same, but by being able to pre-order the material we can achieve a lead time of 12 weeks.”* [Manufacturing Manager MC5] *“Have based design on modularity - we avoid cross -overs (from one manufacturer to another)”* [Well Services Purchasing Supervisor CC2] There was also some evidence of modular approaches in the upstream supply chain: *“We are rationalising gate valves and modular designs are being developed.”* [Manufacturing Manager MC5]

However, not all customers adopt this approach to standardisation and modularisation. Even where components are common between one customer and another, individual customers’ QA requirements mean that the parts cannot be directly interchanged: *“Customers have their own QA requirements for components. For example, you can have 4 part numbers for the same gate valve because the QA requirements may be different for each customer.”* [Manufacturing Manager MC5]

Information Communications Structures

Upstream communication took a relatively OCR-type approach with certain customers, with considerable communication at early stages: *"We take suppliers in to talk about their bid. Frame contracts go to one contractor to ensure fewer interfaces and spares."* [Well Services Purchasing Supervisor CC2]. Downstream communication structures included worldwide stock visibility: *"You can access any plant worldwide to access stock information."* [Manufacturing Manager MC5]

Contract Structures

Improvements to the upstream supply chain lead times were in evidence in this case, mainly due to the use of frame-type agreements reducing the extra time involved in EC tendering requirements. There was a knock-on effect from the longer-term relationship due to the manufacturer committing to raw material stocks: *"Now we can tender once which leads to buy-in on carrying raw materials resulting in 6-9 month lead times."* [Well Services Purchasing Supervisor CC2] *"We have agreement with Manufacturer C for long-term. This involves call-off contracts where the supplier is part of the planning process."* [Supplies Manager CC3]. This situation was, however, complicated by the need at both development and production stages: *"Partner approvals are necessary for existing arrangements."* [Well Services Purchasing Supervisor CC2] *"We restructure the tender with a full spec. and invite offers."* [Well Services Purchasing Supervisor CC2]. On the upstream supply chain ACR-type arrangements were more in evidence: *"We use 3 suppliers for valves – we rotate between them and pick the best product at the time."* [Manufacturing Manager MC5].

10.4.3 Influence of Supply Chain Relationships (Infrastructure)

Contract Relationships

The small actual process time for forging time compared to quoted lead time provided evidence of the large amount of non-value added time within the upstream supply chain and the ACR-type relationship style in place: *"Actual forging time is only 1-11/2 days."*

But presently if you were ordering in now in October its end March before there is capacity. If you have a large enough order, you may be able to jump the queue." [Manufacturing Manager MC5]

ACR-type relations were also in evidence from some customers with regard to a lack of acceptance or trust of manufacturers' QA systems: *"One customer specifies based on a certificate of conformity for things as basic as a ring gasket. It is likely that their inspectors have witnessed the pressure test."* [Manufacturing Manager MC5]. However, there was evidence of relationships moving towards a more OCR-type, with more trust of the manufacturer's internal quality systems: *"Customers used to undertake witness tests and sign off at various stages of the process. Now we have a test certificate and the 3rd party only comes in when he feels it is necessary."* [Manufacturing Manager MC5] *"Strategic purchasing is a major issue. This has led to less buyers (half as many). Means better time for buying with improved procurement systems and closer relationships."* [Customer CC3]

10.4.4 Summary of Case C Findings

Manufacturer C had the poorest lead time performance in the Complex Assembled Products Supply Sub-environment and also appeared to be less aware of the importance of lead time reduction. Customers viewed the company as more sales-oriented than improvement-oriented. Similar to Manufacturer B, the assembly site was remote from customers in Aberdeen, with only sales project managers based close to the customer.

Although Manufacturer C had developed a modular product, this was not being sold in volume at the time of the study interviews. The modularity was based on a standard forging that could be configured with different valve arrangements.

Manufacturer C had customers with frame-type agreements, but this had not led to the development of multifunctional teams as in the other two cases. Resultantly, there had not been the development of standard design solutions. In common with other cases,

however, customers had reduced initial delays relating to partner approvals and EC legislation and this had contributed to the achievement of 6-9 month lead times. They were also using call-off arrangements against these contracts but for non-standard products.

Manufacturer C reacted to this more predictable flow of work by booking capacity at forgemasters based on material type, but they were unable to achieve a flow or stock of forgings as they had not agreed a standard forging size or shape. It would appear that this situation contributed to lead times that were around 50% higher than those in Cases A and B.

There was little evidence of pro-active work to improve the upstream supply chain in this case. Throughout there was evidence of multi-sourcing and ACR-type behaviours in the upstream supply chain. In the downstream supply chain, however, there was some evidence of improved trust in this suppliers' internal QA systems. In the case of one major customer, witness tests had been replaced by a test certificate system operated by the manufacturer and 3rd party hold points had been discontinued. There was, however, still the opportunity for customer to make random checks.

10.4.5 Implications of Case C Findings on Research Questions

The findings of Case C have particular implications for Research Question No 3 (*How do supply chain systems and structures influence lead time performance?*). In cases A, B and C those customers for whom the greatest lead time performance improvement had been achieved all had in place Contract Structures of a long-term, frame-type nature with the manufacturers. In Case C there was little evidence that these structures had led to standardisation of design for key pacing components. The long-term contracts produced an upstream reaction that reduced the lead time of the principal 'pacer', the valve blocks forging. But in Case C this was limited to the booking of forging capacity, rather than the stocking of the pacer or ensuring a regular flow as would be possible with a standard component. It is difficult to be precise about the cause and effect here, but there are

indications from customers that Case C was a more sales-oriented company, in comparison to Case A which was regarded as more supply-chain oriented. This, in turn, seems to have led to a lack of development of multi-functional teams between the manufacturer and customers. This leads to the development of a tentative Proposition No 3a: *That multi-functional customer-supplier team-based communication systems is an influencing factor on lead time performance.*

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10.5 Cross-case comparison between Cases A, B and C

10.5.1 Lead Time Performance

Average lead times for Cases A and B were 6 months, whilst Case C recorded a longer average lead time of 8/9 months (see Table 10.4). Within the last two years all the cases recorded a substantial reduction in average lead times, from original times of between 12 and 18 months. The most important reason for improvement in average lead times was deemed to be due increased standardisation in all Cases, whilst Case B noted reduction in market volume as being a contributing factor to actual lead times. Shortest lead times

	Case A	Case B	Case C
<i>Average Lead Time</i>	6 months	6 months	8/9 months
<i>Shortest</i>	45 days	30 days	60 days
<i>Reason for short Lead Time</i>	[1] standardisation [2] small batch possible	[1] no changes to design specifications [2] forgings in stock	[1] standard sub-assembly [2] proven design, less re-work [3] stocking materials
<i>Longest Lead Time</i>	9 months	12 months	12-14 months
<i>Reason for long Lead Time</i>	[1] specials from customer [2] customer requiring "bells and whistles" [3] re-design time	[1] steel supply [2] factory capacity	[1] R & D work [2] high technology interfaces
<i>Changes in average Lead Times in last 2 years</i>	Reduction from 1 year to 6 month, target is 4 months	Reduction from 18 months to 12 months	Reduction from 12-14 months to 8/9 months
<i>Reason for change</i>	Standardisation	Reduction of market volume	More pre-design to standard

Table 10.4: Cross-case comparison of Lead Time Behaviour

ranged from 30 to 60 days. Two of the cases attributed this to standardisation or the ability to produce standard sub-assemblies; Case A also attributed short lead time on the ability to produce in small batches instead of 'one-offs'. Lack of changes to design specification was seen as an important reason for the shortest lead times in Case B and the other cases also mentioned this as an important factor. Two cases highlighted that

standardisation had permitted them to stock long lead time material components (in particular, forgings) and that this, in turn, had contributed to reducing lead times.

Longest lead times ranged from 9 to 14 months, representing variation factors on average of 50% for Cases A and B and 64% for Case C, based on the longest time in their defined range. Special customer requirements and the related Research and Development (R&D) time was stated in Cases A and C as contributing factors whilst in Case B the supply market issue of steel supply was seen as a contributor to long lead times, together with their own factory capacity. Special designs which the assembler perceived to be for no obvious reason (termed “bells and whistles”) was noted by Case A, Case B highlighted special designs with “a lot of welding”, whilst Cases B and C highlighted “high technology interfaces” as all contributing to long lead times. Respondents confirmed that much of this equipment, particularly in renewal rather than Greenfield projects, requires interfaces with a range of other equipment of varying ages and configuration. Certain customers appeared to addressing this are of standardisation.

10.5.2 Influence Design Standardisation Systems and Attitudes

The influence of product design on lead time performance was probed further, particularly related to the standardisation issue, together with the possible use of modular designs (see Table 10.5). The situation with regard to standardisation was mixed. All cases recorded a degree of standardisation, but only for certain customers. Two cases highlighted a difference between large and small customers with regard to standardisation, where larger companies tended to have more special requirements, whilst smaller customers tend to accept the assemblers’ designs. On one side, this behaviour was attributed to larger customers having more “in-company” engineers, whilst small companies did not have this resource and were also concerned about the price premiums for special designs. However, certain major customers were highlighted as “trying” to standardise. Cases B and C indicated partial standardisation. In Case B standard systems existed, but any customer would still have 4-5 variations; Case C

	Case A	Case B	Case C
<i>Changes in Standardisation</i>	Increased standardisation where they can, but only for certain customers.	Not the “whole hog” on standardisation. There are standard modular systems, but any customer can have 4-5 variations	There have been standardisation in sub-assembly design (e.g. actuators), standard geometry and material standardisation.
<i>Impetus for standardisation</i>	Manufacturer and some customers	Manufacturer and some customers	Manufacturer and some customers
<i>Differences in customer approach to standardisation</i>	One major operator has tried to standardise.	Smaller companies take what they’re offered. Larger companies tend to wish to have special requirements. The more in-company engineers, the more design amendments. Customers can “back off” from specials due to cost that can be 30% more.	“Frame Agreements” have assisted. Some companies become very involved in the details. Larger companies tend to get more involved in details; smaller companies tend to leave it to us.
<i>Impact of Standardisation on Lead Times</i>	Reduction for 12 months to 6 months.	Reduced and sometimes eliminated re-engineering time. We are able to commit to suppliers and can stock forgings.	Reduction of 2-3 months. Able to stock valve blocks.
<i>Changes in Modularisation</i>	[1] Single forging used for family of trees. [2] Bent pipes	Forged bar with bolt-on forged bar, instead of large T-shaped forging.	Modular tree design with wing blocks developed, but not really taken off.

Table 10.5: Influence of Design Standardisation Attitudes

indicated standardisation in sub-assembly design, standardisation of equipment geometry and material standardisation.

All cases indicated that standardisation had had an impact on lead times, with reductions of between 2 and 6 months attributed. Cases B and C indicated that the ability to commit to suppliers and stock components, particularly valve block forgings, was the key reason for standardisation impacting on lead times. The manufacturers had the view that the main impetus for standardisation came from themselves rather than their customers; yet certain customer respondents clearly had undertaken standardisation projects. There was less consensus about significant use of modular designs, but Case A indicated the use of a single forging for a ‘family of trees’ which was then ordered on a regular ‘kanban-type’ call-off arrangement. Case B had “modular systems with min/max requirements” and had developed a “bar....with a bolt on forged bar” which was clearly a modular design. Case

C had developed a modular design with a main standard forging supplemented by wing blocks that could provide different geometry and functionality, but that this had not “really taken off” with customers.

The influence of design standardisation systems and attitudes is compared together in order to assess the interaction between the two factors (see Table 10.6). If customers were following a supply chain approach, it would be expected that they would be increasingly using “functional” rather than “technical” specifications. All cases indicated that there was a rather limited application of this approach. Case A noted that there was “a lot of talk but no action”, whilst case B indicated that only one major operator customer had implemented this approach. For the cases that indicated increased use of functional specifications, Case A indicated that this had not had an impact on lead times, but rather on costs. Case C suggested that there had been an impact on lead times due to the use of more standard components.

	Case A	Case B	Case C
<i>Change in use of Functional Specifications</i>	Little change - a lot of talk but no action.	More function specs, but only from one major oil operator (S).	Yes - staff cut-backs in customers has had an impact.
<i>Impact of Functional Specs. on Lead Times</i>	N/A.	Not on Lead times, but on costs.	Some impact as more scope to offer standard components.
<i>Tracking of same components in different models/orders</i>	Trying to do this; separated family to groups of suppliers.	Yes, ‘where-used’ information is recorded to avoid un-necessary re-engineering.	No; but we could trace if necessary.
<i>Operation or “re-usability” Targets</i>	No	No	No.
<i>Operation of “% reduction” Targets</i>	No	Only on acquisition of companies parts are rationalised.	No.

Table 10.6: Influence of Design Standardisation Systems

Other mechanisms that would contribute to standardisation include the operation of systems to track usage of the same components in different models or orders, the operation of re-usability targets and parts reduction targets. There was minimal evidence of knowledge or use of these systems within the cases. There was, however, evidence

within the cases of other variation control methods, for example, Case A had undertaken a study of “where used” for components and Case B also recorded “where used” information.

10.5.3 Influence of Information Communication Structures and Culture

The influence of information communication structures and culture was interrogated in greater detail (see Table 10.7) examining the interaction between the two factors. There was a negative to the use of functional specifications with suppliers, indicating that the

	Case A	Case B	Case C
<i>Change of use of Functional Specs. by you with your suppliers</i>	Not used.	Work to Bill of Material and common items.	Probably no.
<i>QA inspection or supplier responsibility</i>	Inbound inspection.	If 100% Quality Rating, use supplier inspection report. For lower ratings, use sample inspection.	Use patrol and check at supplier rather than inbound inspection.
<i>Meetings with suppliers</i>	Quarterly. Set agenda includes: quality/delivery performance; non-conformity reports; cost reduction initiatives; lead time reduction.	No.	Informal. Talk about: quality/delivery; cost reduction; market situation; understanding of critical paths; reduction of lead time.
<i>Support for suppliers</i>	No, apart from putting suppliers together to arrange co-operation.	No.	No.
<i>Feedback on performance</i>	Yes.	No.	Yes.
<i>Impact of Feedback on Lead Times</i>	Able to reduce critical lead time components from 12-14 weeks to 8 weeks. By tackling this further these could be 3-4 weeks.	N/A.	Impacted on cost reduction and standardisation. For example we now only have 2-3 choke designs and we now hold inventory of these.
<i>Supplier access to production plans/forecasts</i>	Provide MRP forecasts, but they are useless due to market changes. We plan JIT2 access and e-commerce.	Advise suppliers of programme. No access to MRP.	We have recently developed access to our scheduling system.
<i>Impact of access on Lead Times</i>	N/A.	N/A.	[1]Able to synchronise receipt to assembly. [2] Sole source suppliers have laid down stock and improved response as a result.

Table 10.7: Influence of Information Communications Structure and Culture

behaviour encouraged by the assemblers with regard to their customers, was not actually being undertaken by them in the area where they had the opportunity to influence.

Indication of a supply chain system in this supply environment would be the delegation of Quality Assurance to suppliers and a strong communication system with suppliers, with support for supplier development. There was a very mixed picture across the cases relative to this consideration. Case A used traditional inbound inspection, whilst Case C used a system of patrolling and inspection at suppliers. Only Case B linked their approach to inspection to a quality rating system and used suppliers' own inspection reports for those with a 100% rating.

Two of the cases used meetings with suppliers as a basis for communication and supplier/supply chain development and improvement, one more formally than another. Both of these cases included examination of lead times within this process. There was, however, little evidence of support for suppliers being provided, such as training or resources. Two of the cases operated feedback systems to suppliers. Case A could see a clear link with lead time in this process, with opportunities for further improvement: Case C indicated that feedback had impacted on standardisation and thus indirectly on lead time improvement. A further indication of a supply chain system being in place would be the provision of direct supplier access to production plans and forecasts. Again the situation on this issue was somewhat mixed: Case A provided MRP forecasts, but indicated that due to changes they were generally useless to suppliers, case B provided programme advice but no access to MRP and case C had recently developed access to their scheduling systems for suppliers. Case A planned the use of JIT2 (supplier implants working as buyers) and the use of e-commerce as a basis for better access to production information. Initial e-commerce plans, however, were limited to transmission of purchase orders. Impact of these systems on lead times was only identified by Case C who viewed that key suppliers had laid down stock as a result of better production information and thus had improved lead times. In addition, better synchronisation of component receipt related to required assembly times had been achieved.

10.5.4 Influence of Contract Structures and Relationships

The comparison of contract structures and relationships is undertaken in two sections: firstly, downstream structures and relationships with the customer (see Table 10.8) and secondly, upstream structures and relationships with suppliers.

	Case A	Case B	Case C
<i>Customer Contracts</i>	Varies	Variable, but most are using CRINE standard conditions. Some contracts have risk/reward elements.	Frame agreements for some customers. Other very traditional contract terms.
<i>Influence of contract terms on Lead Times</i>	Not known	Some have improved delivery performance and others operability and installation. No direct link with lead time improvement.	Frame agreements have permitted the standardisation arrangements and lead to lead time improvements.
<i>Early Supplier Involvement</i>	Some companies have started to do this, Majors S & B in particular.	Involvement with larger clients; not much with smaller.	Some customers are very good; others are “hands-off”.
<i>Multi-functional Teams</i>	Involvement only at suppliers’ meetings.	Varies from project to project. Field development and design teams have helped to avoid un-necessary changes.	Field Objectives are established; team from design through to manufacture.
<i>Impact of ESI on lead Times</i>	N/A.	20-30% of time is lost due to changes and avoiding this impacts on lead times.	Helps to reduce lead times as basic issues are sorted out early.

Table 10.8: Influence of Upstream Contract Structures and Relationships

If a supply chain approach was being taken by customers, the features that would be expected would be: non-adversarial contracts, Early Supplier Involvement (ESI) and the use of multi-functional team interaction between customer and supplier.

The nature of customer contracts was viewed as variable in all three cases. All cases recorded that certain customers still used very traditional contract terms. Case B, however, stated that most are now using CRINE standard conditions and that some contracts had ‘partnership-type’ risk/reward elements. Case C highlighted the use of ‘frame-type’ agreements. Only case A3 perceived a link between non-adversarial contract terms and lead time improvement, where they saw ‘frame’ agreements permitting standardisation and in turn improvements in lead time. Case B suggested some

improvements in delivery performance and improvements in operability and installation, but indicated that there was no direct link with improvements further down the chain.

With regard to Early Supplier Involvement (ESI), it was the major oil operators that were highlighted as being most pro-active in this approach. Other customers, particularly the smaller companies tended to be “hands-off”. The involvement of multi-functional teams in the ESI process and in other communication with the case companies was much more mixed. Case A involved suppliers only at supplier meetings, Case B noted involvement in field development and design teams, whilst Case C had more widespread involvement from field objectives through to final manufacture based on a multi-functional team. Impact of this relationship style on lead times was seen by Case B to centre on avoiding “unnecessary” changes which were suggested could contribute to lost time of between 20 and 30%. Case C suggested that there was an impact on lead times due to “basic issues being sorted out early”.

The investigation of the relationship with downstream suppliers focused on the ‘pacer’ suppliers: those that had a critical effect on lead times (see Table 10.9). There was a contrast between the two cases on the nature of contracts. Case A had “typical” oil company contracts with its suppliers, whilst Case C had segmented its supply market and had “alliance agreements with relational wording” with its Original Equipment Manufacturers (OEM’s) and long term supply agreements for commodities. Innovations and changes in contracts appeared to centre more on the growth of “world” contracts rather than non-adversarial contracts, although Case C noted that there were more longer-term agreements in the last two years.

The situation with regard to ESI with suppliers also recorded a contrast between the two cases, with only Case C involving suppliers at the design stage and then later at contract award. There was not, however, any clear evidence of the use of multi-functional teams and Case C considered that ESI impacted on costs rather than lead times.

	Case A	Case B	Case C
<i>Contracts with 'pacer' suppliers</i>	Typical oil company contracts; 5 or 3 years with review.	[1] 2 to 3 quotes. [3] 3 quotes and like it or lump it	[1] OEM alliance agreement with relational wording [2] Long term supply agreements for commodities.
<i>Innovations and changes in contracts in last 2 years</i>	World contracts.	No.	[1] More longer term agreements. [2] Division-wide agreements for world supply.
<i>Early Supplier involvement with suppliers</i>	No.	Not used formally.	Yes. Particularly OEM suppliers. We bring them in and give them the customer design spec; try to identify standard products or what design changes are necessary. At contract award we bring them in again.
<i>Are multi-functional teams involved</i>	No.	No.	We have suppliers' seminars.
<i>Influence of ESI on Lead Times</i>	N/A	N/A.	Not really on lead times, but impact on costs.

Table 10.9: Relationships with Suppliers

10.6 Summary of the Influencing Factors on Lead Time Performance in the Complex Assembled Products Case Environment

- There is significant lack of standardisation of well design within the industry that has in turn contributed to lack of standardisation in capital equipment specification.
- This lack of standardisation is further compounded by further design specialisation. Those larger customers (operators) or alliances with in-house design departments were more likely to create special designs, whilst smaller customers were more likely to accept manufacturers standard packages. In the case of one significantly large customer, however, design expertise had been used to achieve around 80% standardisation.
- The positive relationship between standardisation and the ability to strategically stock critical (pacing) components was borne out by the cases. Where standardisation existed, strategic stocking was undertaken and had been a major contributor to lead time reduction.
- There were indications that downstream information communication structures tended towards a more team-based approach, although the degree of formality of this

was mixed. Upstream communications structures exhibited traditional forms. There was also a lack of communication mechanisms between one project and another.

- Contract structures using 'framework-type' agreements exist in downstream contracts, where they have contributed to increased team-based communication, permitted increased standardisation and consequently influenced improved lead times. Upstream contracts maintain traditional forms.
- Contract relationships downstream exhibit considerable lack of trust from both sides of the relationship. There is evidence from all cases that customers do not trust manufacturers' quality systems and instead use 'in-plant' inspections. Upstream relations are clearly aligned to the ACR-type with the use of standard tendering in most cases, although there was some evidence of single sourcing, particularly related to the purchase of forgings.

10.7 Less Complex Assembled Products (Cases D, E and F)

The Less Complex Assembled Products Case environment provides units of analysis that is based on:

[1] Equipment value >£1m ; [2] Low sub-assembly complexity (less than 5 major sub-assemblies involving different processes); and [3] Lower component complexity (<500 components in the finished product).

Three case companies, manufacturers of well completion equipment, were selected as producing products that met these criteria.

10.8 Case D

Case D is a manufacturer of well completion equipment. The company regard themselves as an industry leader in completion solutions based on reliable technologies. The company has more than five decades of experience. The company is a member of a major multi-national group headquartered in the USA and with manufacturing facilities in the UK and USA. The company's objectives are to produce technically advanced products and solutions on which customer can rely. To this end the company highlights its use of a total product Quality Assurance system.

This equipment is used inside the well bore where they are 'run' or lowered to the appropriate level and 'locked-in' to complete the well. They are cylindrical steel devices that operate at depth and in similar variety of pressure, temperature and corrosion conditions as outlined in Case A. Of critical importance in this environment is high-pressure and high-temperature sealing technology between the metal parts to ensure integrity.

There were 10 key respondents interviewed in this case including customers within operators and contractors, operations, materials and purchasing and customer service managers at the manufacturer and suppliers (see Table10.10).

Respondent	Supply Chain Perspective	Functional Perspective
CD1	Customer of Manufacturer D	Operator Well Engineer
CD2	Customer of Manufacturer D	Contractor Well Engineer
CD3	Customer of Manufacturer D	Drilling Manager
CD4	Customer of Manufacturer D	Supply Chain Manager
MD5	Manufacturer D	Operations Manager
MD6	Manufacturer D	Materials Planner
MD7	Manufacturer D	Purchasing Manager
MD8	Manufacturer D	Customer Services Manager
SD9	Supplier of Elastomer Seals	Sales Manager
SD10	Supplier of Steel	Stock Manager

Table 10.10: Key Respondents in Case D

10.8.1 Lead Time Performance

The average lead time for the sample product in Case D was 8-10 weeks. *“Lead time variation for a standard quote is 10-12 weeks. In an urgent case we can achieve 6-8 weeks and worst cases are 16-18 weeks.”* [Operations Manager MD5] This had improved in the last two years from around 12 weeks, mainly due to the work of a Product Action Team who had undertaken a ‘best value standardisation’ exercise. This exercise had reduced the variants to two sizes and two grades. The shortest lead time was 4-6 weeks, although on occasions equipment was available from stocks. Stocks were not built on any particular market plan, however. Rather they were the chance occurrence of ‘making-up’ speculative equipment to improve batch sizes.

The shortest time on manufacturer was due to two reasons: [1] the production of a standard repeat item and [2] by ‘crashing’ the manufacturing cycle to permit an urgent

order priority. *"We can undertake urgent crashing of the schedule in urgent cases, but this disrupts the normal schedule."* [Operations Manager MD5] *"If the customer comes back requiring the order we can crash the system and deliver in around 4 weeks."* [Materials Planner MD6].

The most important pacing component was metal which could in problem case take up to 20 weeks procurement time. A single source stocking arrangement had substantially improved matters in this area. The next most important pacer was elastomeric seals which had a worst case procurement lead time of 4 weeks. *"Thermoplastic is the main material. Standard deliveries are presently poor due to capacity problems - typically 4 weeks are standard. If earlier times are required we may be able to slot in to production. There is usually 'fat' in the lead time quoted."* [Elastomer Supplier SD8]. The predominance of non-value-added time within the lead time was in evidence in this case: *"Typically there is 40 hours of manufacturing, but we have delivery of 6 weeks."* [Operations Manager MD5]

10.8.2 Influence of Supply Chain Systems (Structures)

Design Standardisation Systems

Design standardisation issues are evident within Case D. From the customers' perspective there is evidence of internal frustration in the planning and execution of drilling programmes: *"Standardisation is not easy as they are all different and require their own running tools."* [Drilling Manager CD3] *"Previously there were hundreds of options with 2 pages of items; 4 sizes of packers; 6 sizes of valves."* [Operator Well Engineer CD1]. Additional variety due to the need to interface the equipment with different manufacturers' or different operator's equipment or standards was also evident within this case: *"Many of the original wells have old technology and thus we have to provide adapters to interface with new systems."* [Drilling Manager CD3] The impact of the creation of these interfaces (or cross-overs) was evaluated from a lead time perspective: *"Cross-overs can lead to extra time."* [Materials Planner MD6]

Apparently valid technical reasons for variety were also evident. Importantly for the supply chain, variation due to well conditions impacts directly on the input materials for the equipment, in particular the metals and the seals: *"Variety exists due to such as Hydrogen Sulphide in wells which requires high chrome. With water injection there are high pressure and also high temperature wells – this requires elastomer seals that are not effected by temperature."* [Operations Manager MD5] *"It is difficult to stock due to the large number of set-ups. In one particular pup joint I investigated variants and gave up at 198."* [Operations Manager MD5] *"For high temperature wells we require exotic materials."* [Purchasing Manager MD7]

With regard to seals, it is not merely a matter of requesting a seal of the same dimensions and configuration in a different material, however, further time is added due to the need to produce new moulds and then related testing of the new seal: *"Shrinkage rates are different in different harnesses of rubber and this leads to a different size mould for the same seal. Different harnesses are required due to well conditions, related to temperature."* [Purchasing Manager MD7] *"When it's a 'first article' (new) part this takes about 12 weeks due to the requirement for tooling."* [Purchasing Manager MD7]

With regard to metals, the more exotic the metal the more limited the supply and the more potential for lead time difficulties: *"Special order of raw materials are particularly a problem with exotic materials – material sourced from Japan can take 6 months."* [Materials Planner MD6]

Special requirements also have lead time implications for the manufacturing process: *"Special raw materials can also cause extra time."* [Materials Planner MD6] *"For a standard item there is 2-3 weeks for drawing, 4-5 weeks for procurement of raw material (steel) and elastomer (seal) and 4-5 weeks for assembly and test. Special items can take 20 weeks to 6 months."* [Materials Planner MD6] *"New drawings and assemblies are required to meet customers' requirements. Seldom we have parts in stock."* [Purchasing Manager MD7] *"On a standard order it can be placed directly on the manufacturing*

plant. If it's a special it has to go to Engineering and this is followed by a manufacturing design review." [Operations Manager MD5]

There was also an indication of a lack of variation control and evidence of significant impact between design changes and lead time performance: *"There are also delays due to design modification."* [Materials Planner MD6] *"We require them to stop production and change from one order to another."* [Contractor Well Engineer CD2] *".....changed customer requirements lead to delays."* [Operations Manager MD5]

The link between standardisation and the ability to hold stock was evident within this case. In Case D there was evidence of stock being held, but the turnover rate was extremely poor: *"Shell don't hold stock and yet they use the same equipment over and over again."* [Contractor Well Engineer CD2] *"If customers standardised, stock would be possible."* [Operations Manager MD5] *"There is a product action team that is working on standardisation of equipment. This is making it easier to process items from stock."* [Materials Planner MD6] Upstream suppliers are also aware of the difficulties of supplying from stock in the current non-standard design environment: *"Around 25% of our turnover can be provided from stock. The need to hold inventory for customers is growing."* [Elastomer Supplier SD8]

Information Communications Structures and Culture

There is evidence that certain oil operators realise that they must take a role in providing a structure for supply chain integration and communication. There appears to be a recognition in some quarters that the integrated service contractor was not fulfilling this role: *"We are unbundling integrated service contracts particularly in well supply chain. We are to become the primary integrator."* [Operator Supply Chain Manager CD4]

Planning information from customers was available to this manufacturer at the well testing stage and they reacted to this by some stocking on a speculative basis. In particular, this manufacturer made up more economical batch sizes by adding some

speculative (unsold) orders: *"With regard to holding of inventory, we can get some information based on the market. If we know of different numbers of well tests which defines the pressure we can put some equipment in stock."* [Operations Manager MD5] *"Customers do not share information on their manufacturing schedules with us."* [Elastomer Supplier SD8]

Contract Structures

With regard to metal supply Manufacturer D had entered into a sole supply arrangement and was operating a call-off arrangement: *"With regard to raw material, we now have a sole supplier."* [Materials Planner MD6] *"We now have raw material support and we call off raw materials from our supplier."* [Operations Manager MD5] The metal was thus bought in a cut form and thus there was a key commitment date for this within the lead time: *"For raw material we have a cut date which is noted on the package and this is done by the raw materials supplier."* [Materials Planner MD6] As a part of this call-off arrangement the supplier had an in-house representative (a previous employee of Manufacturer D) working within the manufacturing plant.

Contract arrangements with the other key 'pacer' supply commodity, elastomeric seals, was more traditional multi-sourcing although there was some evidence of close co-operation, particularly with regard to special or exotic requirements. Testing was, however, undertaken by Manufacturer D's own engineers rather than accepting supplier QA. To some extent this is understandable as it is the integrity of the seal relative to the operation of the manufacturer's equipment that is important. Once again there is evidence of stocking, but this tended to be more related to minimum purchase quantities rather than a conscious stocking plan: *"For standard materials we have 2/3 different suppliers."* [Purchasing Manager MD7] *"Elastomeric has approved test procedures by our own engineers."* [Purchasing Manager MD7]. Although the upstream arrangements exhibited traditional ACR-type forms there was little formality in the arrangement, perhaps indicating the power of the supplier in the relationship: *"Contracts are informal. Even quotes don't have terms and conditions."* [Elastomer Supplier SD8]

10.8.3 Influence of Supply Chain Relationships (Infrastructure)

Design Standardisation Attitudes

Respondents were of the opinion that customers' attitudes to special design went beyond the technical requirements to special requirements that, in their perception, contributed little to functionality: *"Reservoir engineers tend to add 'bells and whistles'. They like to add new ideas. Often we have to undertake R&D when there is no actual order."*

[Operations Manager MD5] *"Drilling engineers want 'bells and whistles'."* [Materials Planner MD6]

Contract Relationships

Upstream relationships with customers were identified as variable within this case. Some customers are engaged in single source arrangements, others are standard ACR-type quote situation and finally some customers purely buy on a commodity basis. There was also evidence of lack of trust in customers undertaking their own inspections: *"The relationship with our customer varies. Sometimes we are a single source, sometimes we have to quote and at other times we have to bid."* [Operations Manager MD5] *"Some customers undertake individual component inspections which may be visual or pressure tests."* [Operations Manager MD5]

There were mixed messages from the manufacturer's perspective on the relationship with customers. On one hand, ACR-type behaviour was evident in price mechanisms being used of urgent orders, whilst, as identified above, there was OCR-type speculative stocking of raw materials prior to firm orders: *"We sometimes say that they must order now or it will cost more. Alternatively we may decide to order raw materials on spec (speculatively)."* [Materials Planner MD6]. There was some evidence of an OCR-type approach to suppliers, but this was mixed with a degree of multi-sourcing and inspection rather than acceptance of suppliers QA: *"Comparison prices are used, but we tend to go to the same companies and build up trust. Everything that comes in is inspected and checked to the drawing."* [Purchasing Manager MD7] *"With seals and elastomers we*

tended to keep our options open and use as many suppliers as possible, but we are now trying to concentrate on a few.” [Materials Planner MD6]

10.8.4 Summary of Case D Findings

Manufacturer D had the best overall lead time performance in the Less Complex Assembled Products sub-environment. Average lead times had reduced from 12 weeks to 8-10 weeks within the last two years and the main influencing factor on this improvement was regarded as standardisation of sizes and grades.

The main influencing factors on shorter lead times were perceived to be the ability to produce a standard repeat item of equipment. Internal lead times were a more significant proportion of overall lead times in Case D and there were further opportunities to reduce lead times in urgent cases by ‘crashing’ the manufacturing schedule. Where non-repeats were produced, Engineering Design time becomes a significant proportion of overall lead time.

Pressure from customers to improve lead times was less significant in the case of Manufacturer D, then in cases in the Complex Assembled Products Sub-environment. The shorter relative lead times in this case meant that they were not a primary pacer within most customers’ offshore projects. There was evidence that different well designs by individual customers and also within a single customer has led to product variety and a lack of standard design solutions. In this supply environment, this was further compounded by different rig designs and the requirement for different interfaces due to lack of equipment standardisation. There was evidence, however, that two major customers had made substantial advances in standardisation and this had produced a response from Manufacturer D in the formation of a ‘Product Action Team’. This team had made improvements in establishing ‘ideal’ material specifications, resulting in less machining and consequently reducing lead times.

Manufacturer D had also taken a supply chain approach with upstream suppliers. The primary pacer in this case was the metal raw material used for the manufacture of the equipment and its sub-assemblies. This supply was most problematic from a lead time standpoint where exotic materials are required, such as Duplex. To improve this situation, Manufacturer D had entered into a single sole supply agreement with a metal stockist. This had, in turn, led to the employment of a previous employee of Manufacturer D as an in-plant representative for the stockist.

The secondary pacer was seals. These are gaskets that are used to provide a seal between various metal components in the equipment. Their integrity is key to the functioning of the equipment under high fluid pressures. The most advanced of these seals are called elastomers and the least advanced are traditional, rubber-based seals. In this commodity area the practice of multi-sourcing was still in evidence. ACR-type purchasing structures were in evidence and contracts tended to be informal and in many cases non-existent. The supply market was, however, relatively small with regard to the number of suppliers and this led to a degree of repeatability.

10.8.5 Implications of Case D Findings on Research Questions

The findings of Case D have particular implications for Research Questions Nos. 2 and 3.1. With regard to Research Question No 2 (*Are upstream (supplier) influencing factors more important than downstream (customer) influencing factors?*), the findings of Case D indicate that in this environment, a further set of influencing factors have to be taken into account. The importance of internal process lead times has been highlighted as more significant to overall lead time performance in this Case. Case D exhibits an ability to “crash” this manufacturing schedule where urgent orders are required. This indicates that lead times are less constrained by upstream ‘pacers’ than in the Complex Assembled Products Environment. This leads to the development of the following tentative Proposition No 2d: *That in supply chains not constrained by upstream ‘pacer’*

components, internal process time will be a more significant influencing factor on lead time performance.

With regard to Research Question No 3.1 (*How do information communication systems influence lead time performance?*), Case D findings concur with other Cases in the contribution of multi-functional customer-supplier team-based communication. In this case the system is called a Product Action Team. However, there is a significant variant with regard to communication with the upstream pacer supplier of metal. In this case a single-source supply arrangement has led to the establishment of a JIT II in-plant representative (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996). Thus although there are significant variety issues still obvious in metal supply, in this Case it is more standardised dimensional form in terms of bar or tube. The special design requirement thus does not extend to the manufacture of the component, as in the case of the forging in cases A, B and C. The metal thus only becomes customised when it is cut to length. This leads to the development of the following Proposition No 3.1a: *That in supply chains with significant flows of standardised raw materials JIT II in-plant representatives are an influencing factor on lead time performance.*

10.9 Case E

Case E is a manufacturer of well completion equipment. The manufacturer is part of a major multi-national group, headquartered in the USA. With a commitment to innovation, research and quality, it claims to have pioneered advanced equipment technology for the oil and gas industry. The group had a \$5bn turnover in 1996 and operates in USA, Latin America, Europe, Asia and Africa. The products are broadly similar to those outlined for case D.

There were 8 key respondents interviewed in this case. This included customers, sales, operations and manufacturing managers (see Table 10.11).

Respondent	Supply Chain Perspective	Functional Perspective
CE1	Customer of Manufacturer E	Purchasing Manager
CE2	Customer of Manufacturer E	Operator Wellhead Engineer
CE3	Customer of Manufacturer E	Operator Wellhead Engineer
CE4	Manufacturer E	Subsea Operations Manager
ME5	Manufacturer E	Completion Products Manager
ME6	Manufacturer E	Wireline Manager
ME7	Manufacturer E	Area Sales Manager
ME8	Manufacturer E	Manufacturing Manager
SE9	Supplier of Elastomer Seals	Sales Manager
SE10	Supplier of Springs	Operations Manager

Table 10.11 Key Respondents in Case E

10.9.1 Lead Time Performance

The average lead time for the sample product in Case E was 12 weeks. This lead time had been coming down in the last two years from around 16 weeks. *"Probably coming down as a result of systems and we have got ourselves organised a little bit better. They are coming down."* [Manufacturing Operations Manager ME8]. The shortest lead time was 8 weeks and this was achieved when it was a repeat item. It was also possible to provide this shorter lead time due to giving an urgent order priority in manufacturing. The longest lead time was 18 weeks and the reason for the time was due to customers variations on standard products. *"Engineering time - worst case 4 weeks, for brand new design, well not completely new, but something requiring significant changes."* [Manufacturing Operations Manager ME8]

The most important pacing component was springs that had an average lead time of 3 weeks and elastomeric seals which had a similar lead time. *"We buy raw polymers on 6 weeks lead time or in-house supply from US 4-8 days"* [Elastomer Supplier SE8]. Internal processes appear to be the largest source of lead time in Case E, due to both engineering and possible re-work time: *"Finishes are critical, so that takes a lot of time to make sure these are exactly to spec. 6-7 weeks. Depends whether there is any chance of re-work or even scrappage on those."* [Manufacturing Operations Manager ME8]. Bottlenecks in the process, particularly related to testing are sources of lead time and also most importantly of lead time variation: *"When we get busy we'll immediately take it out to 12 weeks because one of the processes (say safety valve test panel) was very busy."* [Manufacturing Operations Manager ME8]

10.9.2 Influence of Supply Chain Systems (Structures)

Design Standardisation Systems

The impact of standardisation on lead time performance was clearly identified within this case and the amount of non-value added time within the process was also identified.

Manufacturer E was clear that the impetus for standardisation had come from themselves, rather than customers who were seen as not really interested: *“Short because we know what we’re doing, we’ve done it before and the systems are in place to make it automatically. They are repeat type items of a family. The problems start occurring when the customers start asking for variations on a theme, so then we require engineering time and that increases the delivery time.”* [Manufacturing Operations Manager ME8]. The manufacturer’s view in Case E is that the impetus for standardisation has come mainly from themselves and that there is a lack of customer interest in the benefits of standardisation: *“Impetus for standardisation has come mostly from ourselves through competition.”* [Completion Products Manager ME5] *“Most of them are not interested. They are in the driving seat and probably quite rightly they don’t really care how difficult it gets for us.”* [Manufacturing Operations Manager ME8]. Customers’ “lip service” to standardisation was also identified in this case: *“Standard product is what they claim, but when they deliver the specs. nobody produces a particular valve to suit that in a lot of cases.”* [Area Sales Manager ME7] *“Their applications are generally the same, they have to have a spec. that’s really quite different, we don’t see why.”* [Completion Products Manager ME5]. The impact of standardisation on lead time was estimated in rather conservative terms, but the opportunities for further improvement was indicated: *“It would take at least 10% off the lead time over the last period I would estimate. Maybe more and there’s probably more to come. It could be better but every customer likes to have something slightly different.”* [Manufacturing Operations Manager ME8]

Modular approaches had not really been considered as a solution in the case of Manufacturer E, although they identified some approximations to a modular approach: *“Not really modular. It’s really standardising on elements like the seal assembly, the flapper for industry.”* [Manufacturing Operations Manager ME8]. One upstream supplier also had difficulties with the non-standard nature of the oilfield market: *“The oilfield business is less predictable and delays are critical.”* [Elastomer Supplier SE8] As a response, this supplier is examining the possibility of more standard stock arrangements: *“We are looking at the possibility of consignment stocks, with one invoice raised per month.”* [Elastomer Supplier SE8]

Contract Structures

Downstream contract structures show a systematic qualifications framework for suppliers permitting the possibility of full supplier responsibility at the highest level, but there was evidence of resistance to achieving this responsibility and even at this level manufacturer inspections remain: *"A lot of supplier responsibility. We have different levels of supplier. They start off hypothetically at level 5 go down to 1. At each level there's inspection levels. At level 5 it would possibly be 100%. Sliding scale it goes to zero on a level 1. There's an audit, unfortunately engineers fought against zero inspection."* [Manufacturing Operations Manager ME8]

10.9.3 Influence of Supply Chain Relationships (Infrastructure)

Design Standardisation Attitudes

Customer attitudes towards the acceptance of standard design solutions appear to be more positive in this case, with a standard safety valve becoming more popular. The benefits of this from a point of view of scale economies and minor improvements in lead times were evident: *"Definitely, converging on one design of safety valve and that has helped an awful lot."* [Area Sales Manager ME7] *"We are phasing in the new design so that there's a lot more compatibility of products, same kind of springs are being used over and over, so there's economy of scale."* [Manufacturing Operations Manager ME8]. However, respondents also indicated that customers still had a tendency to specify in detail rather than use functional specifications: *"There's some industry standards which have applied for 10-20 years which haven't really changed in the case of safety valves most customers are quite happy with the API standards."* [Completion Products Manager ME5] *"They're quite happy to get into the detailed design and tell us exactly what they need."* [Manufacturing Operations Manager ME8] *"There is still 'preference engineering' i.e. due to the personal preference of the engineer. It's reducing, but it's still there."* [Operator Wellhead Engineer CE2]

Information Communication Culture

Downstream information communication culture does not profile with a multi-functional team approach and appears not to be pro-active and rather ad-hoc: *"They do have some meetings with suppliers. Nothing specific, just really sales calls."* [Manufacturing Operations Manager ME8]. There was also no evidence of communicating feedback, except on a 'fire-fighting' basis to deal with problems: *"(Feedback?) Don't believe so. Not unless there are problems."* [Manufacturing Operations Manager ME8] *"We work with customers to consider whether they can predict requirements, but there are a lot on non-standard applications."* [Elastomer Supplier SE8]

Contract Relationships

There was evidence of OCR-type relationships with certain customers, based on long-term contracts with a relatively high degree of repeatability, permitting call-off type arrangements, but only in some cases: *"What they have is a list of part numbers which is very good for us which means that we use the same designs over and over. Call-off type contract and we make them in batch sizes to suit us. They take from our stock according to their schedule."* [Manufacturing Operations Manager ME8]. The ability of Manufacturer E to translate their customer relations into stocking arrangements was mixed, although an innovative arrangement had been made with one customer and another tied contracts with Supply Chain Management principles and the management of sub-supplier SME's: *"Not a lot really. Started to stock on the Mobil contract."* [Manufacturing Operations Manager ME8] *"Not until recently, BP/Amoco contract ties in with SCM and SME's."* [Completion Products Manager ME5]

With regard to customers involving the case company in Early Supplier Involvement there was a view that this was limited. From a manufacturing perspective there was a view that some of the difficulties were internal to Manufacturer E, in a lack of understanding by sales staff of the benefits of standardisation: *"Not as much as they*

should. Tell sales guys what they want, but there are fine details unfortunately our salesmen perhaps don't understand. They report back what the customer wants, there's not enough discussion." [Manufacturing Operations Manager ME8]. Contract relations with upstream suppliers clearly profiled with the ACR-type: *"No contracts, they're subject to change at any time. We're not spoiled for choice basically on the key elements. There's a few good suppliers that we use. We maintain the right to change at any time."* [Manufacturing Operations Manager ME8]

10.9.4 Summary of Case E Findings

Manufacturer E had the second best lead time performance in the Less Complex Products Sub-environment. Average lead times had reduced over the last two years from 16 weeks to 12 weeks. In this case the perception was that this change had taken place due to increased competition, rather than from improvements to the supply chain. This perception would appear to indicate that Manufacturer is more of a follower of supply chain trends rather than a pro-active leader.

Shorter lead times were achieved on repeat items that did not require engineering design time. It was also possible to achieve short lead times by giving an individual customer order higher priority in the manufacturing schedule. In a worst case, Engineering Design time was estimated to be 4 weeks for a brand new design, representing around a quarter of overall lead time. Internal processes are also significant from a lead time point of view. Particular sub-assemblies require significant machining due to tolerance requirements and this is a major contributor to overall lead time. The primary pacing component in this case was springs, which had a fairly similar lead time to the second most significant pacer: elastomeric seals.

With regard to standardisation, there was a commonly held view that there was a lack of interest from customers in this issue and that most of the impetus for standardisation had come from the manufacturer. The manufacturer, however, had made pro-active efforts to converge on one design and this had led to more uptake from customers. There was still

evidence, however, of customers becoming involved in detailed design and ‘preference engineering’.

Communication structures and culture upstream did not exhibit a supply chain approach. Contract structures and relationships tended to be informal, multi-sourced and exhibiting ACR-type forms. Downstream, there was evidence, however, of OCR-type contract structures. One customer contract was of a call-off nature and a further customer contract involved stocking products, including management of the product stocks of competing suppliers.

10.9.5 Implications of Case E Findings on Research Questions

The findings of Case E have particular implications for Research Question No 2 (*Are upstream (supplier) influencing factors more important than downstream (customer) influencing factors?*). Firstly, the findings of Case E support Proposition No 2d (*That in supply chains not constrained by upstream ‘pacer’ components, internal process time will be a more significant influencing factor on lead time performance*). Secondly, there is evidence that Case E has not been pro-active in reducing its lead times, but rather has been influenced by the reduction of lead times of competitors. Thus, whereas Case A could be regarded as a ‘leader’ in lead time reduction, case E exhibits more of the features of a ‘follower’. In reaction to this lead time pressure, Case E has “converged” on one design in order to achieve the lead times demanded by the market and uses the price mechanism to attract customers to opt for this model. This leads to the implications for Research Question No 1.2 (*How do design standardisation attitudes influence lead time performance?*), in the development of Proposal No 1.2a: *That manufacturers in certain market situations may choose to produce a lower-priced commodity product as an alternative to an engineered-to-order product as a response to pressures on lead time performance.*

10.10 Case F

Case F is a manufacturer of well completion equipment. It is a smaller organisation than Cases D and E and is independently owned and not part of a major multi-national. The company has two subsidiaries, both located in the UK and is headquartered in Aberdeen. It has sales organisations in USA, Italy, Australia, France and Norway and is represented in around another 7 countries worldwide. The company has a philosophy of participation in ownership by operational management within the company. It sees investment in executive development and commitment as important as investment in technology. The products in Case F are broadly similar to those in Cases D and E, but Case F *“tend to work in more of a ‘niche’ market and deal with developing solutions to specific problems. Our products start as one-offs, but eventually become a commodity”*. [Marketing and Operations Manager MF4]

Summary of key respondents for Case F are shown in Table 10.12

Respondent	Supply Chain Perspective	Functional Perspective
CF1	Customer of Manufacturer F	Well Engineer
CF2	Customer Of Manufacturer F	Purchasing Manager
CF3	Customer of Manufacturer F	Strategic Purchasing Manager
MF4	Manufacturer F	Marketing and Operations Manager
MF5	Manufacturer F	Sales Project Manager
MF6	Manufacturer F	Materials Manager
SF6	Supplier of Rubber Seals	Managing Director
SF7	Machined Parts Supplier	Operations Manager

Table 10.12: Key Respondents for Case F

10.10.1 Lead Time Performance

The average lead time of the sample product in Case F is 10-15 weeks. This has been reduced from around 18 weeks within the last 2 years. The shortest lead time is ex stock, but the shortest manufacturing lead time is 4 weeks. Ex stock supply is possible as Manufacturer F also operates an equipment rental service and can provide immediate reserve stock in this way. This also permits the company to manufacture extra equipment not to sold orders, which can assist in maintaining batch sizes. It is also possible to reduce lead time due to 'jumping the queue' in manufacturing: *"We could make some tools in 3 days, but other orders would suffer in the queue. Typically there is 500 hours of machining time."* [Marketing & Operations Manager MF4]. The longest lead time is 50 weeks, but this is for a more specialised 'smart' completion that is more in line with the Complex Assembled Product Environment and has a cost of £1m. For normal completions the longest lead time is around 20 weeks. The reason for long lead time is special metallurgy and special designs. *"Delivery times are around 12 months. The reasons for the time are firstly metallurgy. Specialist materials such as Inkanel have long procurement lead times."* [Materials Manager MF6]. The most important pacers are related to seals. *"Key 'pacer' is related to seals. We have tended to deal with the same companies for 7-8 years – our company is 10 years old."* [Materials Manager MF6] *"Delivery on O-rings and T-seals ex States can be around 12 weeks."* [Materials Manager MF6] *"The second most important pacer is exotic metal"* [Marketing & Operations Manager MF4]

The non-standard nature of the process is a key reason for internal lead time, as, being a smaller organisation, it tends to attract the more specialised orders: *"We are essentially a Job Shop and our production scheduling is not up to the task."* [Marketing & Operations Manager MF4]

10.10.2 Influence of Supply Chain Systems (Structures)

Design Standardisation Systems

Lack of standardisation of design is evident within this case: *“Customers’ systems are never the same. BP Foinaven, Agip and Shell Tern had similar temperature requirements, but their connections were all different.”* [Sales Project Manager MF5]. However, there are some customers who are making an effort to improve standardisation: *“Standardisation is around 80%. We put the risk on to the supplier and drove them to work for standardisation.”* [Well Engineer SF1] *“The market is changing, we previously undertook 100% custom design, but there are more commodities now, but we tend not to get into competitive product areas.”* [Marketing & Operations Manager MF4]

The ability to support and improve manufacturing lead times by holding inventory is not positive in this case: *“The only inventory that we hold are consumables: O-rings, Shear screws etc.”* [Marketing & Operations Manager MF4] *“For example, take a component like the Retrievable Bridge Plug. It uses a rubber seal and is a core product produced to an industry standard. All the engineering was done before.”* [Materials Manager MF6]. Lack of standardisation had led to a situation where the supply chain could not use inventory for support or as a mechanism to reduce lead times: *“We never have enough time, only questions: when do you want it? What size? Nothing is manufactured for inventory.”* [Marketing & Operations Manager MF4]

Information Communications Structures

Respondents agreed that customers communicated and shared certain information, but it was usually at too broad a level to be of any real use: *“We have shared information from customers, which is their drilling schedule. For larger completion-related products the drilling programme is worth its weight in paper – it’s not helpful. There is a sequence of events, but the timings are ‘guesstimates’.”* [Sales Project Manager MF5] Regular meetings were, however, taking place with customers and they took a multi-functional

approach: *"There are about 14 people at the meetings, including 8/9 from the client side. We see Shell every day."* [Marketing & Operations Manager MF4]

Contract Structures

There was evidence from respondents of frame-type agreements in place in the downstream supply chain: *"We work in commodity ranges to ensure frame agreements are in place for future arrangements."* [Customer CF3] *"We have some frame contracts for BP Miller, Magnus etc."* [Sales Project Manager MF5]. Upstream, there was evidence of OCR-type contract structures in the existence of a single source supply agreement for metal raw material: *"Our supplier supplies all raw material – they have lengths of steel and cut and send."* [Materials Manager MF6] On the other hand, sub-contract machining was a multi-source arrangement, normally depending on which supplier had available capacity at the time: *"Manufacturing or sub-contract machining is done with home suppliers with short lead times."* [Materials Manager MF6] *"We tend to use more than one source for sub-contract engineering and fabrication, as one couldn't handle the volume. We use 5/6 suppliers in this area."* [Marketing & Operations Manager MF4]

10.10.3 Influence of Supply Chain Relationships (Infrastructure)

Design Standardisation Attitudes

There was evidence in this case that the manufacturer actually promoted non-standard designs. Part of its competitive advantage as a smaller company in the market was seen as its ability to produce non-standard and in some cases innovative solutions: *"The customer comes with a problem, basically conditions information e.g. prevention of full-blown work-overs. On new wells they may not want the full spec, so we run calculations here and suggest equipment."* [Sales Project Manager MF5] There also appears to be less involvement of customers in the design process in this case: *"Our customers have a very small involvement in design or technological innovation."* [Marketing & Operations Manager MF4]

Information Communication Culture

This customised approach to design is followed through in an open and OCR-type problem-solving culture between the manufacturer and the customer: *"Marketing discuss the problem with the oil operator or lead contractor. Usually we talk to the Well Engineer. The final spec. is based on what they want to achieve and what is practical. Load, pressure etc facilities depend on well conditions."* [Sales Project Manager MF5] However, there was evidence from respondents that the customers were not always fully open with the manufacturer: *"We are not party to the internal politics in the operator (Customer). The programmes are constantly changing."* [Sales Project Manager MF5]

Contract Relationships

There was evidence from respondents in this case of ACR-type relationships with customers. Perhaps because Manufacturer F was a smaller organisation there was a perception from a number of respondents of wielding of power by the customer: *"Whoever shouts the loudest gets priority for capacity. This is based on the size of the customer and the amount of ongoing business."* [Marketing & Operations Manager MF4] Manufacturer F was also concerned about the increased power of lead contractors. Many of these contractors had group companies that could be competitors of Manufacturer F. Respondents also saw the use of contractors by oil operators as disjointing the supply chain from the ultimate customer, the oil operator: *"The change to the use of 'Lead Contractors' is not helpful. Shell and BP are now more remote from frontline requirements."* [Sales Project Manager MF5] *"Head Contractors are our main competitors as they also have manufacturing capabilities."* [Marketing & Operations Manager MF4] This contractor layer in the supply chain was perceived as causing lead time delays: *"Manning is lower (in contractors) and communication is poorer particularly in divorced offices. We couldn't do without networked computers. Even with this there is delay in telling us about their requirements. Where there is more involvement the problem solution is good."* [Sales Project Manager MF5]

There was evidence of OCR-type relationships being promoted by Manufacturer F in the upstream supply chain, with less multi-sourcing giving way to the use of one supplier related to a commodity area on a particular project: *“With regard to our suppliers we are undertaking to form liaisons and relationships. In the past we sent out drawings to 6 people and picked the cheapest. Now we deal with one company as a project and can work with him. We tell them ways of improving work methods.”* [Materials Manager MF6] This approach has led to OCR-type co-operation and development work with suppliers: *“We work with suppliers and informally transfer staff where there are problems. Rubber supplier will talk to us when prototyping and will test in our facilities.”* [Materials Manager MF6]

10.10.4 Summary of Case F Findings

Lead time performance in Case F is the poorest in the Less Complex Assembled Products Sub-environment. Partially this appears to be due to the nature of the case company and its market situation that has some differences from Cases D and E. Manufacturer F is an independent company, whilst D and E are part of major multi-nationals. As such, the company has developed a competitive advantage based on its ability to produce innovative design solutions. The existence of smaller high-technology design-based companies is a well known source of innovation in capital equipment industries.

An entrepreneurial approach is evidenced in its involvement in providing equipment from a rental service. Most equipment rental companies are independent of oil equipment manufacturers. This approach gives them the opportunity to provide off-the-shelf service in some of their more standard products and, in turn, to maintain a better production flow with more cost-effective batch sizes.

Where goods are manufactured to order, short lead times are influenced by the ability of the company to permit urgent orders to ‘jump the queue’. It is accepted, however, that this approach means that other orders may suffer as a result.

Long lead times exist in this case where they produce their more innovative products. These products do not fully profile with the definition of Less Complex Products and thus it is the lead times of normal products that have been used for comparison. On these products the primary pacer is that of exotic metals.

Respondents indicated that internal lead times were a significant element with the whole lead time picture. Much of this was due to the non-standard process environment that was regarded as more akin to a job shop. Downstream information communication structures and culture could not be fully profiled with the OCR-type. Shared information is provided, but it is too general and thus inaccurate to be of any real practical use to the manufacturer. There are regular meetings with customers of a multi-functional team nature, but respondents questioned the culture of open-ness from customers. Customers appeared to wield their power and there was perception that downstream relationships lacked an atmosphere of mutual co-operation, particularly related to schedule changes. Manufacturer F, being a smaller organisation, appeared to be more affected by downstream behaviours based on the power of the operator and contractor customer.

There was some evidence of OR-type relations in the upstream supply chain. Moves towards single sourcing were in evidence and OCR-type behaviours such as the secondment of staff to suppliers and the provision of access to suppliers to the manufacturer's own testing facilities.

10.10.5 Implications of Case F Findings on Research Questions

Th findings of Case F have particular implications for Research Question No 4 (*How do supply chain relationships and infrastructure influence lead time performance?*). Case F is a smaller locally-owned company in comparison with the other Cases that are all major multi-nationals. In Case F there was significant evidence of more informal arrangements with upstream pacer suppliers. Contract arrangements with these suppliers tended to be non-existent, but there was evidence of close co-operation and sharing of resources and expertise. Thus these arrangements profiled most closely with the Case A single-source

arrangements with upstream pacer suppliers, but in Case A the contracts were more formal. Although, case F was a relatively small organisation for this environment, these informal arrangements were with even smaller proprietor-owned SME's. This leads to Proposition No 4c: *That collaborative relationships based on informal styles in certain cases contribute to lead time performance improvement.*

10.11 Cross-case Comparison between Cases D, E and F

10.11.1 Lead Time Performance

Average lead times ranged from 8 to 15 weeks in this sub-environment (see Table 10.13). Within the last two years all cases recorded reduction in average lead times although respondents indicated that this was variable from one customer to another. On the conservative side of estimated provided, however, lead times had reduced between 20 and 30% which is a significant improvement. Reasons for improvements were attributed to standardisation of products, permitted at least in part by more frame-type agreements. Case E appeared to be more of a follower in supply chain improvement, viewing the main reason for lead time improvement as competition. In Cases D and E the principal reason for short lead times was perceived to the ability to produce a standard repeat item. All cases also exhibited an ability to ‘crash’ or change the manufacturing schedule to accommodate urgent orders that would then achieve a very short lead time. In one case a lead time as low as 3 days was deemed to be possible. Clearly this highlights the substantial amount of non-value-added time with the lead time in these cases.

	Case D	Case E	Case F
<i>Average Lead Time</i>	8-10 weeks	12 weeks	10-15 weeks
<i>Shortest</i>	4-6 weeks	8 weeks	4 weeks
<i>Reason for short Lead Time</i>	[1] Standard repeat item [2] ‘Crash’ manufacturing schedule	[1] Repeat item [2] Priority in manufacturing	Changed scheduling ‘jumping the queue’
<i>Longest Lead Time</i>	16-20 weeks	18 weeks	20 weeks
<i>Reason for long Lead Time</i>	[1] Exotic materials [2] Engineering design and testing	Customer variations	[1] Non-standard processes [2] Exotic metallurgy
<i>Changes in average Lead Times in last 2 years</i>	Variable, but some improvement from around 12 weeks.	Coming down from 16 weeks.	Variable, but coming down from 18 weeks.
<i>Reason for change</i>	Standardisation of sizes and grades	Competition	Call-off arrangements on ‘frame’ contracts

Table 10.13: Cross-case comparison of Lead Time Behaviour

Longest lead times ranged from 16 to 20 weeks representing variation factors of 140% in Case D, 83% for Case E and 125% for Case F, based on the longest time in their defined

range. Exotic metal pacers and customer variations to design were identified as the main influencing factors on long lead times.

10.11.2 Influence of Design Standardisation Systems and Attitudes

The influence of attitudes to product design, particularly related to the standardisation issue was rather mixed in this sub-environment. Cases D and E perceived increased standardisation, whilst Case F perceived no change (See Table 10.14). Case F, however, has been identified as a smaller independent organisation in comparison with the other two cases which are major subsidiaries of multi-nationals. It was identified that much of Case F's competitive advantage came from innovative design and thus it would be expected that this organisation would be less exposed to standardisation.

	Case D	Case E	Case F
<i>Changes in Standardisation</i>	Increased standardisation	Increased, but a mixed picture	No change
<i>Impetus for standardisation</i>	Both from customer and manufacturer	Mostly from manufacturer	N/A
<i>Differences in customer approach to standardisation</i>	[1] Two major customers have standardised. [2] EC-owned operating companies have little standardisation	[1] Many customers not interested. [2] Many pay 'lip service' to standardisation.	N/A
<i>Impact of Standardisation on Lead Times</i>	Reduction of 2-3 weeks from design time and 4-5 weeks from procurement time.	Around 10% reduction in lead time.	N/A
<i>Changes in Modularisation</i>	Not significant.	Not really modular, but some component standardisation	None.

Table 10.14: Influence of Design Standardisation Attitudes

Case E perceived that the impetus for standardisation had come mostly from themselves, whereas Case D perceived that both customer and manufacturer had been involved in fostering this approach. There was evidence of considerable differences between customers in their approach to standardisation. Case E indicated that many of their customers were not interested in this approach and tended to pay 'lip service' to the idea. Case D had more positive examples, with two major customers undertaking

standardisation. The respondents in this case indicated that continental EC-owned companies tended to be much more involved in specific design than UK or US companies. There were no significant modular approaches identified in these cases.

The influence of Design Standardisation Systems drew a generally negative response in these cases (see Table 10.15). There was no real evidence of increased use of functional specifications, although in Case A customers were increasingly accepting functionality advice related to seals and were tending not to include these in their

	Case D	Case E	Case F
<i>Change in use of Functional Specifications</i>	[1] Not a lot of change. [2] Customers increasingly accept functionality advice on metal and seals.	Not really used by customers except for API standards.	Not used significantly by customers.
<i>Impact of Functional Specs. on Lead Times</i>	Insignificant.	N/A	N/A
<i>Tracking of same components in different models/orders</i>	Yes, 'where used' statistics are available.	Industrial Control Department looks at usages.	No.
<i>Operation or "re-usability" Targets</i>	No.	No.	No.
<i>Operation of "% reduction" Targets</i>	Yes, including obsolescence targets.	No.	No.

Table 10.15: Influence of Design Standardisation Systems

technical specifications. There was a lack of formal or pro-active use of mechanisms to reduce component variety, although Cases D and E did record and to some extent examine 'where used' statistics recording in which models or orders there was component commonality. Case D had percentage reduction targets in place and these included obsolescence targets related to the discontinuance of certain products to avoid range proliferation.

10.11.3 Influence of Information Communication Structures and Culture

The influence of Information Communication Structures and Culture with suppliers was analysed (See Table 10.16). Indication of a supply chain approach in this environment

	Case D	Case E	Case F
<i>Change of use of Functional Specs. by you with your suppliers</i>	Yes, some progress in specifying based on grades linked with applications.	Not used.	Not used formally.
<i>QA inspection or supplier responsibility</i>	[1] Dependant on supplier. [2] Core steel and elastomer suppliers are not inspected.	[1] Different supplier quality levels are specified. [2] Almost zero inspection at Level 1, but engineers have fought against it.	Incoming inspection used on all supplies.
<i>Meetings with suppliers</i>	Limited to purchasing communication.	Some meetings, but no formal structure.	Informal arrangements.
<i>Support for suppliers</i>	No real support.	None.	None.
<i>Feedback on performance</i>	Technical and delivery problems only.	No.	No formal system.
<i>Impact of Feedback on Lead Times</i>	Not significant.	N/A.	N/A.
<i>Supplier access to production plans/forecasts</i>	Yes, but only key steel supplier. Supplier representative works in-house.	No.	Only on large systems.
<i>Impact of access on Lead Times</i>	Definite impact, particularly on exotic steels.	No real impact.	Some impact – but could be better.

Table 10.16: Influence of Information Communication Structures and Culture

would be the delegation of Quality Assurance to suppliers and strong communication systems and culture with suppliers, providing support in supplier development. In Cases D and E there was a considered system of delegation of supplier responsibility for QA based on specified quality levels. In Case D this resulted in core pacer suppliers not being inspected and in Case E there was almost zero inspection at the best supplier level, but they had difficulty in achieving this due to resistance from engineers. In Case F incoming inspection was used on all supplies. Communication through meetings with

suppliers was limited and there was no evidence of multi-functional teams operating upstream. There was also no evidence of supplier development support and feedback was only noted in Case D and this related purely to problem-solving. In Case D the sole metal supplier had direct access to production plans and forecasts and this was assisted by the presence of the in-plant supplier representative. Respondents in Case D perceived that this arrangement had contributed significantly to lead time reduction.

10.11.4 Influence of Contract Structures and Relationships

The first issue within this section was the analysis the downstream relationship between the case companies and their customers (see Table 10.17). All the cases had standard ACR-type contracts with customers, but this was more prevalent in Case D. Case F had some frame-type agreements, which had permitted more call-offs of standard equipment. Case E had one major contract with call-off arrangements and a further contract which included stocking arrangements and these were perceived as permitting shorter lead times

	Case D	Case E	Case F
<i>Customer Contracts</i>	[1] Standard ACR contracts. [2] 3 to 4 contracts with each customer. [3] Penalty clauses.	[1] One major long-term contract with call-offs. [2] One contract has stocking arrangement. [3] Other contracts standard ACR-type.	Some 'frame' agreements.
<i>Influence of contract terms on Lead Times</i>	None.	Permits shorter lead times due to standardisation and stocking ability.	Has permitted more call-offs of standards equipment.
<i>Early Supplier Involvement</i>	Very much involved.	[1] Not as much involved as they should be. [2] Sales engineers can be a barrier between customer/manufacturing.	Some ESI, but contractors tend to be a barrier and cause delays.
<i>Multi-functional Teams</i>	Groups of sales and development engineers, along with customers.	No.	Only on large systems.
<i>Impact of ESI on lead Times</i>	Definite impact, particularly where there are exotic materials involved.	No real impact.	Some impact – but could be better.

Table 10.17: Influence of Contract Structures and Relationships – Downstream Supply Chain with customers

due to both standardisation and stocking ability. Multi-functional teams only operated in the downstream supply chains of Cases D and F and in the case of the latter this was only on large systems and not on regular products. In these companies Early Supplier Involvement by customers was seen as having a definite impact on lead times in Case D and some impact in Case F. Upstream contract structures were informal and in case of Cases E and F no contracts existed with pacer suppliers (See Table 10.18). There was also little evidence of

	Case D	Case E	Case F
<i>Contracts with 'pacer' suppliers</i>	Informal.	None.	None.
<i>Innovations and changes in contracts in last 2 years</i>	No.	No.	No.
<i>Early Supplier involvement with suppliers</i>	Only on some projects.	Rarely – sometimes on new designs.	Informal communication.
<i>Are multi-functional teams involved</i>	Some design engineers involved – not really multi-functional.	No.	No.
<i>Influence of ESI on Lead Times</i>	Some improvements.	N/A.	N/A.

Table 10.18: Influence of Contract Structures and Relationships – Upstream with Suppliers

Early Supplier Involvement or the use of multi-functional teams. In turn, as would be expected, little influence of these features on lead time was perceived, except in the Case D.

10.12 Summary of the Influencing Factors on Lead Time Performance in the Less Complex Assembled Products Case Environment

- There has been a mixed picture with regard to standardisation attitudes, but where this existed it was an influencing factor of lead time improvement.
- There was limited use of variety reduction standardisation systems, but where used they had been perceived as improving lead time performance.

- Downstream information communication structures and culture evidenced OCR-type forms in some cases, but there was a perception of lack of sharing of information that would be useful to lead time performance.
- Upstream information communication structures and culture tended gave some evidence of OCR-type forms in delegation of QA responsibility to good quality suppliers. There was little evidence of useful feedback or information access and sharing, except in one sole-sourcing arrangement.
- Downstream contract structures and relationships provided some examples of frame-type agreements in two of the three cases, permitting call-off arrangements and improved lead times. There was limited downstream Early Supplier Involvement except in Case D.
- Upstream contract structures and relationships tended to be informal, with limited multi-functional team involvement and little impact on lead times, except in the case of one sole-sourcing arrangement.

10.13 Summary of Case Research Findings

The case research of the capital equipment supply environment to the offshore oil exploration and production industry has provided evidence that the following are influencing factors of lead time performance:

- Both sub-environments exhibited evidence of an Integrated Supply Chain Process based on a differing levels of development of the blend of supply chain systems/structures and relationships/ infrastructure.
- Within each environment, cases exhibited different levels of development of Integrated Supply Chain Process.
- Best lead time performance was found where customers had been pro-active in seeking supply chain solutions. This included the use of frame-type agreements, permitting long term agreements with manufacturers.

- The manufacturers that achieved best lead times had customers that used functional specifications within frame-type agreements permitting standardised and modular design solutions.
- The manufacturers with best lead time performance had pro-actively pursued supply chain improvement upstream with their suppliers, based on single source agreements and on strategic stocking of primary pacer components.
- Upstream systems/structures and relationships/infrastructure profiled more frequently to ACR-types than in the downstream supply chain that had more evidence of OCR-type.
- Throughout there was more evidence of the development of supply chain systems/structures and less evidence of the parallel development of relationships/infrastructure to support these.

11. LEAD TIME PERFORMANCE IN THE SUPPLY CHAIN:

Synthesis and further discussion of the influencing factors in the Capital Equipment supply environment

This chapter synthesises the findings of the Case Research in Chapter 10 in the light of the evidence from the Survey Data in Chapters 8 and 9 to provide an overall picture of the influencing factors on lead time performance in the Generic Case Environment. The research questions and propositions are interrogated with reference to the empirical data obtained in the study and informed by the existing theory, previously critically analysed in the literature review. This is used to refine the conceptual model proposed in Chapter 6 into a 'Model for a Time-based Supply Chain Improvement Process' applicable to the Capital Equipment supply environment. The contribution of current literature, reviewed since the completion of the study is discussed. The contribution of this research study is evaluated, its limitations considered and the potential for ongoing research in this area discussed.

11.1 Research Question No 1

How does the Design-to-order nature of the Capital Equipment supply environment influence lead time performance?

The generic nature of the Capital Equipment supply chain was reviewed in relation to the literature in 5.9 above. Relative to the Sweeney and Szwejczewski (1996) conceptual framework Capital Equipment can be mainly classified within Quadrant 2 (Innovator) where there is new process design and high customer service criteria. In this quadrant "each manufactured product required an innovation to a standardised product design". The Generic Case Environment profiles with this definition. The Sweeney and Szwejczewski (1996) study considered companies in this quadrant to have low 'throughput efficiency' (i.e. the proportion of value adding time to manufacturing throughput time), which is in line with the problems identified within the wider supply chain in this supply environment. The Batreezzaghi (1994) taxonomy is perhaps even

more helpful in defining the generic nature of Capital Equipment. This taxonomy examines “process steadiness” against “object interchangeability”. The Engineer-to-Order environment is defined as medium process steadiness (compared, at one extreme, to new product development which would have low process steadiness) and at the other extreme, make-to-stock environments, which would have high process steadiness). Thus where there is less standardisation and repeatability of product design, the process steadiness will be lower. The engineer-to-order environment is also classified by Batreezzaghi (1994) at the low end with respect to the other variable, ‘object interchangeability’. This refers to the degree of interchangeability of materials and/or information passing through the process. This concept has some common features with the Battacharya (1996) ideas of ‘turbulence’ in high complexity/high uncertainty environments, which he sees as tending towards product development rather than production-type models. In a design/engineer-to-order environment new product development essentially becomes a part of the order process, rather than being a separate lead time cycle.

The extension of these concepts to the wider supply chain is particularly useful to improve supply chain understanding. By doing this, a contribution is made towards the Lamming (2000) call for the development of classifications of supply chains and the Cox (1999) emphasis on the importance of understanding supply chain contexts.

11.1.1 Evidence from Survey Data

The nature of the generic products in this supply environment was investigated within the *Supplier Survey*. The assembled products have high complexity, as measured in the number of components and sub-assemblies, and they record average lead times of 3-6 months, shortest lead times of 1-3 months and longest lead times of 9-12 months (see 9.1). The relationship between the complexity profile [variable a] and lead time performance was found to be as would be expected: the higher the complexity profile, the longer the lead time. The second variable investigated [variable b] was the “nature of the product”. Respondents were asked to classify their orders based on a 4-part design

standardisation classification: [1] Sales catalogue item; [2] Sales catalogue item with customer choice options; [3] Customer specific design to repeat orders; and [4] Unique customer specific design. Assemblers recorded 67% of products were to unique customer specific designs (see 9.1).

The Survey Research thus informed the Case Research phase by identifying the importance of comparing supply chains at similar complexity levels. This would then permit the investigation of the design standardisation variable and its influence on lead times in the order cycle. Thus Cases were profiled into two sub-environments: [1] Complex Assembled Products and [2] Less Complex Assembled Products.

Product features and performance were rated as the most important customer service criteria in this environment, with supply chain performance being rated as less important (see 9.2). There is an indication, therefore, that in a design/engineer-to-order supply environment, that organisations may be more focused on differentiation based on product features, rather than engaging in time-based competition (Stalk & Hout, 1990).

The following propositions was derived from the survey research:

Proposition 1a

That design standardisation has a positive influence on lead time performance

11.1.2 Evidence from Individual Cases

Research Question No 1

How does the design-to-order nature of the capital equipment supply chain influence lead time performance?

Case Research data was first triangulated within each Case by using a number of key respondents from different perspectives in a purposive sample, using the “Supply Chain Trace-back” methodology (see 2.6 above).

Differences between interchangeability of materials (Batrezzaghi, 1994) were found in the Cases. In the Less Complex Products environment, there is a higher level of “object interchangeability.” Relatively high upstream material interchangeability was identified in Case D. One of the two upstream pacers in this Case was that of metal supply. The degree of interchangeability of this pacer permitted Case D to engage in a JIT II in-plant representative with a single source supplier (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996). This arrangement had substantially contributed to lead time performance improvement. There was also evidence in Case D of an elastomeric seal supplier considering the use of consignment stocks with this manufacturer. It was discovered that the cost of a seal or gasket is very highly related to the initial design and testing time. The marginal cost of manufacturing extra seals once set-up is relatively low and thus the inventory holding cost of extras can easily be written off against the “first order” design. Clearly obsolescence is potentially high in this scenario, but even the costs of obsolescence are relatively small.

In the Complex Products environment, inventory-holding costs of pacers were found to be significantly higher. In Case A, there is evidence of one customer who has accepted a standard design for the primary ‘pacer’, the valve block forging. This led to a stocking agreement for this ‘pacer’, the inventory-holding cost of which had been underwritten by the customer. Thus whereas much of the literature related to Concurrent Engineering (Jayaram et al, 1999; Kumar et al, 1995; Ahmed et al, 1996; Maylor, 1997; Yan and Jiang, 1999) has centred on the impact of standardisation on the design phase of the lead time, the evidence from this case indicates a more significant influence on lead times is related to the solution of lead time problems with upstream ‘pacers’.

The solution to upstream pacers in the Complex Products supply environment is considerably different. In this environment, a pacer such as the primary pacer of the valve block forging (in Cases A, B and C) requires special geometries as well as special metals. It is only by standardisation at the component level that lead time reductions are possible. Two methods were revealed: [1] the use of a standard block that could be

adapted to different geometries by additional machining, or [2] the use of a modular approach with geometry being achieved by different ‘bolt-on’ components. The potential for the latter is clearly greater from a lead time standpoint. Unfortunately, although modular designs existed there was strong resistance to them by Well Engineers. This was related to the fact that each time a component is bolted-on there requires to be a sealing mechanism, and thus an increased risk of failure.

The findings of Case B have particular implications on Research Question 2.1 (*How does design standardisation affect lead time performance?*). Case B provides evidence of modular approaches being made to the component design of the principal ‘pacer’, the valve block forging. In Case A, a single forging design had been developed for a ‘family’ of trees and was customised by varying degrees of machining. In this case, a modular tree design had been developed, with the use of wing blocks as a means of customisation. This, in turn had permitted an ability to stock this pacer. In Case B the stocking was undertaken on a speculative basis, with inventory-holding costs being borne by the manufacturer. Together with the evidence from Case A, this Case emphasises the importance of focusing the design standardisation effort on upstream ‘pacers’ and including the alternative approach of modular design of those components.

An alternative situation was shown in Case E where there is evidence that this company has not been pro-active in reducing its lead times, but rather has been influenced by the reduction of lead times of competitors in their market. Thus, whereas Case A could be regarded as a ‘leader’ in lead time reduction, case E exhibits more of the features of a ‘follower’. In reaction to this lead time pressure, Case E has “converged” on one design in order to achieve the lead times demanded by the market and uses the price mechanism to attract customers to opt for this model.

The individual Cases led to the development of the following propositions:

Proposition 1.1a: *That design standardisation/modularization leads to an ability to influence lead time improvement through the strategic stocking of pacing components.*

Proposition 1.2a: *That in certain market situations, manufacturers may choose to produce a lower-priced commodity product as an alternative to an engineered-to-order product as a response to follower pressure on lead times.*

11.1.3 Triangulation from Cross-Case Comparisons

The Case Research was triangulated within the Complex Assembled Products environment (Cases A, B and C) and the Less Complex Assembled Products environment (Cases D, E and F).

This final analysis of the Case Research compares the key aspects of the Complex Assembled Products Supply Environment (Wellhead Equipment Supply Chains in Cases A, B and C) with the Less Complex Assembled Products Supply Environment (Well Completion Equipment Supply Chains in Cases D, E and F). Where there is triangulation of data across the two case environments this is recorded as representative of the Capital Equipment Supply Chain.

Cases A and B recorded fairly similar levels of lead time performance, whilst Case C had a poorer performance, measured on lead time length and variability. There was considerable triangulation across cases for the reasons for short lead times that were perceived to be due to standardisation and the consequent ability to stock materials. Long lead time due to special exotic metals and variety created by different “interface requirements” (particularly the need to interface with legacy systems in ‘brown-field’ projects) were also recorded as influencing factors. All Cases recorded a reduction in lead time over the previous 2 years and Cases A and B attributed this to increased

standardisation, whilst Case C considered market reasons to be the main influencer. Case C thus seems to be partially deviant from Cases A and B. Customers indicated that Case C was a more sales-oriented organisation, whereas Case A was commented on as being more pro-active in its supply chain management. Case C, like Case E (in the Less Complex Products environment) thus may be more of a 'follower' than a 'leader' in supply chain lead time improvement.

Average lead time performance was, as would be expected, substantially higher in the Complex Products sub-environment compared to the Less Complex Products sub-environment (see Table 11.1). In Complex Products design standardisation contributing to the ability to stock primary pacing components was the main influencer of short lead time performance. There was a reasonable degree of triangulation on the length and variability of lead times in the Less Complex Products environment. Reasons for short lead times were special/exotic materials and customer variations. Lead time improvement in the previous 2 years was recorded by all Cases, but it was highly variable. In Less Complex Products, standardisation and repeatability were also important, but the upstream pacers were not as significant to lead time performance as in Complex Products.

Internal process was more significant in the Less Complex Products environment and there was evidence of a degree of agility in an ability to crash the manufacturing schedule for urgent orders. Reasons for long lead times were similar in both environments, particularly relating to extra engineering design time required for special products and the upstream supply problems of exotic materials. Exotics for Less Complex products were standard steel bar and tube, which were catered for in single-source stocking agreements in Cases D, E and F. This was more difficult in Complex Products where it was not only material type but also size and shape of forgings that were a variation factor. This tended to lead to a requirement to commit to a strategic stock of the primary pacer in Cases A and B.

	<i>Complex Assembled Products (Cases A, B & C)</i>	<i>Less Complex Assembled Products (Cases D, E & F)</i>
<i>Average Lead Times</i>	26 weeks	10 weeks
<i>Shortest Lead Times</i>	4 weeks	4 weeks
<i>Reasons for Short Lead Times</i>	[1] Standardisation [2] Ability to stock materials	[1] Repeat items [2] 'crashing' manufacturing schedule
<i>Longest Lead Times</i>	52 weeks +	20 weeks
<i>Reasons for Long Lead Times</i>	[1] Specials requiring R & D time [2] Exotic materials [3] Interface requirements	[1] Specials requiring engineering and testing [2] Exotic materials [3] Variations to orders
<i>Lead Time Variability</i>	269%	160%
<i>Lead Time Improvement (2 years)</i>	25 weeks 42% improvement	6-14 weeks
<i>Reasons for Lead Time Improvement</i>	Standardisation	Standardisation Competition

Table 11.1: Cross-case comparison of Lead Time Performance

In order to address Research Question No 1.1 (*How do design standardisation systems influence lead time performance?*) and Research Questions No 1.2, (*How do design standardisation attitudes influence lead time performance?*), the incidence of Design Standardisation influencing factors were mapped against the Cases (see Table 11.2). Those factors in which there was evidence of the factor being present are marked with a symbol "+" (score = 2), those factors where there is mixed evidence of presence are marked "+/-" (score = 1) and those factors for which there is no evidence are marked "0" (score = 0).

There was a high incidence of product standardisation as an influencing factor across the Cases (Score = 13). The incidence was higher in the Complex Products environment (Score = 10) and relatively low in the Less Complex Products environment (Score = 3). With regard to standardisation, Case F may be regarded as a deviant, as it was a smaller

organisation, dealing more commonly with innovative product solutions. As such it would be in the low-low quadrant of the Batreezzaghi (1994) taxonomy.

<i>Design Standardisation Systems</i>												
	<i>Case A</i>		<i>Case B</i>		<i>Case C</i>		<i>Case D</i>		<i>Case E</i>		<i>Case F</i>	
		<i>U/S</i>	<i>D/S</i>	<i>U/S</i>	<i>D/S</i>	<i>U/S</i>	<i>D/S</i>	<i>U/S</i>	<i>D/S</i>	<i>US</i>	<i>D/S</i>	<i>U/S</i>
Product Standardisation	+	+	+	+	+/-	+/-	+	0	+/-	0	0	0
Variety/Complexity Reduction Systems	+	0	+	0	0	0	+	0	+/-	0	0	0
Functional Specifications	+/-	0	+/-	0	+	0	+/-	0	0	0	0	0
<i>Design Standardisation Attitudes</i>												
	<i>Case A</i>		<i>Case B</i>		<i>Case C</i>		<i>Case D</i>		<i>Case E</i>		<i>Case F</i>	
		<i>U/S</i>	<i>D/S</i>	<i>U/S</i>	<i>D/S</i>	<i>U/S</i>	<i>D/S</i>	<i>U/S</i>	<i>D/S</i>	<i>US</i>	<i>D/S</i>	<i>U/S</i>
Proactive/interested	+	+	+/-	+	0	0	+/-	0	+	0	0	0
<i>D/S = Downstream; U/S = Upstream</i>												

Table 11.2: Incidence of Design Standardisation Factors mapped against Cases

There was a low incidence of the use of variety/complexity reduction systems (such as ‘where-used’ tracking, re-usability targets and %age reduction targets on part numbers). There was also a surprisingly low incidence of the use of Functional Specifications (rather than Technical Specifications). Secondary interviews with customers had indicated a substantial growth in the use of this mechanism, but from the manufacturer’s perspective there was “more talk than action” on this particular topic.

Mapping of attitudes to Design Standardisation recorded a higher level of interest and pro-activity in the Complex Products environment (Score =24) in comparison with the Less Complex Products environment (Score = 10). Within each supply environment there was a correlation between the incidence of design standardisation systems/attitudes and lead time performance. In the Complex Products environment, Case A recorded the highest score relative to the incidence of these influencing factors and this Case recorded

the best lead time performance. All other Cases profiled in a similar fashion, within each environment.

Proposition 1a *That design standardisation has a positive influence on lead time performance* is upheld on triangulation across the six cases and elaborated to Proposition 1.1b *That design standardisation/modularisation leads to an ability to influence lead time performance improvement through strategic stocking of pacer components* and was found to be upheld in Cases A, B and C where there is a low level of upstream interchangeability.

Cross-case triangulation of Proposition 1.1c: *That in supply environments with a relatively high level of raw material interchangeability, raw material stocking arrangements are a significant influencer of lead time performance* indicated that the proposition is upheld in Cases D, E and F where there was evidence of single-sourcing arrangements, although only Case D had developed to the extent of JIT II in-plant arrangements (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996).

Proposition 1.2a *That in certain market situations, manufacturers may choose to produce a lower-priced commodity product as an alternative to an engineered-to-order product as a response to follower pressure on lead times* is only fully upheld in Case E, thus cannot be fully upheld in the Engineer-to-order environment, but is interesting as a deviant case.

11.2 Research Question No 2

Are upstream (supplier) factors more important than (downstream) customer factors in influencing lead time performance improvement?

The Preliminary and Secondary Interviews within the Case Environment identified Capital Equipment as the key pacer in offshore projects. Respondents identified that one of the main reasons for the problematically long and variable lead time in this environment was the existence of upstream pacing components. The intuitive basis for this study was very much predicated on this idea of identifying the upstream pacers and finding out the reasons for their poor lead time performance. This followed an adaptation of the Berry (1994) approach in identifying constraints (Goldratt, 1990). In an engineer-to-order environment many of these were seen to be potentially capacity-related (Christopher, 1998).

11.2.1 Evidence from Survey Data

The *Supplier Survey* indicated the importance of the downstream customer in influencing lead time performance (see 9.3). Downstream customer influences related to on-time and unaltered specifications were ranked as more important than upstream supplier influences in the achievement of short lead times. Downstream influences on long lead times were the requirement for special rather than standard designs.

The supplier survey produced evidence of a difference in perception of customer service criteria at different tiers in the supply chain and also evidence of differences between the upstream and downstream influencing factors related to systems/structures and relationships/infrastructure. For Assemblers, downstream (customer) factors were ranked as marginally more important than upstream (supplier) factors in contributing to short lead times. The most important criteria were “on-time receipt of specification” and “customer specification not altered from time of order”. With regard to factors contributing to long lead times, downstream (customer) criteria were again ranked as most important: “special designs” was ranked as the most significant contributor to long lead times, followed by “delay in decisions on specifications” and “changes in customer specification” (see 9.3).

The following propositions were derived from the survey research:

Proposition 2a: *That influencing factors are perceived as different at different supply tiers in the supply chain.*

Proposition 2b: *That downstream (customer) factors are perceived in most cases as more important influencing factors than upstream (supplier) factors.*

Proposition 2c: *That downstream (Customer) factors are perceived in all cases as more important influencing factors on long lead times.*

11.2.2 Evidence from Individual Cases

The findings of Case A had particular implications for Research Question No 2. Case A bears out the importance of the upstream pacer to lead time performance. However, when perceptions of what influenced the primary, secondary and tertiary pacers were examined, the importance of the downstream customer was highlighted as significant. Those customers for whom the greatest lead time improvement was recorded were those that had engaged Case A in long-term trading agreements. This in turn had permitted Case A to develop similar long-term, single-sourcing arrangements with upstream suppliers. These arrangements were shown, in further investigation, to lead to substantial improvements in lead time performance.

The findings of Case D also had particular implications for addressing Research Question No 2, which indicated that the nature of the supply environment requires to be taken into account when considering this research question. Case D exhibits an ability to “crash” the manufacturing schedule where urgent orders are required. This indicates that lead times are less constrained by upstream ‘pacers’ in this Case. This Case is contained within the Less Complex Products environment. This has been noted as higher in object interchangeability with regard to upstream materials and with a higher degree of process steadiness.

This led to Proposition 2d: *That is supply chains not constrained by upstream pacer components, internal process time will be a more significant influencing factor on lead time performance being refined to Proposition 2e: That in supply chains with high level of upstream interchangeability not constrained by upstream pacer components, manufacturing schedules can be 'crashed' in an urgent case.*

11.2.3 Triangulation from Cross-Case Comparison

The cross-case comparison in the Complex Products environment exhibited 7 reasons extracted from triangulated responses of reasons for short lead times, and of these only one related to an upstream (supplier) issue (i.e. “forgings in stock”). However, as noted above in Cases A and B this stock situation was only permitted due to the customer accepting a standardised component (see 10.5.1). When reasons for long lead times are examined, of 7 reasons for long lead times only one (“steel supply”) related to upstream.

Improvements in lead times were seen as due to customer influences in 4 of the 6 Cases. Cases C and E, already identified as somewhat deviant from the general pattern, saw market forces as the influence. This again indicated that these cases were followers and reacting to lead time improvements rather than pro-actively seeking to influence lead time performance improvement.

Thus two findings have emerged. Firstly, that although pacers are highly important in the Complex Products environment, they are considerably less so in the case of Less Complex Products. This means that upstream supply chain improvement requires a close understanding of the differentiation of product/manufacturing environments. Secondly, the influence of the downstream customer on the improvement of lead times was severely underestimated.

Cross-case triangulation of Proposition 2a: *That downstream (customer) factors are perceived in most cases as more important influencing factors than upstream (supplier) factors* provided evidence that this proposition was upheld across all cases.

Cross-case triangulation of Proposition 2c: *That in Supply Chains with a high level of upstream interchangability not constrained by upstream pacer components, manufacturing schedules can be 'crashed' in an urgent case* showed this upheld in Cases D, E and F and is thus related to the high upstream material interchangability environment.

11.3 Research Question No 3

How do supply chain systems and structures influence lead time performance?

11.3.1 Evidence from Survey Data

The *Supplier Survey* revealed that communication systems and structures tended to be related to delivery and supplier performance rather than sharing of information on costs or advanced warning of orders.

The *Customer Survey* provided evidence of customers' internal supply chain showing integration features such as growth of cross-functionality and the use of integrated supply chain information systems. Whereas supply chain visibility was technically possible, evidence of positive attitudes to the sharing of information was more sparse.

The *Customer Survey* provided evidence that customers see drivers for supply chain integration being present in their own corporate culture, in industry initiatives such as CRINE and in the economic atmosphere within the industry. Accountancy systems,

particularly related to the requirements of investing partners were seen as the main obstacle to integration.

With regard to Research Question No 3 the survey only examined the nature of communication systems and structures in order to inform the case research phase (see 9.4). The results indicate the highest level of disagreement on both upstream and downstream communication related to the use of team meetings and providing information on costs. This information provides some indication of communications systems and culture problems in the capital equipment supply chain which require further investigation within the case research phase.

11.3.2 Evidence from Individual Cases

With regard to Research Question No 3 (*How do supply chain systems and structures influence lead time performance?*) Case C provides some elaboration on the survey research, in this Case although long-term, frame-type agreements were in place with downstream customers, there was little evidence that this had resulted in standardisation of product. There was some evidence that the missing factor in this Case was the lack of development of multi-functional teams between the manufacturer and the customer. There was still an upstream reaction to reducing the principal 'pacing' component, but in Case C this was limited to the booking of forging capacity, rather than either stocking of the 'pacer' or ensuring a regular flow of a standard component. This leads to the derivation of the following propositions:

Proposition No 3a: *That multi-functional customer-supplier team-based communication systems influence lead time performance improvement is upheld in cross-case triangulation across all six Cases.*

With regard to Research Question No 3.1 (*How do information communication systems influence lead time performance?*), Case D findings concur with other Cases in the contribution of multi-functional customer-supplier team-based communication. In this

Case the system is called a Product Action Team. However, there is a significant variant with regard to communication with the upstream pacer supplier of metal. In this Case a single-source supply arrangement has led to the establishment of a JIT II in-plant representative (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996). Thus although there are significant variety issues still obvious in metal supply, in this Case it is more standardised dimensional form in terms of bar or tube. The special design requirement thus does not extend to the manufacture of the component, as in the case of the forging in Cases A, B and C. The metal thus only becomes customised when it is cut to length. This leads to the development of the following proposition:

Proposition No 3.1a: *That in supply chains with significant flows of standardised raw materials JIT II in-plant representatives can influence lead time performance.*

11.4 Research Question No 4

How do supply chain relationships and infrastructure influence lead time performance?

11.4.1 Evidence from Survey Data

Supply chain relationship types were profiled relative to the Sako (1992) ACR/OCR types (see 9.5). Downstream relationships recorded an OCR score of 15% for Assemblers, but this was translated to a 17% ACR score upstream. This leads to the following propositions:

Proposition 4a: *That obligational (OCR-type) supply chain relationships alone may not influence lead time performance.*

Proposition No 4b: *That obligational (OCR-type) supply chain relationships downstream in a supply chain do not necessarily translate to the same form upstream.*

11.4.2 Evidence from Individual Cases

With regard to Research Question 4 (*How do supply chain relationships influence lead time performance?*) the survey provides no clear evidence of a relationship between OCR-type relationships and lead time performance. In retrospect, it may have been possible to measure an effect if a better measure had been made of lead time improvement. Another interpretation worthy of further testing is that OCR-type relations alone cannot influence lead time improvements.

The findings of Case F have particular implications for Research Question No 4 (*How do supply chain relationships and infrastructure influence lead time performance?*). Case F is a smaller locally-owned company in comparison with the other Cases that are all major multi-nationals. In Case F there was significant evidence of more informal arrangements with upstream pacer suppliers. Contract arrangements with these suppliers tended to be non-existent, but there was evidence of close co-operation and sharing of resources and expertise. Thus these arrangements profiled most closely with the Case A single-source arrangements with upstream pacer suppliers, but in Case A the contracts were more formal. Although, Case F was a relatively small organisation for this environment, these informal arrangements were with even smaller proprietor-owned SME's. This leads to the following proposition:

Proposition No 4c: *That collaborative relationships based on informal styles may contribute to lead time performance improvement.*

11.5 Research Questions 3 and 4: Triangulation from Cross-case Comparison

The triangulation of data for Research Questions 3 and 4 shall be undertaken together in order to investigate the interaction between the systems/structural aspects and the relationships/infrastructural aspects

Research Question No 3.1

How do information communication systems influence lead time performance?

Research Question No 3.2

How do contract structures influence lead time performance?

Research Question No 4.1

How does information communications culture influence lead time performance?

Research Questions No 4.2

How do contract relationships influence lead time performance?

11.5.1 Influence of Design Standardisation Systems and Attitudes

In the upstream supply chain there was no real evidence of variety reduction techniques in either supply environment (see Table 11.3). Standardisation of componentry, such as the main block forging was, however, a significant influencer of lead time performance. There was more evidence in Complex Products of pro-active supply chain improvement upstream, with the use of single sourcing and OCR-type arrangements with Case A being the most advanced. In Less Complex Products there were examples of single sourcing only in the case of steel supply. Manufacturers used variety reduction techniques in some cases in both environments.

There was more evidence of standardisation and modularisation in the Complex Products than in Less Complex Products. This is the opposite from what would be expected. It is possible that because Complex Products impact more significantly on offshore projects from a lead time standpoint, that engineers have been forced to consider more standard solutions. In Less Complex Products, where upstream component lead times are less significant, there is still enough slack in the project schedule to accommodate design time. Downstream supply chain systems and attitudes saw more significant use of functional specifications in Complex Products. In both environments there was still considerable use of technical variations.

	<i>Complex Assembled Products (Cases A, B & C)</i>	<i>Less Complex Assembled Products (Cases D, E & F)</i>
UPSTREAM SUPPLY CHAIN	[1] No use of functional specifications or complexity reduction techniques. [2] Standardisation of main valve block forging.	No use of functional specifications or complexity reduction techniques.
	[1] Use of complexity reduction techniques in some cases. [2] Evidence of standardisation and modularisation.	[1] Use of complexity reduction techniques in some cases. [2] Rather mixed picture on standardisation, but some component standardisation evidenced.
DOWNSTREAM SUPPLY CHAIN	[1] Increased use of functional specifications. [2] Acceptance of more standard products in some cases, but still considerable technical variations.	[1] Many customers not interested in product standardisation. [2] Many pay 'lip service' to standardisation.

Table 11.3: Cross-case comparison of Design Standardisation Systems and Attitudes

11.5.2 Influence of Communication Structures and Attitudes

Upstream, there was greater evidence of formal feedback structures in the Complex Products compared to Less Complex Products (see Table 11.4). In both supply environments there was a lack of sharing of information that had the potential to influence lead time performance.

Downstream information communication structures and culture also provided evidence of problems with information-sharing. Multi-functional team structures were more in evidence in the Complex Products environment with positive examples of Early Supplier Involvement and Ongoing Supplier Involvement. This was more poorly developed in the Less Complex Products environment.

	<i>Complex Assembled Products (Cases A, B & C)</i>	<i>Less Complex Assembled Products (Cases D, E & F)</i>
UPSTREAM SUPPLY CHAIN	[1] Some evidence of formal feedback structures. [2] No significant information sharing	[1] No real feedback structures. [2] No information sharing.
DOWNSTREAM SUPPLY CHAIN	[1] Problems with internal information-sharing and communication between projects. [2] ESI and OSI with multi-functional teams. [3] Some information-sharing, but at too broad a level to be of any real use.	[1] Some ESI, but a mixed picture on OSI. [2] Barriers of contractors and sales engineers highlighted. [3] Low development of multi-functional teams.

Table 11.4: Cross-case Comparison of Information Communications Structures and Culture

The evidence for influencing factors was mapped across the six cases in order to identify common influencers in comparison to those influencers for which there was no evidence (see Table 11.5). Those factors in which there was evidence of the factor being present are marked with a symbol “+” (score = 2), those factors where there is mixed evidence of presence are marked “+/-” (score = 1) and those factors for which there is no evidence are marked “0” (score = 0).

The cases with the best lead time performance in the Complex Products environment (Case A) and in the Less Complex Products environment (Case D) were also those cases that had the highest scores for the incidence of these influencing factors (Case A Score = 12; Case D Score = 5). In the Less Complex Products environment the incidence of these factors in Cases E and F was very low. In the Complex Products environment Case C had a higher score (Score = 8) compared to Case B (Score = 6) and this related to more upstream feedback and information-sharing.

<i>Information Communications Structures</i>												
	<i>Case A</i>		<i>Case B</i>		<i>Case C</i>		<i>Case D</i>		<i>Case E</i>		<i>Case F</i>	
		U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	US	D/S	U/S
Feedback arrangements	+	+	+	0	+	+	+/-	+/-	+/-	0	+/-	0
Multi-functional teams	+	+	+	0	0	0	+/-	0	0	0	0	0
Direct Access to plans/forecasts	+/-	+/-	+/-	+/-	+/-	+	0	+/-	0	0	0	0
<i>Information Communication Culture</i>												
	<i>Case A</i>		<i>Case B</i>		<i>Case C</i>		<i>Case D</i>		<i>Case E</i>		<i>Case F</i>	
		U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	US	D/S	U/S
Positive/open culture to sharing information	+/-	+/-	0	0	0	+/-	0	+/-	0	0	0	0
<i>D/S = Downstream; U/S = Upstream</i>												

Table 11.5: Influencing Factors of Information Communications Structure and Culture mapped across Cases

11.5.3 Influence of Contract Structures and Relationships

The upstream supply chain exhibited a considerable degree of multi-sourcing in most cases in both supply environments (see Table 11.6). In Case A there was more evidence of pro-active supply chain improvement, based on single-sourcing arrangements with suppliers. Single-sourcing also existed in Cases D and E, but only related to stockists of metal raw material.

	<i>Complex Assembled Products (Cases A, B & C)</i>	<i>Less Complex Assembled Products (Cases D, E & F)</i>
<i>UPSTREAM SUPPLY CHAIN</i>	[1] Clearly ACR-type relationships. [2] Multi-sourcing.	[1] Informal contract arrangements. [2] Single sourcing for steel but multi-sourcing for elastomers.
<i>DOWNSTREAM SUPPLY CHAIN</i>	[1] More evidence of OCR-type relationships. [2] Use of 'frame-type' long-term contracts.	[1] Many contracts still standard ACR-type. [2] Some long-term contracts and frame-type agreements.

Table 11.6: Cross-case Comparison of Contract Structures and Relationships

There was evidence of downstream OCR-type arrangements in both supply environments, including the use of frame-type contracts and these had influenced improved lead time performance. There was still, however, considerable ACR-type contract types and relationships for certain customers and this was more prevalent in the Less Complex Products environment.

The evidence for influencing factors was mapped across the six cases in order to identify common influencers in comparison to those influencers for which there was no evidence (see Table 11.7). Those factors in which there was evidence of the factor being present are marked with a symbol "+" (Score = 2), those factors where there is mixed evidence of presence are marked "+/-" (Score = 1) and those factors for which there is no evidence are marked "0" (Score = 0).

Case A had the highest incidence score (Score = 8) in the Complex Products environment, whilst Case D had the same score in the Less Complex Products environment. Cases A, B and C show a correlation between the incidence of these influencing factors and their lead time performance. Case E showed the lowest factor score (Score = 2), whilst Case F recorded a higher incidence of these influencing factors (Score = 5), possibly due to its informal business style.

Contract Structures												
	Case A		Case B		Case C		Case D		Case E		Case F	
		U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	US	D/S	U/S
Long-term 'Frame-type' Contracts	+	0	+	0	+/-	0	0	0	+/-	0	+/-	0
Early Supplier Involvement	+/-	0	+/-	0	+/-	0	+	+/-	0	0	+/-	0
Ongoing Supplier Involvement	+/-	0	+/-	0	+/-	0	+	+/-	0	0	+/-	0
Contract Relationships												
	Case A		Case B		Case C		Case D		Case E		Case F	
		U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	US	D/S	U/S
Obligational-type	+	+	+/-	0	+/-	0	+	0	+/-	0	+/-	+/-
<i>D/S = Downstream; U/S = Upstream</i>												

Table 11.7: Influencing Factors of Contract Structures and Relationships mapped across Cases

Across all categories of influencing factors the ranked order of influencing factor incidence is: "Feedback Arrangements" (Score = 14); "Product Standardisation" (Score = 13); "Obligational-type Relationships" (Score = 11); "Early Supplier Involvement" (Score = 9); "Direct Access to Plans/Forecasts" (Score = 8); "Long-term 'Frame-type' Contracts", "Ongoing Supplier Involvement", "Multi-functional Teams," "Variety/Complexity Reduction Systems" (Scores = 7); "Functional Specifications" (Score = 5); "Positive/open culture to Sharing Information" (Score = 4).

In the Complex Products Supply Environment, "Product Standardisation" and "Feedback Arrangements" have the strongest Scores (Scores = 10), followed by "Proactive/interested in Design Standardisation" and "Direct Access to plans/Forecasts" (Scores = 7). The latter category should be treated with caution, as many respondents commented that although they had access, the information was too general to be of any real use in improving lead time performance. The Less Complex Products Supply Environment had significantly lower evidence of influencing factors (Overall Score = 33 cf. Complex Products Score = 68).

There is also a significant difference between upstream and downstream Scores. The downstream supply chain has a much higher incidence of influencing factors (Score = 72), compared to upstream (Score = 30). The difference is even more marked in the Less Complex Products supply environment (Downstream Score = 27; Upstream Score = 7) in comparison to the Complex Products supply environment (Downstream Score = 45; Upstream Score = 23).

Proposition 3a: *That multi-functional customer-supplier team-based communication systems influence lead time performance improvement* was upheld in cross-case comparison.

Proposition No 4a: *That obligational (OCR-type) supply chain relationships downstream in a supply chain do not necessarily translate to the same form upstream* was upheld across the Cases and leads to Proposition 4c.

Proposition No 4c: *That collaborative relationships based on informal styles may contribute to lead time performance improvement* was upheld only in Case F and is thus regarded as a deviant.

The understanding from cross-case comparison of the importance of the interaction between systems/structure and relationships/infrastructure led to the development of Proposition 4c: *That communication structures based on multi-functional customer supplier teams will foster an obligational (OCR-type) communications culture that will influence lead time performance* which was upheld across all the Cases.

11.6 Synthesis of Influencing Factors on Lead Time Performance

The evidence for the perception of respondents of the impact of the identified influencing factors on lead time performance was mapped across the six cases in order to identify

those influencing factors perceived as influencing lead times in the capital equipment supply environment (see Table 11.8). The categories are referenced against the question numbers in the interview guide (see Appendix D).

Where the Case respondents indicated a positive impact on lead time performance, this is marked “++” (Score = 2); where there is a minor impact this is marked “+” (Score = 1); where no impact was indicated this is marked “0” (Score = 0); where an approach is not used this is marked “N”; where the impact is not known or not measured this is marked “N/K”.

In Table 11.8 the impact factors have been ranked in descending order of impact score. “Design Standardisation” was perceived most widely as having an impact on lead time performance (Score = 10), followed by “Obligational Contract Terms” (Score = 7). “Downstream Early Supplier Involvement” (ESI) was perceived as having the next most

<i>Impact Factor</i>	<i>Case A</i>	<i>Case B</i>	<i>Case C</i>	<i>Case D</i>	<i>Case E</i>	<i>Case F</i>	<i>Score</i>
Standardisation [Q 42]	++	++	++	++	++	0	10
Obligational Contract Terms [Q73]	N/K	+	++	0	++	++	7
Downstream Early Supplier Involvement [Q 76]	+	++	++	+	N	N	6
Communications Feedback [Q62]	++	N	++	+	N	N	5
Access to production plans/forecasts [Q65]	N	N	++	++	0	+	5
Upstream Early Supplier Involvement [Q 79]	++	N	0	+	N	N	3
Functional Specifications [Q 50]	+	0	+	0	0	0	2
Variety/Complexity Reduction Systems [Q55]	0	0	N/K	0	0	N	0

Table 11.8: Perceptions of Respondents of Impact of Influence factors across Cases

significant impact, which scored considerably higher than “Upstream Supplier Involvement”. Lower scores are affected by the Cases that do not use these approaches (marked “N”). The N scores are highest for “Communications Feedback” and “Upstream

Early Supplier Involvement” (3 out of 4 Cases do not use these approaches) and next highest for “Access to Production Plans/Forecasts” and “Downstream Early Supplier Involvement” (2 out of 6 Cases do not use these approaches). Lack of use of the approaches is more marked in the Less Complex Products Environment (Cases D, E and F) with an N score of 7. In particular, “Downstream/Upstream Early Supplier Involvement” and “Communication Feedback” are only used in one Case in this environment.

The factor that records the most frequent incidence of ‘no impact’ is “Variety/Complexity Reduction Systems” (0 = 4). The Case narratives show, however, that these techniques are generally not being used pro-actively within the Case organisations.

Perhaps surprisingly, “Functional Specifications” are not seen by 4 of the Cases as providing an impact on lead times. The Case narratives reveal, however, that Functional Specifications have led to increased standardisation, particularly of pacer components and consequently to impact on improved lead time performance. Thus the impact of this factor is of an indirect nature and it is possible that certain respondents may not have perceived this indirect impact or not seen it as relevant. The Less Complex Product environment has a higher incidence of ‘no impact’ (0 = 8), compared to the Complex Products environment (0 = 4).

11.7 Summary of Research Questions and related Propositions

The following is a summary of the propositions derived from addressing the research questions:

Research Question No 1

Proposition 1a: *That design standardisation has a positive influence on lead time performance.*

Proposition 1.1a: *That design standardisation/modularization leads to an ability to influence lead time improvement through the strategic stocking of pacing components.*

Proposition 1.1b *That design standardisation/modularisation leads to an ability to influence lead time performance improvement through strategic stocking of pacer components.*

Proposition 1.1c: *That in supply environments with a relatively high level of raw material interchangeability, raw material stocking arrangements are a significant influencer of lead time performance.*

Proposition 1.2a *That in certain market situations, manufacturers may choose to produce a lower-priced commodity product as an alternative to an engineered-to-order product as a response to follower pressure on lead times.*

Research Question No 2

Proposition 2a: *That influencing factors are perceived as different at different supply tiers in the supply chain.*

Proposition 2b: *That downstream (customer) factors are perceived in most cases as more important influencing factors than upstream (supplier) factors.*

Proposition 2c: *That downstream (Customer) factors are perceived in all cases as more important influencing factors on long lead times refined to Proposition 2e: That in Supply Chains with a high level of upstream interchangeability not constrained by upstream pacer components, manufacturing schedules can be 'crashed' in an urgent case*

Proposition 2d: *That is supply chains not constrained by upstream pacer components, internal process time will be a more significant influencing factor on lead time performance* being refined to Proposition 2f: *That in supply chains with high level of upstream interchangeability not constrained by upstream pacer components, manufacturing schedules can be 'crashed' in an urgent case.*

Research Question No 3

Proposition No 3a: *That multi-functional customer-supplier team-based communication systems influence lead time performance improvement*

Proposition No 3.1a: *That in supply chains with significant flows of standardised raw materials JIT II in-plant representatives can influence lead time performance.* (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996).

Research Question No 4

Proposition 4a: *That obligational (OCR-type) supply chain relationships alone may not influence lead time performance.*

Proposition No 4b: *That obligational (OCR-type) supply chain relationships downstream in a supply chain do not necessarily translate to the same form upstream.*

Proposition No 4c: *That collaborative relationships based on informal styles may contribute to lead time performance improvement.*

Proposition 4d: *That communication structures based on multi-functional customer supplier teams will foster an obligational (OCR-type) communications culture that will influence lead time performance.*

11.8 Perceptions of Influencing Factors on Lead Time Performance

The evidence for the perception of respondents of the impact of the identified influencing factors on lead time performance was mapped across the six cases in order to identify those influencing factors perceived as influencing lead times in the capital equipment supply environment. “Design Standardisation” was perceived most widely as having an impact on lead time performance, followed by “Obligational Contract Terms”. “Downstream Early Supplier Involvement” (ESI) was perceived as having the next highest impact, which scored considerably higher than “Upstream Supplier Involvement”. There was a low use of approaches to influence lead time performance in some Cases. Lowest use of influencers was for “Communications Feedback” and “Upstream Early Supplier Involvement” (3 out of 4 Cases do not use these approaches) and next lowest for “Access to Production Plans/Forecasts” and “Downstream Early Supplier Involvement” (2 out of 6 cases do not use these approaches). Lack of use of the approaches is more marked in the Less Complex Products environment (Cases D, E and F). In particular, “Downstream/Upstream Early Supplier Involvement” and “Communication Feedback” are only used in one Case in this environment.

The factor that records the most frequent incidence of ‘no impact’ is “Variety/Complexity Reduction Systems” (0 = 5). The Case narratives show, however, that these techniques are generally not being used pro-actively within the Case organisations.

Perhaps surprisingly, “Functional Specifications” are not seen by 4 of the Cases as providing an impact on lead times. The Case narratives reveal, however, that Functional Specifications have had an indirect influence on lead time performance though the approach fostering increased standardisation, particularly of pacer components. The Less

Complex Product environment has a higher incidence of ‘no impact’ of this influencing factor, compared to the Complex Products environment .

12 CONCLUSIONS

12.1 Influencing Factors on Lead Time Performance

Research Question No 1

How does the Design-to-order nature of the Capital Equipment supply environment influence lead time performance?

The propositions derived from the study contribute to the literature in Supply Chain Management by providing an analysis of the influencing factors on lead time performance in this particular type of supply chain. The analysis and results are discussed in relation to literature up to 1999. The further implications of literature in 2000 is discussed in 12.5 below and the importance of this type of study to the understanding of supply chains has been highlighted in current literature (Lamming, 2000; Cox, 1999). The research contributes to comparative understanding by adding to case studies already undertaken in other sectors of design/make-to-order type businesses (Meijboom, 1999 [make-to-order clothing]; Berry et al, 1994 [electronics]). It also provides an illuminating comparison to the vast range of literature based on repetitive industries, particularly the large research base in the automotive sector (Lamming, 1993; Womack et al, 1990; Hines, 1994b). The research has provided a first step towards an outline type classification (by adaptation of the Bartezzaghi, 1994 taxonomy) of supply chains in capital equipment manufacture (producers of industrial products broadly classified as being within the engineering industry by Sweeney and Szwejczewski, 1996).

Where there is a requirement for design/engineer-to-order, it has been found that a key differentiator in determining the factors that influence lead time performance, is the extent of “object specificity” (Babu, 1999). This supply environment, which tends towards “new product development models” rather than “production-type models” (Battacharya, 1999) has led to consideration of the use of Concurrent Engineering (CE)

practice as a key contributor to lead times through flexibility or agility (Jayaram et al, 1999; Kumar et al, 1995; Ahmed et al, 1996). This study has not attempted to look in detail at the adaptation of CE to the order cycle, although this is clearly an area for further detailed research. Instead, this study contributes by taking a wider supply chain view of influencing factors. The propositions thus derived from Research Question No 1 contribute to understanding that where there is a low level of material interchangeability related to upstream pacers, these pacers shall be key influencers of lead time performance. In order to improve lead time performance, priority should be given to approaches to standardise and/or modularise the designs for these components (Proposition 1a). This permits lead time performance through the strategic stocking of these pacing components (Proposition 1b). On the other hand, where upstream material interchangeability is high, raw material stocking arrangements will be a more significant influencer (Proposition 1c).

Research Question No 2

Are upstream (supplier) factors more important than (downstream) customer factors in influencing lead time performance improvement?

There has been a tendency for supply chain studies to centre on one dyadic relationship (Harland, 1996) and this study provides a contribution in looking at the supply chain both downstream (towards the customer) and upstream (towards the supplier) of capital equipment manufacturers. Intuitively, the research was originally predicated on views gleaned from preliminary interviews that centred on the importance of constraints in upstream supply as the key influencing factor. Firstly, where there is low material interchangeability this is still the case, but the research provides a contribution that identifies some differentiation, even within this design/engineer-to-order sector. This is elaborated further in 12.2 below. Secondly, this study provides a contribution in providing evidence of the importance of downstream (customer) influences on lead time performance (Proposition 2a). These influences are further synthesised in Research

Questions 3 and 4 below. Thirdly, where there is low object interchangeability there was more opportunity to “crash” manufacturing schedules to provide improved lead time performance in an urgent case (Proposition 2b).

Research Questions Nos. 3 and 4

How do supply chain systems and structures influence lead time performance?

How do supply chain relationships and infrastructure influence lead time performance?

As the further cases were written up and the case analysis developed, it became clear that systems/structure and relationships/infrastructure could not be seen in isolation, but that there was an important interaction between the two. The existence of broad trading frameworks (Frame-type contracts) were initially established in the industry sector under study to alleviate the problems with internal delays due to investment-partner decision-making and the advertising requirements of EC Procurement Legislation. However, this study has provided a managerial contribution in identifying the importance of these structures to permitting lead time performance improvement in the supply chain (Proposition 3a). Where these structures had led to multi-functional customer-supplier teams, there was evidence of a more pro-active approach to standardisation developing (Proposition 3b). The mutual benefits of shorter and more reliable lead times became more evident and there was a move away from “silo-type” attitudes. In turn, these structures led to more obligational (OCR-type) relationships developing.

A contribution to supply chain literature (Sako, 1992) is made in the finding that obligational (OCR-type) relationships and broad trading frameworks established downstream, do not necessarily translate into the same form upstream (Proposition 4a). Case A was a positive deviant where translation did take place and long-term, single-sourced contracts led to obligational relationships with key upstream suppliers. This in turn led to systematic pro-active efforts to identify and reduce the impact of upstream pacers. A further deviant Case F, provided a contribution in understanding the importance of informal styles and relationships as an alternative style for smaller

organisations (Proposition 4b). These findings provide a contribution to the literature on trust and power in supply chains, which is worthy of further detailed research.

12.2 Implications of Findings on Supply Chain Classification

The findings of this study contribute to supply chain literature in providing some tentative evidence of the generic nature of a particular type of supply chain, that of Capital Equipment supply within the particular case environment of the offshore oil exploration and production industry on the UK Continental Shelf. The extent to which these results can be generalised to other supply environments, can only be validated based on further comparative research within other supply environments. The importance of identification of generic supply chain types has been highlighted by Lamming (2000) and Cox (1999) and this study contributes in a small way to the building of such a classification.

The nature of the supply environment under study is of the Design/Engineer-to-order and thus provides information about the nature of a less repetitive supply chain type. The Bartrezzaghi et al (1994) Process Taxonomy for Lead-time modelling has been found to be useful in explaining the difference between the Cases in this study. On the basis of the study findings an amended model is proposed (see Fig 12.1). The variable of “object interchangeability” is adapted to “upstream interchangeability”, the extent to which upstream pacer components are interchangeable.

In the Complex Products environment (Cases A, B and C) the extent of interchangeability of components from one order to another was low due to the individual design configuration of the components with regard to specific shape/geometry (e.g. the valve block forging). This quadrant with relatively high downstream standardisation, but low

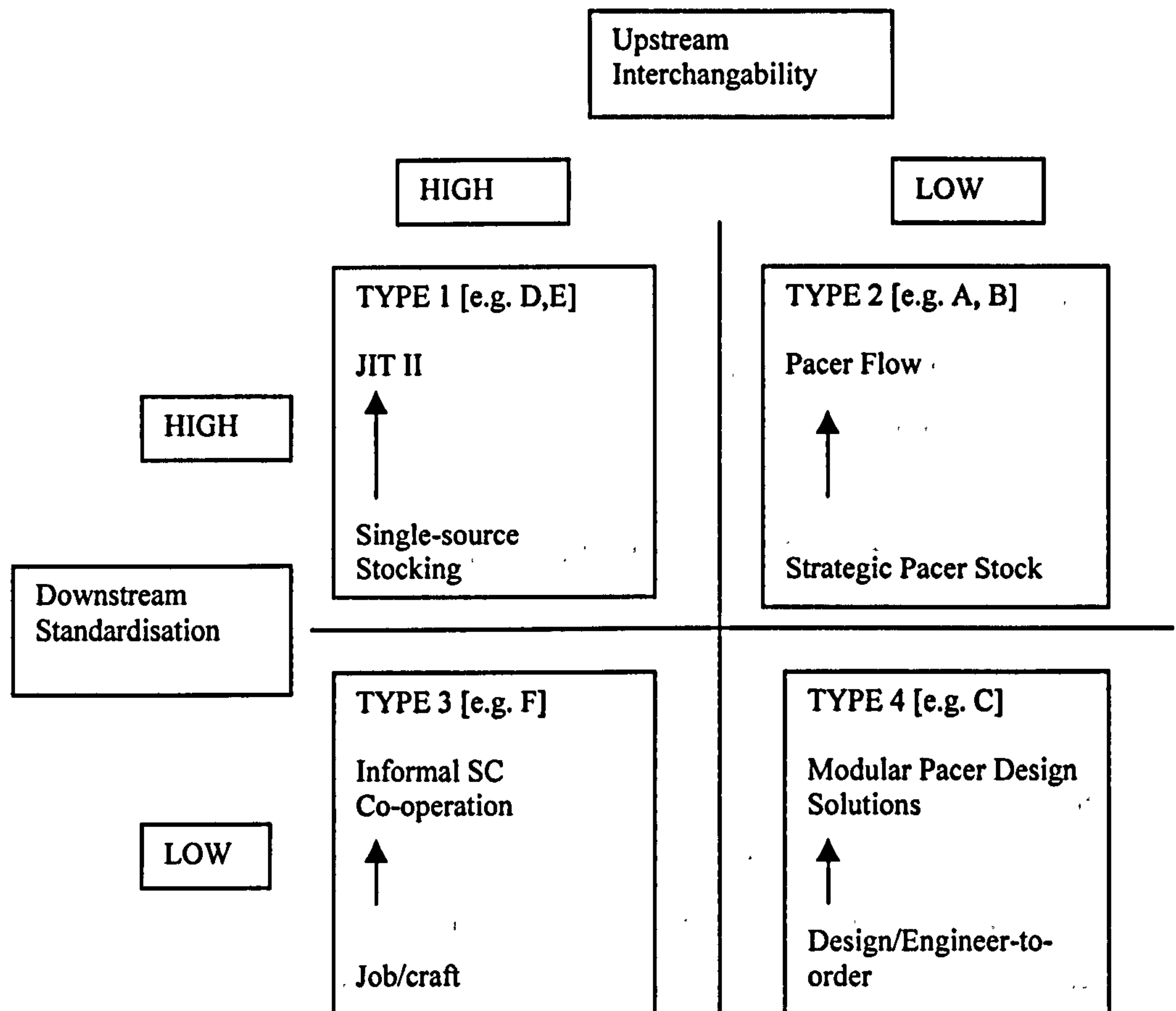


Fig 12.1 Types Classification Model of Capital Equipment Supply Chains

upstream interchangeability is defined as Type 2. The importance of the downstream (customer) influences on lead time performance has been a significant finding in this study. Where the customer has engaged in long-term contracts, used functional specification and engaged in multi-functional team-based communication, this has permitted manufacturers to engage in standardisation of upstream pacers. This has improved lead time performance due to an ability to undertake a strategic stocking arrangement for these pacing components. Where the downstream standardisation becomes higher, it is then possible to convert this stocking arrangement into a 'kanban-type' flow of components. Once this stage is reached it is possible for the manufacturer to

systematically remove constraints in the upstream supply chain, through the use of single-source supply contracts and obligational supply relationships with upstream suppliers, as was the situation in Case A.

In the Less Complex Products environment, there was still differentiation in metal type, but more standard dimensional configurations were possible (tube and bar). This permitted the possibility of single-source type stocking arrangements and in Case D a JIT II in-plant arrangement had developed. This quadrant (Type 1), with high upstream interchangeability and high downstream standardisation profiles most closely with a repeatable, make-to-stock environment. In Case E there had been a decision to standardise on a particular product design and promote this through selling at a lower price and in this case the supply chain would no longer be categorised as Engineer-to-order. Accepting that this was a special case even within Case E, in the normal Engineer-to-order environment, there will be differing levels of standardisation from the downstream customer. Adaptation of Concurrent Engineering (CE) practices to reduce design lead times will be more significant in this quadrant. In addition, internal influences on lead times are more significant than external constraints upstream and it is possible in this type to “crash” the production schedule to reduce lead times in an urgent case.

Type 4 has a lower relative extent of downstream standardisation than in Type 2, along with low upstream interchangeability. Due to the lack of design standardisation, particularly related to upstream pacers, it is more difficult to remove these constraints. Where there are long-term contracts, it is possible that the volume information related to these contracts can permit the booking of capacity at upstream pacer suppliers. This will have an impact on lead times, but improvements are unlikely to be as great as in Type 2. Type 4 supply chains are likely to have the poorest lead time performance. This is the problem quadrant and organisations in Type 4 require to work with downstream customers to move up to Type 2.

Type 3 has low downstream standardisation, but relatively high upstream interchangeability. This quadrant profiles most closely with job/craft type processes,

with a high degree of specialisation of product using relatively interchangeable, standard materials. Case F profiled with this type. Case F was a smaller organisation and saw much of its competitive advantage in its innovative design solutions. Improvement in lead time performance in this environment was achieved in this environment using a much more informal style within the supply chain. Close relations were evident with pacer suppliers, usually smaller than the manufacturer and facilities and information were freely shared in an atmosphere of mutual trust and co-operation.

12.3 Development of a Time-based Process Improvement Model for a Capital Equipment Supply Chain

Based on the Propositions in 12.1 and the Type Classification in 12.2, a Time-based Process Improvement Model has been derived (see Fig 12.2). Clearly the model has an empirical basis in the Capital Equipment environment, but its principles may be transferable to other engineer-to-order type environments and used to contrast with models in more repeatable make-to-stock type environments. The model thus provides a potential managerial contribution to the sector under study and provides an approach for further validation in other similar environment. The model has 4 steps as follows:

12.3.1 Step 1: Profile Supply Chain Type

Having established the above classification model, it is then possible to define the key influencers of lead time performance related to the different types, as defined above.

Type 1

Long-term contract structures and the use of functional specifications are more likely to lead to a pro-active attitude to standardisation. This is more likely to be achieved within the communications structure of the cross-functional customer-supplier team. As this supply chain type has a higher degree of upstream interchangeability, it is more important to focus on the downstream supply chain. Lead time improvements are more likely to be achieved by improvement of internal processes at the manufacturer and at the design

stage. Adaptations of Concurrent Engineering (CE) practices have potential to improve lead time performance, along with a pro-active attitude to design change minimisation. Stocking arrangements with pacer suppliers should be considered, with possible use of single-source stocking arrangements, consignment stocks or JIT II in-plant representatives (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996).

Type 2

As in Type 1, long-term contract structures and the use of functional specifications, are more likely to lead to a pro-active attitude to standardisation. This is more likely to be achieved within the communications structure of the cross-functional customer-supplier team. Lead time improvements are more likely to be achieved by standardised solutions to upstream pacing components or the use of modular approaches. Techniques such as "where-used" statistics or "%age reduction" targets to reduce component variety contribute to these solutions. Techniques such as pacer standardisation will permit lead time performance improvement through stocking of pacers. Where these downstream arrangements lead to more significant flows of more standardised orders, it is possible for this strategic stocking arrangement to be converted to a 'kanban-type' flow. The systematic removal of upstream pacing constraints is the key to lead time improvement in this environment. This improvement is more likely to be achieved where there are single-source arrangements for upstream pacers. Here a next tier level of customer-supplier multi-functional team permits encouragement of an obligational approach, including information-sharing, the building of trust and an atmosphere of time-based improvement.

Type 3

Type 3 supply chains may not be able to achieve the level of pacer standardisation to have significant impact on lead time performance. Long-term contract structures in this environment may not lead to standardised solutions for upstream pacers. Lead time improvement is still possible in this environment through reproducing these long-term

contracts upstream. Although strategic stocking is not possible, it may be possible to book capacity with upstream suppliers and thus improve lead time performance.

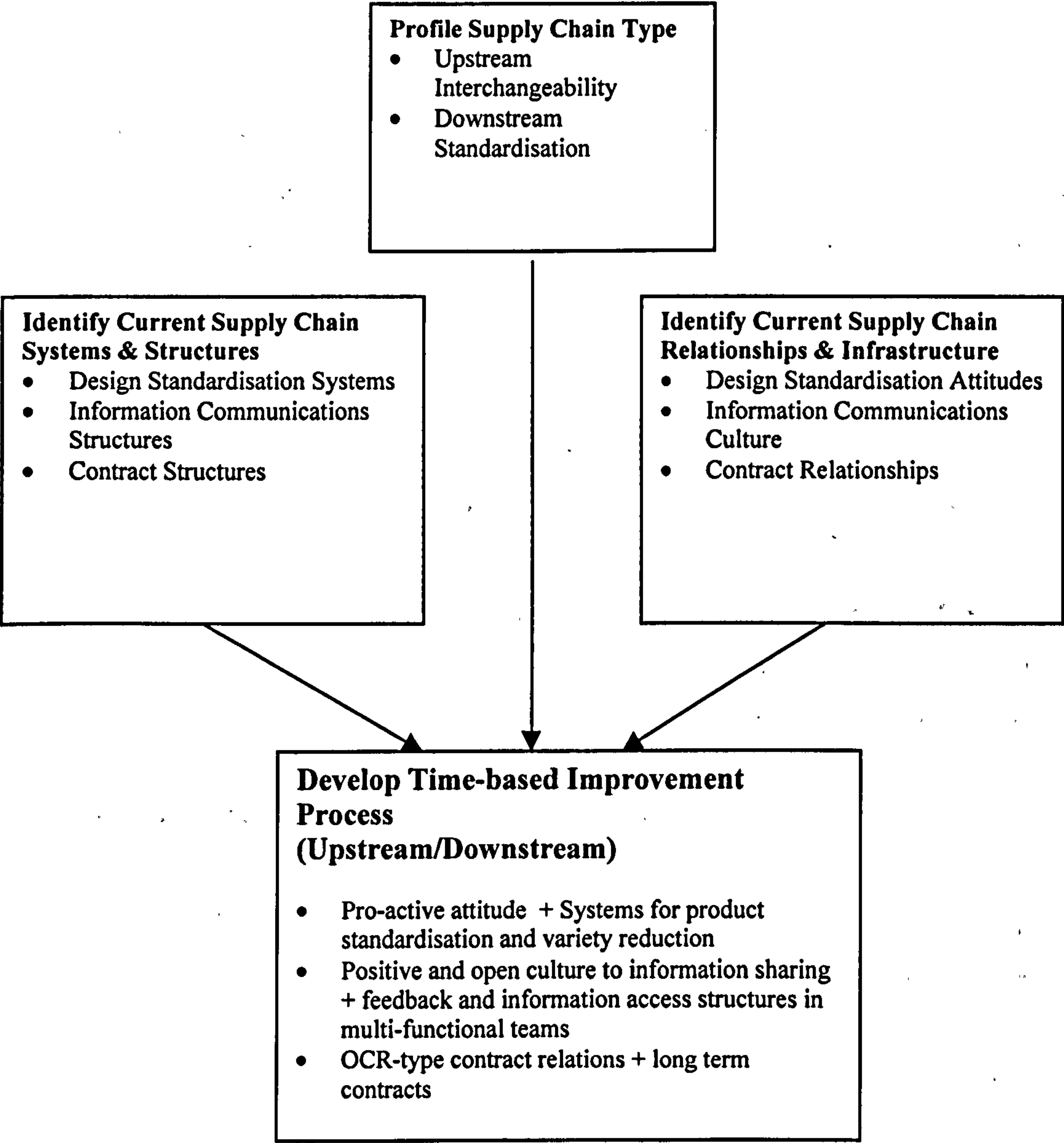


Fig 12.2: Time-based Supply Chain Process Improvement Model

Type 4

Type 4 supply chains profile closely with job/craft types. In this type supply chain improvement is possible though more flexible and informal arrangement with suppliers. Although volumes are unlikely to be sufficient for consignment stocks or JIT II-type arrangements (JIT II is the location of a member of the supplier's staff in the customer's premises, see Pragman, 1996), flexible arrangements with smaller suppliers may permit lead time improvements. In this type where there is high upstream interchangeability, the use of single-sourced stockists is still possible. An alternative approach would be multi-sourcing with the use of e-procurement to reduce transaction costs.

12.3.2 Step 2: Identify Current Supply Chain Systems and Structures

The current status of Design Standardisation Systems, Information Communications Structures and Contract Structures are examined.

12.3.3 Step 3: Identify Current Supply Chain Relationships and Infrastructure

The current status of Design Standardisation Attitudes, Information Communications Culture and Contract Relationships are examined.

12.3.4 Step 4: Develop Time-based Improvement Process

The information in Steps 2 and 3 is profiled with supply chain type as classified in Step 1 and a time-based improvement process is developed for both the upstream and downstream supply chain. This process will concentrate on the interaction between:

[1] Design Standardisation Systems and Attitudes; [2] Information Communications Structures and Culture; and [3] Contract Structures and Relationships.

12.4 Revisiting of Research Aims and Objectives

The Overall Research Problem *What are the influencing factors on lead time performance in a capital equipment supply chain?* was derived from an industry problem in the generic case environment. As new oilfield projects became smaller due to the maturity of the oil province, previous lead times for larger projects were found unacceptable. There was thus an industry problem that there required to be substantial improvement of lead times in capital equipment supply if the province was to remain competitive. The research was thus initially justified on the basis of a contribution to industrial competitiveness. The problem has been addressed at an industry level based on the findings of the study and the Process Model. Through the classification proposed in the Types Model, there are opportunities for generalization beyond the industry domain.

The aim of the research is as follows:

To evaluate the influencing factors on lead time performance in capital equipment supply environment.

This has been addressed in the development of research propositions, by the Types Model and the Process Model.

In order to achieve the above aim the main research objectives are as follows:

- i *To investigate the state of integration of the capital equipment supply chain within the case environment of the offshore oil exploration/production industry on the UK Continental shelf.*

This objective was achieved through the medium of the Integration Survey, see Chapter 8 above.

- ii *Empirically investigate the influencing factors on lead time performance within the case environment.*

This objective was achieved through the Supplier Survey (see Chapter 9) and the Case Research (see Chapter 10).

- iii *In the light of the empirical evidence, derive and validate propositions about the influencing factors on lead time performance in a capital equipment supply environment.*

This objective was met through the development of the propositions (Chapter 10 above) and their validation by cross-case analysis. The generalisation to the capital equipment supply environment was achieved through the development of the Types Model and the Process Model.

12.5 Discussion in relation to Recent Literature

Management research can be sometimes regarded as a ‘moving target’. As an applied research discipline, change happens due to changing practice as well as academic endeavours. As an emerging discipline, Supply Chain research is all the more dynamic. Perhaps, however, the most significant change within the period of undertaking this study has been the rapid change in the development of the Internet and the effect that this has had on the cost and capability of information communication within a supply chain. For a less repetitive supply chain, the ability to communicate using standard database and spreadsheet applications, can potentially permit rapid low-cost communication capability, that took substantial time and investment in EDI systems in industries such as retail or automotive. The impact of e-procurement on supply relationships is also an area of rapid change and will be an interesting phenomenon to observe in times ahead. Skjoett-Larsen (2000) identifies the “virtually integrated supply chain” and the growth of e-business as key features of the supply chain beyond the year 2000.

There has been a rapid growth of interest in time-based approaches to supply chain improvement and the further refinement of flexibility and agility concepts (Takahashi and Nakamura, 2000; Abdel-Malek et al, 2000; Narain et al, 2000; Assen et al, 2000; Zhang and Shafrifi, 2000). The relationship between these concepts such as Concurrent Engineering and Flexible Production to the relationship/infrastructure aspects of the supply chain (Pfohl et al, 2000; Anumba et al, 2000) have been reviewed in the light of the virtual enterprise and the growth of the discipline of Knowledge Management. Meantime, authors continue to supply more case study information (Perry and Sohal, 2000 [textiles, clothing and footwear]; Fan et al, 2000) [aerospace]) that permit, perhaps

along with this study, the comparison of different supply chain models to inform the proposed Lamming (2000) classification.

With regard to possible solutions for capital equipment supply chains Evan and Jukes (2000) have provided new empirical information on the use of suppliers as development partners and how this relates to product development and is facilitated through multi-functional involvement and integrated teamworking. Spring and Dalrymple (2000) have provided a helpful review of manufacturing strategy, which provides understanding on the nature of product customisation and even debate on what constitutes a standard product. These writers identify that the most important aspect of customisation is the amount and nature of original design work involved. These studies thus emphasise the importance of building up further knowledge of the interaction between the customer, the product, the manufacturer and the upstream supplier. There is a substantial supply chain research agenda in developing further understanding in all these areas.

12.6 Contribution of this Research

The discussion in this chapter has focused throughout on the contribution of this research study. It is not proposed to repeat this justification, but merely to address the nature of the contribution related to the original research justification in 1.6 above.

12.6.1 Contribution to Literature

With regard to the literature on time-based management, the study has supported authors findings about the low level of value-added time in supply chains and concurs with many authors on the reasons for this wasted time; it has also provided comparative information for design/engineer-to-order chains (Stalk and Hout, 1990; Beesley, 1995). In particular, the Stalk and Hout (1990) assertions about the relationship between complexity and time in product development have been supported and this study found a need for this to be understood as part of the order cycle. The study also supports the Ferrin (1994) model, which highlighted the influence of product complexity and product diversity on JIT

supply. The study indicates that there are particular contextual factors in the design/engineer-to-order environment that amend the Christopher (1992) “virtuous circle”. Although a reduction in cumulative lead time may result in lower inventory in the complete order cycle, certain of the lead time improvements have been shown to be based on ability to actually have stocks where previously this was impossible. The study has shown that the strategic stocking of pacer components is a particular influencer of improved lead time performance where there is low upstream interchangeability. Where there is higher upstream interchangeability the Lamming (1993) JIT model of the use of consignment stocks is more applicable. There is thus a small contribution in the understanding about which supply environments can use consignment stock to improve time-based performance of the supply chain.

With regard to the understanding of upstream and downstream influences, the study has assisted in a small way in filling a gap in the literature identified by Cooper and Ellram (1993): namely, some increased knowledge about how members that are more than one level apart interact. The study found that obligational relationship types downstream, did not necessarily translate to the same form upstream. With regard to Cooper and Elram’s (1993) gap about answering the question as to whether supply chains are characterised by one strong leader or multi-firm leadership, this study indicated that downstream influences are particularly important as influencers and leadership and pro-active involvement from the downstream customer significantly influenced supply chain performance.

With regard to the literature on integration the study has provided support for the importance of co-ordinating mechanisms (McGinnis and Kohn, 1990; Armistead and Mapes, 1993; Stevens, 1989; Larson, 1994) in the achievement of an integrated supply chain, but has shown that these mechanisms may exist but do not necessarily produce the sharing of relevant or useful information. The study has shown that it is through mutual trust built up through multi-functional customer-supplier team-based communication that results in a willingness to share “useful” information.

With regard to the literature on Supply Chain Systems, the study has provided understanding on the contribution of multi-functional customer-supplier teams to the information communication and 'feedback' in supply chains to give a practical backdrop to the work of the Systems Dynamics School (Towill, Naim, Wilkner, 1992 and others). The study has provided interesting insight on the importance of the strategic positioning of inventory in an Engineer-to-order type supply chain. There is clear evidence to support the importance of strategic positioning (Sharman, 1984, Christopher, 1998). Where there low upstream interchangeability of strategic pacer stock. But where there is high upstream interchangeability, traditional raw material stocks are more suitable. This contributes to an understanding that the Berry et al (1994), Horscroft and Braithwaite (1990), Christopher (1992) debate on where to position inventory in the chain has to be undertaken in the light of the context of the supply chain type. With regard to contract structures, the importance identified by Waters-Fuller (1995) of time-based improvement is supported by this study and a contribution made to the understanding as to how long-term, broadly-based contract structures can lead to an atmosphere for time-based improvement.

With regard to the literature on supply chain relationships, the research has produced some comparative evidence on which to judge the applicability of the Cox (1995) "step-ladder" of contractual relationships. The evidence from this study is that various types of relationship will exist in any one chain at any time and that the downstream and upstream contexts must be taken into account, as a relationship at one level will not necessarily translate to the same at another level. The challenge for researchers and practitioners alike will be to explain ways in which this translation across levels can happen. This study perhaps provides some clues in this respect. The study also raises questions on some of the assumptions that obligational-type relationships can only persist where there is a balance of power. The study did not focus specifically on these areas but it has perhaps assisted in providing some information to enhance the understanding provided by Burnes and New (1995), Ramsay (1996) and Mudami and Scrunder (1996) about assertions that assume partnership development cannot take place where there is an unequal balance of power. This study indicates something of the opposite; that there is

some evidence that a powerful downstream player can engage upstream suppliers in systems and relationships that can be of mutual benefit.

12.6.2 Contribution to Supply Chain Theory

The role of case research is to expand and generalise theories (Yin, 1994). Case research moves from the exploratory and descriptive to an explanatory mode based on generalising to prior theory. Hypothesis-testing is problematic within a case research design and this study has taken the view that cross-case comparison be limited to the generation and validation of a number of propositions. These propositions address the research questions derived from the literature review. The prime contribution of this study from a theoretical standpoint relates to the use of these propositions and how they relate to individual Cases or sub-units of analysis to attempt a Type Classification of supply chains in this environment, by adapting the Bartezzaghi (1994) taxonomy. This addresses a research gap that was an original motivation for the study by the researcher, but which has been recently codified by Lamming (2000) and Cox (1999). This contribution must, however, be evaluated in the light of the exploratory nature of this study. The Type classification is qualitatively derived and justified based on the case and survey evidence. However, the classification is a starting point and should be regarded as tentative and requires further testing.

12.6.3 Methodological Contribution

The use of a study of a Supply Environment as a Case provides a methodological contribution within supply chain research along with the translation of cross-case comparison to provide a supply environment classification. Use has been made of supply chain trace-back methodology as an adaptation of the Berry et al (1994) approach. Although this method was originally predicated on the intuitive importance of pacers, it was found to be useful in providing the different perspectives necessary in a supply chain study. It does, however, provide a methodology for sampling within the wider supply chain. The partial use of telephone methodology within the study contributes to understanding the benefits of this medium in the investigation of geographically dispersed supply chains, whilst keeping in mind the limitations of this method (Frey,

1983). The limitations of supply chain trace-back require further study in more controlled environments. Its iterative nature requires a number of cases to be 'live' at any one time. This extends the data collection period substantially, particularly if the research is a part-time pursuit. Considerable ongoing work is thus required to evaluate the limitations of supply-chain trace-back, in order that the trade-off between benefits and drawbacks can be systematically examined.

12.6.4 Managerial Contribution

Any sectoral study will provide managers within that sector with further understanding of supply chain behaviour and influences within that sector. If Daugherty and Pittman's (1995) assertion that customer tolerance levels of long lead times in engineer-to-order industries are decreasing is correct (and the evidence from this case environment certainly supports it) then this study has something to offer to those organisations that wish to move towards the solution of lead time problems.

The researcher has the benefit of co-ordinating an Elective Module on Supply Chain Management within the Masters Programme at Aberdeen Business School at the Robert Gordon University. This has permitted ongoing checking of the credibility of findings with an informed group of practitioners. It also provides a platform for the dissemination of ideas to the particular sector under study. Practical experience of application of the Process Model will contribute to further understanding of managers within the industry and will permit ongoing validation and refinement of the model. The use of the Type Classification will extend the potential managerial contribution to other similar sectors in design/engineer-to-order. It must be emphasised, however, that further work is required to evaluate the Process Model and it is only presented as one option for further rigorous evaluation and this limitation must be recognised by those who might consider its application.

12.7 Methodological Justification and Limitations

The basic concept behind the study is that a contribution to knowledge about the influencing factors on lead times in a supply chain can be made by studying a particular Case Supply Environment - in this case the Capital Equipment supply chain in the offshore oil exploration and production industry on the UK Continental Shelf. The boundaries of the Case Environment are thus threefold: [1] the generic supply environment; [2] the industry and [3] the industry within this geographical boundary. Yin (1994) suggests the use of a single case to confirm, challenge or extend theory. The use of an earlier quantitative phase provided “benchmark” data which informed both the case research phase and the subsequent analysis.

Within the single Case Environment six individual Cases were investigated. The logic behind a multiple-case design is based on “replication logic” rather than “sampling logic” (Yin, 1994). Cases are selected in order to produce similar results (literal replication) or contrasting results for predictable reasons (theoretical replication). The use of two sub-environments based on different levels of product complexity permitted both these types of replication. The use of underlying theoretical frameworks were used as a basis for generalisation by cross-case comparisons (Yin, 1994). Propositions were developed based on the individual cases and then triangulated in a cross-case comparison. In the process, deviant cases were identified with regard to certain influencing factors. These were not ignored, but used to inform the comparison.

The study methodology was based on two important principles of data collection (Yin, 1994): [1] Multiple Sources of Evidence; [2] Chains of Evidence. With regard to the first principle, triangulation was obtained by the selection of respondents from customer, manufacturer and supplier perspectives within each case. The nature of the supply chain trace-back methodology, meant that the selection of these respondents was not defined by the researcher, but by the downstream customer. As such, researcher bias in the selection of cases was minimised. However, access requirements in case research means that the

cases studied are those to which access is granted and this can affect internal reliability. With regard to the second principle “Chains of Evidence”, the reporting and analysis of direct quotations from respondent interviews, permits the reader to verify or contest the researcher’s interpretation.

In Case Research there is a trade-off between the number of cases studied and the extent of depth within each case. On balance, the researcher is satisfied that the outcome has been a satisfactory trade-off that provides a more successful picture of the supply environment than would have been available from a smaller number of cases. The complexity of supply chain research that crosses several organisational boundaries does not make for economy in data collection. By taking the supply environment approach, the researcher has traded a degree of depth of study in any one case for the number of cases under study. However, the consequent advantage occurs in the improved validity provided by the replication of the case six times. With greater time resources than those available to the doctoral student, additional respondents could have been accessed and the component supply tier included in the study. The research design means, however, that propositions were derived based on judgmental rather than statistical verification. It is accepted that the opportunity for “theoretical saturation” (Yin, 1994) is reduced by the depth of analysis trade-off. On the other hand, however, the increased number of cases makes the derivation of the two tentative models much more likely than in a single case in-depth design. The use of taped interviews, suitably transcribed and a standard analytical format for the analysis of the results provides the basis of a protocol (Yin, 1994) that guards against researcher bias. Researcher bias in the analysis has also been reduced by feedback to informed industry players, explained in 12.5.4 above. It is accepted, however, that subjectivity cannot be completely removed by such methods, although the acceptance and reporting of deviant cases (Silvermann, 2000) is an indication of lack of selective bias.

The limitations of this study are thus in line with the limitations of case research. By nature, case research is located in a context and much of the advantages of the methodology relate to the richness of contextual detail and the close connection with

reality. By rooting the study within existing theory, a number of propositions were developed. The length of time taken by a part-time researcher to access data, combined with the time-consuming methodology of supply chain trace-back has meant that data has been collected over a longer period than would have been preferred. This has created some difficulties related to cross-case comparison protocol and the results must be viewed in the light of these data collection shortcomings. In an ideal world, comparison would be in the same 'snapshot' in time. This is never possible in case research, but the iterative and uncertain nature of supply chain trace-back makes this all the more problematic. Due to the methodology adopted, these propositions therefore require to be regarded as tentative and require further research to test their external validity. The ability to generalise from the case context to other contexts has been aided by the amendment of a type classification model permitting some tentative generic understanding of lead time behaviour that could be translated and compared with other types of supply chain.

12.8 Further Research

As noted in 12.6.2 above, this research was undertaken as a study of a supply environment using the adopted case research methodology and has limited the outcome to the generation of a number of propositions related to the research questions derived from the literature review. These propositions, summarised in 11.7 above, gained internal validity through the adopted methodology for the study. As such, the outcome is likely to be regarded as exploratory research. On the basis of the study findings, further research may consider the opportunity to test the propositions. There are a number of methodological possibilities for this ongoing testing. Using hypotheses based on the propositions, a smaller number of more in-depth cases could potentially focus on an individual, more rigorously defined, sub-environment. Alternatively, more focused case research could investigate the domain of a single research question. There are also opportunities for more large-scale quantitative survey research based on hypothesis testing.

Parallel case studies in other capital equipment supply environments would further extend knowledge of influencing factors on lead times and assist in validation of the Type Classification Model based on a wider sample of supply chains. Application of the Time-based Supply Chain Process Improvement Model to specific supply chain cases is also required to evaluate its usefulness.

More specific research areas that have been identified within this research as worthy of further study include the following: [1] The importance of the downstream customer in relation to different tiers of the upstream supply chain. In particular, the potential benefits and drawbacks of the use of supplier power and influence is worthy of further study in the context of the wider supply chain. [2] The application of Concurrent Engineering (CE) practices to the improvement of the order cycle in design-to-order environments is worthy of more detailed study. This would include approaches in relation to design change control. [3] The measurement of the development of obligational relationships and trust within customer-supplier teams in a design/engineer-to-order environment is an area where more potential information is required. [4] The contribution of techniques for the control of variety proliferation was not conclusive within the study due to the lack of application of the techniques and is worthy of further investigation. Related techniques on generic function coding of parts and its contribution to modular design in engineer-to-order situations and its impact on supply chain improvement appears to have potential as part of time-based process improvement and requires further development. [5] The study of further comparative cases of pro-active upstream supplier development, as a basis for systematically removing pacing constraints would bring in-depth understanding of the contribution of this approach. [6] Identification of alternative informal styles to supply chain improvement in Small to Medium Enterprises (SME's) by further studies of these organisations would be worthy of consideration.

BIBLIOGRAPHY

- Abdel-Malek, L, Das, S K, and Wolf, C (2000) Design and Implementation of Flexible Manufacturing Solutions in Agile Enterprises International Journal of Agile Manufacturing Systems, Vol 2, No 3.
- Ackoff, R. L. (1979) The Future of Operational Research is Past Journal of the Operational Research Society, Volume 30.
- Ackoff, R. L. (1960) Systems, Organisations and Interdisciplinary Research General Systems Yearbook, Vol. 5.
- Ahmed, N V Montagno, R V and Firenze, J (1996) Operations Strategy and Organisational Performance International Journal of Operations and Production Management, Vol 16, No 5
- Ali, H and Birley, S (1998) The Role of Trust in the Marketing Activities of Entrepreneurs Establishing New Ventures. Journal of Marketing Management, 14, 749-763.
- Angyal, A. (1941) Foundations for a Science of Personalities Harvard University Press
- Amstel, M. J. Ploos van. (1990) Managing the Pipeline Effectively Journal of Business Logistics, Vol. 11, No. 1.
- Andries, B & Gelders, L (1995) Time-based Manufacturing Logistics. Logistics Information Management, Vol 8, No 3.
- Anumba, C J, Siemieniuch, C E, and Sinclair, M A (2000) Supply Chain Implications of Simultaneous Engineering International Journal of Physical Distribution and Logistics Management, Vol 30, No 7/8.
- Armistead, C G and Mapes, J (1993) The impact of supply chain integration on operating performance. Logistics Information Management, Vol 6, No 4.
- van Assen, M F, Hans, E W and van de Velde, S L (2000) An agile planning and control framework for customer-order driven discrete parts manufacturing environments International Journal of Agile Management Systems, Vol 2, No 1.
- Babu, A S (1999) Strategies for enhancing agility of make-to-order manufacturing systems International Journal of Agile Management Systems, Vol 1, No 1.
- Bailey, G S (1996) Strategies for the Development of Supply Chain Management unpublished MBA thesis, Aberdeen University and The Robert Gordon University.

Bambridge M (1995) Supply Chain Improvement through Asset Based Mapping proceeding of the Re-engineering the Supply Chain Conference, Aberdeen, September 1995.

Barker, B and Helms, M H (1992) Production and Operations Restructuring: using time-based strategies Industrial Management and Data Systems, Vol 92, No 6.

Barker, R C (1993) Time-based performance measurement: a model to aid competitive restructuring. Logistics Information Management, Vol 6, No 1.

Bartezzaghi, E, Spina, R, and Verganti, R (1994) Lead-time Models of Business Processes International Journal of Operations and Production Management, Vol 14, No 5.

Batchelor, J Donelly, T and Morris, D(1995) Learning in a Lean Environment: customer-supplier relationships as a key aspect of the Learning Organisation Proceedings for 1st Worldwide Research Symposium on Purchasing and Supply Chain Management, Arizona, March, 1995.

Beecham M A (1995) Technology Partnering Arrangements in the Offshore Supplies Industry CALtec, Cranfield.

Beesley, A (1995) 'Time Compression' Tools, Logistics Focus, August 1995.

Berry, D, Towill, D R, and Wadsley (1994) Supply Chain management in the electronic products industry, International Journal of Physical Distribution and Logistics Management, Vol 24, No 10.

Bertalanffy, L. von. (1950) The Theory of Open Systems in Physics and Biology Science, Vol. 111.

Bhattacharya, A K, Coleman, J L, Brace, G & Kelly, P J (1996) The Structure Conundrum in Supply Chain Management, International Journal of Logistics Management, Vol 7, No1.

Bhattacharya, A K, Jina, J and Walton, A D (1996) Product Market, turbulence and time compression International Journal of Operations and Production Management, Vol 16, No9.

Blois, K (1998) A trust interpretation of business to business relationships: a case-based discussion, Management Decision, 36/5, 302-308.

Bowersox, D. J. (1978) Logistical Management (2nd Ed.) Macmillan, New York.

Bowersox, D. J. & Closs, D. J. (1989) Simulation in Logistics: A Review of Present Practice and a look to the Future Journal of Business Logistics, Vol. 10., No. 1.

Bowersox, D. J. & Daughterty, P. J. (1987) Emerging Patterns of Logistical Organisations Journal of Business Logistics, Vol. 8, No. 1.

Bozarth, C and Chapman, S (1996) A contingency view of time-based competition for manufacturers, International Journal of Operations and Production Management, Vol 16, No 6.

Braithwaite, A. (1992) Integrating the Global Pipeline: Logistics Systems Architectures Logistics Information Management, Vol. 5., No. 3.

Braithwaite, A (1993) Logistics Systems or Customer Focused Organization: which comes first? Logistics Information Management, Vol 6, No 4.

Burnes, B and New, S (1996) Understanding supply chain improvement, European Journal of Purchasing and Supply Management, Vol 2, No 1.

Burnes, B, New, S and Young, S (1995) Profiting from Partnership, Logistics Focus, December 1995.

Burns, T and Stalker, G. M. (1966) The Management of Innovation Tavistock Publications.

Bytheway A J, and Dhillon, G (1996) Significance of Partnerships in the Management of Interorganisational Systems, International Journal of Information management, Vol16, No 5.

Canadine, I (1994) Logistics Yearbook 1994 Institute of Logistics, Corby, UK.

Cardale T (1995) Re-engineering the Supply Chain opening address to the Re-engineering the Supply Chain Conference, Aberdeen, September 1995

Carmichael D (1995) Developing the Alliancing Concept to Ensure the Survival of the High Performance, High Quality UKCS Industry, Proceedings of the Partnering and Alliancing Agreements Offshore Conference, Aberdeen, October 1995.

Charnes, A., Cooper, W.W. & Rhodes, E. (1978) Measuring the Efficiency of Decision Making Units European Journal of Operations Research, November 1978, pp 429-44.

Charters R (1995) Assessing what is the most effective approach to Integrated Alliance Project Management Proceedings of Partnering and Alliancing Agreements Offshore Conference, Aberdeen, October 1995.

Christopher, M. (1986) Implementing Logistics Strategy International Journal of Physical Distribution and Materials Management, Vol.16., No. 1.

Christopher, M. & Braithwaite, A. (1989) Managing Strategic Lead Times Logistics Information Management, Vol. 2., No 4.

Christopher, M. (1992) Logistics and Supply Chain Management Pitman, London.

Christopher, M. (1998) Logistics and Supply Chain Management (2nd Edition) Pitman, London.

Churchman, C.W. (1970) Operations Research as a Profession Management Science, Vol. 17.

Cooper, J and Griffiths, J (1994) Managing Variety in Automotive Logistics with the Rule of Three, International Journal of Logistics Management, Vol 5, No 2.

Cooper, M C and Gardner, J T, (1993) Building Good Business Relationships: more than just partnering or strategic alliances, International Journal of Physical Distribution and Logistics Management, Vol 23, No 6.

Cooper, M C & Ellram, L M (1993) Characteristics of Supply Chain management and the Implications for Purchasing and Logistics Strategy, International Journal of Logistics Management, Vol 4, No 2.

Cox, A (1995) Relational Competence and Strategic Procurement Management, 1st Worldwide Research Symposium on Purchasing and Supply Chain Management, Arizona, 1995.

Cox, A (1999a) Power, Value and Supply Chain Management Supply Chain Management, Vol 4, No 4.

Cox, A (1999b) A research agenda for supply chain and business management thinking Supply Chain Management, Vol 4, No 4.

Cravens, D W, Piercy, N F & Shipp, S H (1996) New Organizational Forms for Competing in Highly Dynamic Environments: the Network Paradigm, British Journal of Management, Vol 7, 203-218.

CRINE (1994) The CRINE Report CRINE, London.

CRINE (1996) The Common Working Practices CRINE, London.

CRINE (1997) The Standard Contracts CRINE, London.

CRINE (1999) Supply Chain Management in the UK Oil and Gas Sector, CRINE, London.

Croom-Morgan, S (1995) Competitive Advantage through Effective Purchasing: the strategic management of Supplier Interaction, Proceedings of the First Worldwide Symposium on Purchasing and Supply Management, Phoenix, Arizona, March 22-25.

Daugherty, P J and Pittman, P H (1995) Utilization of time-based strategies: creating distribution flexibility/responsiveness, International Journal of Operations and Production Management, Vol 15, No 2.

Davis Jr., F W and Manrodt, K B (1991) Service Logistics: an introduction, International Journal of Physical Distribution and Logistics Management, Vol 24, No 4.

Drucker, P. F. (1962) The Economy's Dark Continent Fortune, April 1962.

Drucker, P. F. (1990) The Emerging Theory of Manufacturing Harvard Business Review, May-June 1990.

DTI (1993) The Development of Oil and Gas Resources in the UK DTI, Aberdeen.

DTI (1993) Report on the Working Group on UKCS Competitiveness DTI, Aberdeen

DTI (1999) The Oil and Gas Industry Task Force Report DTI, Aberdeen.

Ellram, L M & Hendrick, T E (1995) Partnering Characteristics: a dyadic perspective, Journal of Business Logistics, Vol 16, No 1.

Evans, G N, Naim, M M and Towill, D R (1993) Dynamic supply chain performance: assessing the impact of information systems, Logistics Information Management, Vol 6, No 4.

Evans, S and Jukes, S (2000) Improving co-development through process alignment International Journal of Operations and Production Management, Vol 20, No 8.

Fan, I, Russell, S and Lunn, R (2000) Supplier knowledge exchange in aerospace product engineering Aircraft Engineering and Aerospace Technology, Vol 72, No 1.

Farrell, J. W. (1985) New Clout for Logistics Traffic Management, Vol. 24, No. 9.

Farrell, J. W. (1987) Logistics: the Evolution Continues Traffic Management, Vol. 26., No. 9.

Farrell S & McDermott J Ray (1995) An International Perspective on Risk/Reward Contracting: comparison of US, Middle East and UK alliances Proceedings of Offshore Europe Conference, Aberdeen, September 1995.

Ferrin, B (1994) Planning Just-in Time Supply Operations: a multiple case analysis, Journal of Business Logistics, Vol 15, No 1.

Fiorito, S S, May, E G and Straughn, K (1995) Quick Response in Retailing: components and implementation International Journal of Retail and Distribution Management, Vol 23, No 5.

Forrester, J. W. (1961) Industrial Dynamics M.I.T. Press, Cambridge, MA.

Forza, C (1996) Achieving superior operating performance from integrated pipeline management: an empirical study, International Journal of Physical Distribution and Logistics Management, Vol 26, No 9.

Frey, J H (1983) Survey Research by Telephone Sage, Newbury Park

Fry, T D (1990) Controlling input: the real key to shorter lead times, International Journal of Logistics Management, Vol, No 1.

Gattorna, J. L., Chorn, N. H. & Day, A. (1991) Pathways to Customers: Reducing Complexity in the Logistics Pipeline International Journal of Physical Distribution and Logistics Management, Vol. 21., No. 8.

Gehani, R R (1995) Time-based management of technology: a taxonomic integration of tactical and strategic roles International Journal of Operations and Production Management, Vol 15, No 2.

George, N (1996) Subsea Production Standardisation Initiative, Procs. Of the Offshore Technology Conference, Houston, Texas, 6-9 May, 1996.

Geyskens, I, Steenkamp, J E M, Scheer, L K and Kumar, N (1996) The effects of trust and interdependence on relationship commitment: a trans-atlantic study, International Journal of Research in Marketing, 13, 303-317.

Goldratt, E M and Cox, J (1986) The Goal North River Press

Green, R L (1995) Partnering and Alliances: theory and practice Proceedings of the Offshore Europe Conference, Aberdeen, September, 1995.

Greenwood, J (1994) Representing Interests in the European Union: Sectors, Case Studies and Generalisations, Procs. Of the 9th International Council of European Studies Conference, 31 March-4 April, Chicago.

Harland, C (1996), Supply Network Strategies: the case of Health Supplies, European Journal of Purchasing and Supply Management, Vol2, No 4.

- Harland, C M, Lamming, R C and Cousins, P D (1999) Developing the concept of supply strategy International Journal of Operations and Production Management, Vol 19, No 7.
- Hewitt, F (1994) Supply Chain Redesign International Journal of Logistics Management, Vol 5, No 2.
- Hill, R. M. (1990) Measuring Stock Service Levels International Journal of Retail and Distribution Management, Vol. 18., No. 3.
- Hines, P (1993) Integrated Materials Management: the Value Chain Redefined, International Journal of Logistics Management, Vol 4, No 1.
- Hines, P (1994a) Internationalization and Localization of Kyoryoku Kai: the Spread of Best Practice Supplier Development, International Journal of Logistics Management, Vol 5, No1.
- Hines, P (1994b) Creating World Class Suppliers Pitman, London.
- Hines, P (1996a) Network Sourcing: a discussion of causality within the buyer-supplier relationship, European Journal of Purchasing & Supply Management, Vol 2. No 1.
- Hines, P (1996b) Network Sourcing in Japan, International Journal of Logistics Management, Vol 7, No 1.
- Hise, R T (1995) The implications of time-based competition on international logistics strategies, Business Horizons, Sept-Oct 1995.
- Horscroft, P. & Braithwaite, A. (1990) Enhancing Supply Chain Effectiveness - the Strategic Lead Time Approach The International Journal of Logistics Management, Vol. 1., No. 2.
- Huang, G Q and Mak, K L (1999) Current practices of engineering change management in UK manufacturing industries International Journal of Operations and Production Management, Vol 19, No 1.
- Jarvis, M (1999) Concurrent Engineering Work Study, Vol 48, No 3.
- Jayaram, J, Vickery, S K and Droge, C (1999) An empirical study of time-based competition in the North American automotive supplier industry International Journal of Production and Operations Management, Vol 19, No 10.
- Johnson, G & Scholes, K. (1988) Exploring Corporate Strategy Prentice Hall, Hemel Hempstead.

Jones, D T, Hines, P and Rich, N (1997) Lean Logistics International Journal of Physical Distribution and Logistics Management, Vol 27, No 3&4.

Jones T. C. & Riley, D. W. (1985) Using Inventory for Competitive Advantage through Supply Chain Management International Journal of Physical Distribution and Materials Management, Vol. 15., No. 5.

Kathawala, Y & Nauo, H. H. (1989) Integrated Materials Management: a Conceptual Approach International Journal of Physical Distribution and Materials Management, Vol. 19., No. 8.

Katz, D. & Kahn, R. L. (1966) Common Characteristics of Open Systems Wiley.

Kearney, A T (1995) Profiting from Partnership: maximising benefits from supply chain collaboration, AT Kearney/Manchester School of Management/Institute of Logistics survey.

Koeler, W. (1938) The Place and Values in the World of Facts Liveright.

Kritchanchai, D and MacCarthy, B L (1999) Responsiveness of the order fulfilment process International Journal of Operations and Production Management, Vol 19, No 8.

Kumar, A and Motwani, J A methodology for assessing time-based competitive advantage of manufacturing firms International Journal of Production and Operations Management, Vol 15, No 2.

LaLonde, B J and Masters, J M (1994) Emerging logistics strategies: blueprints for the next century, International Journal of Physical Distribution and Logistics Management, Vol 24, No 7.

Lamming, R (1993) Beyond Partnership: Strategies for Innovation and Lean Supply, Prentice Hall Europe, ISBN 0 13 143785 2.

Lamming, R C, Cousins, P D and Notman, D M (1996) Beyond vendor assessment: relationship assessment programmes, European Journal of Purchasing and Supply Management, Vol 2, No 4.

Lamming, R, Johnsen, T, Zheng, J and Harland, C (2000) An initial classification of supply networks International Journal of Operations and Production Management, Vol 20, No 6.

Larson, P D (1994) An empirical study of inter-organizational functional integration and total costs, Journal of Business Logistics, Vol 15, No 1.

- Latham G & Clark G (1995) Clyde Project Case Study: an alternative incentivised approach to turn-key contracting proceedings of Partnering and Alliancing Agreements Offshore Conference, Aberdeen, October 1995.
- Lawrence, P. & Lorsch, J. W. (1969) Organisation and Environment Irwin.
- Litterer, J. A. (1987) The Analysis of Organisations (2nd Ed.) Wiley, New York.
- LOGIC (1999a) A methodology for Supply Chain Improvement LOGIC, Aberdeen.
- LOGIC (1999b) UKCS vs Gulf of Mexico – a study of the differences LOGIC, Aberdeen.
- Macbeth, D K (1994) The role of Purchasing in a Partnering Relationship European Journal of Purchasing and Supply Chain Management, Vol 1, No 1.
- Macbeth, D K and Ferguson, N, (1994) Partnership Sourcing: an integrated supply chain management approach, Pitman, ISBN 0 273 60208 X.
- McGinnis, M. A. & Kohn, J. W. (1990) A Factor Analytic Study of Logistics Strategy Journal of Business Logistics, Vol. 11., No. 2.
- McGinnis, M A and Kohn, J W (1993) Logistics Strategy, Organizational Environment and Time Competitiveness, Journal of Business Logistics, Vol 14, No 2.
- Mahmoud, M. M. (1992) Optimal Inventory Consolidation Schemes: a Portfolio Effect Analysis Journal of Business Logistics, Vol. 13., No. 1.
- Martin D (1995) Optimising Supply Chain Performance - a Facilities Manager's Approach proceedings of the Re-engineering the Supply Chain Conference, Aberdeen, September 1995.
- Mayhew, P (1999) Collaborate Early to Operate Economically Society of Petroleum Engineers (SPE 56905), Offshore Europe Conference, 7-9 Sept.
- Maylor, H (1997) Concurrent new product development: an empirical assessment International Journal of Operations and Production Management, Vol 17, No 12.
- Meijboom, B (1999) Production-to-order and international operations International Journal of Production and Operations Management, Vol 19, No 5/6.
- Mentzer, J T and Kahn, K B (1995) A Framework for Logistics Research Journal of Business Logistics, Vol 16, No 7.
- De Meyer, A, (1993) Integrated European Logistics: the barriers to overcome, Ernst and Young 1993 survey.

Michell, P, Reast, J and Lynch, J (1998) Exploring the Foundations of Trust, Journal of Marketing Management, 14, 159-172.

Mudambi, R and Schrunder, C P (1996) Progress towards buyer-seller partnerships: evidence from small and medium-sized manufacturing firms, European Journal of Purchasing and Supply Management, Vol 2, Nos 2&3.

Naim, M M and Towill, D R (1994) Establishing a framework for effective materials logistics management, International Journal of Logistics Management, Vol 5, No 1.

Narain, R, Yadav, R C, Sarkis, J and Cordeiro, J J (2000) The strategic implications of flexibility in manufacturing systems International Journal of Agile Management Systems, Vol 2, No 3.

Nyerges, R. (1992) The inventory investment decision and firm value: a conceptual framework International Journal of Production Economics, Vol. 26.

O'Laughlin, K. A., Cooper, J. & Cabocel, E. (1993) Reconfiguring European Logistics Systems Council for Logistics Management, Oak Brook, IL.

Oliver, N and Wilkinson, B (1998) The Japanesation of British Industry Blackwell, Oxford.

Ong, N S (1997) Productivity improvements for a small "make-to-order" manufacturing environment Industrial Management and Data Systems, Vol 97, No 7.

Perry, M and Sohal, A S (2000) Quick response practices and technologies in developing supply chains International Journal of Physical Distribution and Logistics Management, Vol 30, No 7/8.

Persson, G (1991) Achieving competitiveness through logistics, International Journal of Logistics Management, Vol2, No1.

Persson, G (1995) Logistics Process Redesign: some useful insights International Journal of Logistics Management, Vol 6 No 1.

Pfohl, C and Buse, H P (2000) Inter-organizational logistics systems in flexible production networks International Journal of Physical Distribution and Logistics Management, Vol 30, No 5.

Pfohl, H. & Zollner, W. (1987) Organisation for Logistics: the Contingency Approach International Journal of Physical Distribution and Materials Management, Vol. 17., No. 1.

Porter, M. E. (1985) Competitive Advantage: creating and sustaining superior performance Free Press.

Pragman, C H (1996) JIT II: a purchasing concept for reducing lead times in time-based competition, Business Horizons, Vol 39, No 4.

Price, H (1996) The anthropology of the supply chain: fiefs, clans, witch-doctors and professors, European Journal of Purchasing and Supply, Vol2, No 2/3.

Ragin & Becker (1992) What is a Case? – exploring the fundamentals of Social Enquiry Cambridge University Press, UK.

Rahman, S (1998) Theory of constraints International Journal of Operations and Production Management, Vol 18, No 4.

Ramsay, J (1996) Power measurement, European Journal of Purchasing and Supply Management, Vol 2, Nos 2&3.

Roy, M H and Dugal, S S (1998) Developing Trust: the importance of cognitive flexibility and co-operative contexts, Management Decision, 36/9, 561-567.

Rushton, A. & Saw, R. (1992) A Methodology for Logistics Strategy Planning International Journal of Logistics Management, Vol. 2., No. 1.

Saunders, M (1995) Chains, Pipelines, Networks and Value Streams: the role, nature and value of such metaphors in forming perceptions of the task of purchasing and supply management Procs. for 1st Worldwide Symposium on Purchasing and Supply Chain Management, Arizona, March 1995.

Sako, M (1992) Prices, Quality and Trust: inter-firm relations in Britain and Japan, Cambridge University Press, UK, ISBN 0 521 41386 9.

Scott, C. & Westbrook, R. (1991) New Strategic Tools for Supply Chain Management International Journal of Physical Distribution and Logistics Management, Vol. 21., No. 1.

Sharman, H. D. (1984) Improving the Productivity of Service Business Sloan Management Review, Vol. 25.

Silveira, G Da (1998) A framework for the management of product variety International Journal of Production and Operations Management, Vol 18, No 3.

Skjoett-Larsen, T (2000) European Logistics beyond 2000 International Journal of Physical Distribution and Logistics Management, Vol 30, No5.

- Smith, S L (1995) The Harding Field: a low cost per barrel concept becomes a reality Proceeding of Offshore Europe Conference, September 1995.
- Spence, S, McIlroy, R, Leyshon, W and Kreutz, H (1999) The Kingfisher Field Society of Petroleum Engineers (SPE 56927) Offshore Europe Conference, Aberdeen, 7-9 Sept.
- Spring, M and Dalrymple, J F (2000) Product customisation and manufacturing strategy International Journal of Operations and Production Management, Vol 20, No 4.
- Stalk, G (Jr) and Hout, T M (1990) Competing against Time Free Press, New York.
- Stannack, P (1996) Purchasing power and supply chain management power – two different paradigms? – a response to Ramsay's 'Purchasing Power' (1995), European Journal of Purchasing and Supply Management, Vol 2, No 1.
- Stevens, G. C. (1989) Integrating the Supply Chain International Journal of Physical Distribution and Materials Management, Vol. 19., No. 8.
- Stock, J. R. (1990) Logistics Thought and Practice: a Perspective International Journal of Physical Distribution and Logistics Management, Vol. 20., No. 1.
- Stubbs, J (1999) Synergies between two neighbouring major developments Society of Petroleum Engineers (SPE 56929), Offshore Europe Conference, Aberdeen, Sept 7-9.
- Sussams, J. E. (1992) Logistics Modelling Pitman, London.
- Swaine R (1995) Promoting Trust and Avoiding Conflict in the Alliance by Open Access to Information and Effective Inter-Alliance Communication, Proceedings of Partnering and Alliancing Agreements Offshore Conference, Aberdeen, October 1995.
- Sweeney, M T and Szwejczewski, M (1996) Manufacturing strategy and performance International Journal of Operations and Production Management, Vol 16, No %.
- Swenseth, S R and Buffa, F P Just-In-Time: some effects on the logistics function, International Journal of Logistics Management, Vol 1, No 2.
- Takahashi, K and Nakamura, N (2000) Agile control in JIT ordering systems International Journal of Agile Management Systems, Vol 2, No 3.
- Tersine R J and Hummingbird, E A (1995) Lead Time Reduction: the search for competitive advantage International Journal of Operations and Production Management, Vol 15, No 2.
- Towill, D R (1995) Industrial dynamics modelling of supply chains, International Journal of Physical Distribution and Logistics Management, Vol 26, No 2.

- Towill, D R (1996) Time compression and supply chain management – a guided tour Supply Chain Management, Vol 1, No 1.
- Towill, D R, Naim, M M and Wilkner, J (1992) Industrial dynamics simulation models in the design of supply chains, International Journal of Physical Distribution and Logistics Management, Vol 22, No 5.
- Tracy, M, Tan, C L, Vondrembse, M and Bardi, E J (1995) A Reexamination of the Effects of Just-in-Time on Inbound Logistics, International Journal of Logistics Management, Vol 6, No 2.
- Vernadat, F B (1999) Research agenda for agile manufacturing International Journal of Agile Management Systems, Vol 1, No 1.
- Wafa, M A, Yasin, M M and Swinehart, K (1996) The impact of supplier proximity on JIT success: an informational perspective, International Journal of Physical Distribution and Logistics Management, Vol 25, No 4.
- Walton, L W (1996) Partnership Satisfaction: using the underlying dimensions of supply chain partnership to measure current and expected levels of satisfaction, Journal of Business Logistics, Vol 17, No 2.
- Waters-Fuller, N (1995) Just-in-Time Purchasing and Supply: a review of the literature, International Journal of Operations and Production Management, Vol 15, No 9.
- Watson, G (1999) Cost Reduction in Downhole Completion Equipment Society of Petroleum Engineers (SPE 53914), Latin American and Caribbean Petroleum Engineering Conference, Venezuela, 21-23 April.
- Wilding, R D & Newton, J M (1996) Enabling time-based strategy through logistics – using time to competitive advantage, Logistics Information management, Vol 9, No 1.
- Wilkins, R. (1987) The Management Challenge of Hybrid Organisations Administrator, Vol. 7., No. 8.
- Williams A (1995) SAP software in the UK Upstream Oil Industry Offshore Management Centre, The Robert Gordon University, Aberdeen.
- Williamson, K.C., Spritzer Jr., D.M., & Bloomberg, D.J. (1990) Modern Logistics Systems: theory and practice Journal of Business Logistics, Vol. 11, No. 2.
- Williamson, O E (1975) Markets and Hierarchies, Free Press, New York.
- Womack, J P, Jones, D T and Roos, D (1990) The Machine that Changed the World, Rawson Associates, New York.

Yan, H S and Jiang, J (1999) Agile concurrent engineering Integrated Manufacturing Systems, Vol 10, No 2.

Yin, R Y (1994) Case Study Research – design and methods (2nd Ed), Sage, London.

Zhang, Z and Sharifi, H (2000) A methodology for achieving agility in manufacturing organisations International Journal of Operations and Production Management, Vol 20, No 4.

Zinn, W. & Charnes, J. (1992) The Effect of Autocorrelated Demand on Customer Service Journal of Business Logistics, Vol. 13., No. 1.

APPENDIX A
Preliminary
Interview
Guide

Cranfield University

OFFSHORE SUPPLY CHAINS

INITIAL INTERVIEWS

Name..... Position.....

Company..... Date.....

Supply Chain: general

Supply Chain Issues

End Users

Who are they?

What do they want?

How much weight have they got to get what they want?

PCB for PC Chain.....what for offshore chain

Order/info/materials flow

Active/passive components

Computer/info systems

Inventory categories

Supply chain

Other systems

APPENDIX B
Integration
Survey

150.

2

4

SUPPLY CHAIN INTEGRATION in the OFFSHORE OIL INDUSTRY

This survey will help clarify the state of the art in supply chain management in the UKCS oil and gas industry. The research is being carried out for the purposes of academic research for a Phd at Cranfield University and the researcher is a lecturer in the Business School at The Robert Gordon University.

CONFIDENTIALITY

Your response will be treated in the strictest confidence and you or your company's identity will not be disclosed.

PLEASE ANSWER QUESTIONS BASED ON YOUR COMPANY'S ACTIVITIES IN THE UKCS

SECTION 1: Supply Chain Organisation

1.1 Please indicate which section of your company is responsible for *medium term planning* of the management of the following supply chain activities:

	(1) Supply Chain Dept	(2) Purch- asing dept	(3) Inventory/ Materials Dept	(4) Logistics Dept	(5) Logistics Contractor	(6) Contracts Dept	(7) None of these
1. Road freight transportation	☐	☐	☐	☒	☐	☐	☐
2. Chartering mariner vessels	☒	☐	☐	☐	☐	☐	☐
3. Warehousing	☒	☐	☐	☐	☐	☐	☐
4. Inventory management	☐	☐	☒	☐	☐	☐	☐
5. Containers/lifting equipment	☐	☐	☐	☒	☐	☐	☐
6. Deciding stock holding levels	☐	☐	☒	☐	☐	☐	☐
7. Supplier appraisal	☐	☒	☐	☐	☐	☐	☐
8. Supplier quality development	☐	☒	☐	☐	☐	☐	☐
9. Materials demand forecasting	☐	☐	☒	☐	☐	☐	☐
10. Performance monitoring	☒	☐	☐	☐	☐	☐	☐

If you have indicated 'none of these' to any of the above please indicate who is responsible overleaf:

If you have indicated 'none of these' to any of the activities in 1.1 above please indicate who is responsible below:

Activity No..... Responsible.....

Activity No..... Responsible.....

Activity No..... Responsible.....

1.2 Please indicate which section of your company is responsible for the *day-to-day operation* of the following supply chain activities:

	(1) Supply Chain Dept	(2) Purch- asing dept	(3) Inventory/ Materials Dept	(4) Logistics Dept	(5) Logistics Contractor	(6) Contracts Dept	(7) None of these
1. Arranging road transportation	[]	[]	[]	[x]	[]	[]	[]
2. Arranging collections from suppliers	[]	[]	[]	[x]	[]	[]	[]
3. Marine vessel routing	[]	[]	[]	[x]	[]	[]	[]
4. Allocating freight to vessels	[]	[]	[]	[x]	[]	[]	[]
5. Warehousing	[]	[]	[]	[x]	[]	[]	[]
6. Open storage	[]	[]	[]	[x]	[]	[]	[]
7. Containers/lifting equipment	[]	[]	[]	[x]	[]	[]	[]
8. Stock control	[]	[]	[x]	[]	[]	[]	[]
9. Processing orders from offshore/ user departments	[]	[x]	[]	[]	[]	[]	[]
10. Placing purchase orders	[]	[x]	[]	[]	[]	[]	[]

If you have indicated 'none of these' to any of the above please indicate who is responsible below:

Activity No..... Responsible.....

Activity No..... Responsible.....

Activity No..... Responsible.....

1.3 Does your company have a senior manager responsible for the supply chain

Yes

No

☒

☐

If, yes, please answer questions 1.4 and 1.5.

If, no, please go to question 2.1.

1.4 Is the senior manager responsible for the supply chain or immediate management team involved in the planning process for any of the following activities?

	Substantial Involvement	Minor Involvement	No Involvement
1. Drilling programmes	☐	☐	☒
2. Platform maintenance programmes	☐	☐	☒
3. Construction projects	☒	☐	☐
4. Other offshore projects	☒	☐	☐

1.5 At what level of reporting responsibility is the senior manager responsible for the supply chain within your company? Indicate how many levels below the Chief Executive Officer of your company responsible for UKCS.

Tick one box

1. One level below C.E.O. ☐

2. Two levels below C.E.O. ☒

3. Three levels below C.E.O. ☐

4. More than three levels
below C.E.O. ☐

SECTION 2: Supply Chain Developments

2.1 Companies often undertake programmes and initiatives. *Tick the box which best describes the status of your organisation with regard to the following:*

	Established and effective	Established but ineffective	Currently being implemented	Likely within 2 yrs	Relevant but unlikely	Not relevant	Don't know
1. Total Quality Management	☐	☐	☒	☐	☐	☐	☐
2. BS/EN/ISO 9000	☐	☐	☐	☐	☐	☒	☐
3. Investors in People	☐	☐	☐	☐	☐	☒	☐
4. Just-in-time purchasing/ deliveries from suppliers	☐	☐	☒	☐	☐	☐	☐
5. Supplier holding consignment stock in supplier's premises	☐	☐	☒	☐	☐	☐	☐
6. Supplier holding consignment stock in my premises	☐	☐	☐	☐	☐	☒	☐
7. Supplier involved in company project teams	☐	☐	☐	☐	☐	☐	☒
8. Supply base rationalisation (fewer suppliers)	☐	☐	☒	☐	☐	☐	☐
9. Supply base expansion (more suppliers)	☐	☐	☐	☐	☐	☒	☐
10. Strategic long-term supply agreements for materials	☒	☐	☐	☐	☐	☐	☐
11. Strategic long-term supply agreements for services	☐	☐	☒	☐	☐	☐	☐
12. Partnership relationships with material suppliers	☒	☐	☐	☐	☐	☐	☐
13. Partnership relationships with service contractors	☐	☐	☐	☒	☐	☐	☐
14. Total Cost of Ownership analysis	☐	☐	☐	☐	☐	☒	☐
15. Incentive-based contracts for service contractors	☒	☐	☐	☐	☐	☐	☐
16. Incentive-based contracts for Logistics contractors	☐	☐	☐	☐	☐	☒	☐
17. Incentive-based contracts for material suppliers	☐	☐	☒	☐	☐	☐	☐
18. Ordering by user direct to supplier	☒	☐	☐	☐	☐	☐	☐
19. Benchmarking of supply chain activities	☐	☒	☐	☐	☐	☐	☐
20. OTHER (please specify):	☐	☐	☐	☐	☐	☐	☐

.....

2.2 Development of outsourcing of supply chain activities. *Tick the box which best describes your organisation with regard to the following:*

	Established and effective	Established but ineffective	Currently being implemented	Likely within 2 yrs	Relevant but unlikely	Not relevant	Don't know
1. Use of Logistics contractor for warehousing/transportation	[]	[]	[]	[]	[]	[✓]	[]
2. Use of Logistics contractor for managing inventory	[]	[]	[]	[]	[]	[✓]	[]
3. Use of Logistics contractor for offshore marine distribution	[]	[]	[]	[]	[]	[✓]	[]
4. Use of Logistics contractor for purchasing	[]	[]	[]	[]	[]	[✓]	[]
5. Use of Logistics contractor for OTHER (state):	[]	[]	[]	[]	[]	[✓]	[]

2.3 Development of supply chain information systems. *Tick the box which best describes your organisation with regard to the following:*

	Established and effective	Established but ineffective	Currently being implemented	Likely within 2 yrs	Relevant but unlikely	Not relevant	Don't know
1. Electronic Data Interchange via fax to suppliers	[✓]	[]	[]	[]	[]	[]	[]
2. Electronic Data Interchange computer to computer	[✓]	[]	[]	[]	[]	[]	[]
3. Barcoding in offshore distribution	[]	[]	[]	[]	[]	[✓]	[]
4. Barcoding in warehouse	[]	[]	[]	[]	[]	[✓]	[]
5. Materials inventory system	[✓]	[]	[]	[]	[]	[]	[]
6. Materials inventory system linked with purchasing	[✓]	[]	[]	[]	[]	[]	[]
7. Supply chain information system that links purchasing, inventory and logistics	[✓]	[]	[]	[]	[]	[]	[]
8. Supply chain information systems that interface with accounting	[✓]	[]	[]	[]	[]	[]	[]

2.4 Which of the following best describes your company's current supply chain information system.
Tick ONE box.

- 1. Number of non-integrated systems custom-made []
- 2. Number of non-integrated standard packages []
- 3. Partially integrated network custom-made []
- 4. Partially integrated network standard package []
- 5. Fully integrated network custom-made [☒]
- 6. Fully integrated network standard package []
- 7. Fully integrated network customised standard package []
- 8 OTHER (state) []
.....

If you operate standard packages, please indicate name and supplier:

Software name.....

Software supplier.....

SECTION 3: Supply Chain Integration

3.1 Indicators of supply chain integration. *Please indicate the status of the following supply chain activities with regard to your company:*

	Established and effective	Established but ineffective	Currently being implemented	Likely within 2 yrs	Relevant but unlikely	Not relevant	Don't know
1. Job title cross-function (e.g. Supply Chain Manager)	☒	☐	☐	☐	☐	☐	☐
2. Integrated information systems	☒	☐	☐	☐	☐	☐	☐
3. Information access for end-users	☒	☐	☐	☐	☐	☐	☐
4. Information access for material suppliers	☒	☐	☐	☐	☐	☐	☐
5. Information access for service contractors	☐	☐	☐	☒	☐	☐	☐
6. Shared ownership of drilling schedules	☐	☐	☐	☐	☐	☒	☐
7. Shared ownership of maintenance schedules	☐	☐	☐	☐	☐	☒	☐
8. Shared ownership of production schedules	☐	☐	☐	☐	☐	☒	☐
9. Cross-functional supply chain task/project teams	☒	☐	☐	☐	☐	☐	☐
10. Cross-functional supply chain training programmes	☐	☐	☐	☐	☒	☐	☐
11. Senior management committ- ment to integrated supply chain	☒	☐	☐	☐	☐	☐	☐
12. Supply chain performance measurement	☐	☐	☒	☐	☐	☐	☐

3.2 Future indications for supply chain integration. *Please read the following statements and tick the box for the response that best indicates your company's position over the next 3 years:*

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	Don't know
1. I expect increased emphasis on integrated information systems within my company	☐	☐	☒	☐	☐	☐
2. I expect increased emphasis on electronic data interchange with suppliers and other parties	☒	☐	☐	☐	☐	☐
3. In my company the logistics/supply chain function increasingly will co-ordinate its activities with other departments	☒	☐	☐	☐	☐	☐
4. I expect growth in the sharing of information with material suppliers	☒	☐	☐	☐	☐	☐
5. I expect growth in sharing of information with service contractors	☐	☒	☐	☐	☐	☐
6. I expect growth in outsourcing of logistics/supply chain activities	☐	☐	☐	☒	☐	☐
7. Co-ordination of logistics/supply chain activities is increasingly part of the overall strategic planning process	☒	☐	☐	☐	☐	☐
8. I expect a 'shared vision' to be developed between my company and its suppliers	☐	☒	☐	☐	☐	☐
9. Sharing of resources between operators will be a growing feature	☒	☐	☐	☐	☐	☐
10. Partnering with service contractors will improve supply chain efficiency in the future	☐	☐	☐	☒	☐	☐

3.3 What is the practical outcome of supply chain integration for your company. *Tick ONE BOX that best describes your company's position.*

- 1. No effect ☐
- 2. Equal partnerships along the supply chain ☐
- 3. Relationships which favour you, over your suppliers and contractors ☐
- 4. Relationships which favour your contractors and suppliers over you ☐
- 5. Improved internal relationships only ☐
- 6. OTHER (please state)..... ☐
-
- 7. Don't know ☒

3.4 What best represents your company's overall business strategy. *Please tick ONE BOX.*

- 1. Reduction in production costs ☐
- 2. Reduction in development costs ☐
- 3. Reduction in working capital ☐
- 4. Expansion into new oil provinces ☐
- 5. Increased production from current assets ☐
- 6. Increased production revenue from the development of new assets ☐
- 7. OTHER (please state)..... ☒
- 8. Don't know ☐

SECTION 4: Supply Chain Attitudes

Please read the following statements and tick the box for the response that best indicates your opinion:

	Strongly agree	Agree	Neither agree or dis- agree	Disagree	Strongly disagree	Don't know
1. My company actively helps its suppliers to improve quality	☐	☐	☒	☐	☐	☐
2. My company actively helps suppliers to reduce costs	☐	☒	☐	☐	☐	☐
3. My company communicates with its suppliers' suppliers	☐	☐	☐	☒	☐	☐
4. My company shares forecasts/plans/call-offs with suppliers	☒	☐	☐	☐	☐	☐
5. My company encourages co-operation with other operators to use the same supplier	☐	☒	☐	☐	☐	☐
6. My company uses the threat of withdrawing business to secure low prices from suppliers	☐	☐	☐	☐	☒	☐
7. My company shares data on its own inventory levels with suppliers	☐	☒	☐	☐	☐	☐
8. My suppliers share detailed cost information with my company	☐	☐	☐	☒	☐	☐
9. My company provides detailed feedback on suppliers' performance	☐	☒	☐	☐	☐	☐
10. My company shares marine distribution resources with other operators	☒	☐	☐	☐	☐	☐
11. My company shares warehouse resources with other operators	☐	☐	☒	☐	☐	☐
12. Partnering arrangements with service contractors improve supply chain performance	☐	☐	☐	☒	☐	☐

SECTION 5: Obstacles and opportunities

There are a number of features which may have an impact on supply chain effectiveness. In your opinion what is the impact on the supply chain of the following for your company? Please tick box that is most applicable.

	Helps	Neutral	Hinders	Effect varies	Don't know
1. Corporate culture of company	☒	☐	☐	☐	☐
2. Corporate culture of suppliers	☐	☐	☐	☒	☐
3. Supply chain performance measures	☐	☐	☐	☐	☒
4. Incentive contracts for service contractors (not logistics)	☐	☐	☒	☐	☐
5. Incentive contracts for logistics contractors	☐	☐	☒	☐	☐
6. Financial resources	☐	☐	☐	☐	☒
7. Cost-benefit of supply chain relative to other activities	☐	☐	☐	☒	☐
8. Top management in UKCS	☒	☐	☐	☐	☐
9. Top management world-wide	☐	☒	☐	☐	☐
10. Size of company	☒	☐	☐	☐	☐
11. Investment in warehouses/supply bases	☒	☐	☐	☐	☐
12. Accounting systems	☐	☐	☒	☐	☐
13. Standard contractual terms and conditions	☒	☐	☐	☐	☐
14. Organisation structure	☐	☐	☐	☒	☐
15. Supply chain skills base	☒	☐	☐	☐	☐
16. Level of trust	☒	☐	☐	☐	☐
17. Information systems	☒	☐	☐	☐	☐
18. Partnering arrangements with service contractors	☐	☐	☒	☐	☐
19. Use of logistics contractors	☐	☒	☐	☐	☐
20. Arrangements with investing partners (i.e. other oil companies)	☒	☐	☐	☐	☐
21. Partnership accounting arrangements	☐	☒	☐	☐	☐
22. Oil industry economic atmosphere	☒	☐	☐	☐	☐
23. Distance from downstream competition	☐	☒	☐	☐	☐
24. Relative maturity of UKCS oil and gas assets	☐	☐	☐	☐	☒
25. Industry CRINE initiative	☐	☒	☐	☐	☐

SECTION 6: Classification Data

Please complete the following information about your company.

7.1 Your job title:.....

7.2 Number of staff immediately reporting to you (if appropriate).....

	Northern UKCS	Southern UKCS
7.3 Number of offshore production platforms operated:		
7.4 Number employed offshore (including contractors):		
7.5 Estimated annual spend: production	£(m)	£(m)
7.6 Estimated annual spend: drilling	£(m)	£(m)
7.7 Estimated annual spend: construction/development	£(m)	£(m)
7.8 Estimated total annual spend	£(m)	£(m)

7.9 Classify the age of your production installations based on number of years from first commissioned.

	Number	Estimated Total Annual Spend
over 20 years old		£(m)
15-19 years old		£(m)
10-14 years old		£(m)
5-9 years old		£(m)
up to 5 years old		£(m)

7.9 Classify the stage of development of the above production installations:

	Number	Estimated Total Annual Spend
Abandonment		£(m)
Decline		£(m)
Normal production		£(m)
Development		£(m)

Thank you for taking time to complete this questionnaire. *Please complete the following details. This is optional if you would prefer not to be identified.*

Please indicate if you would like a summary report of the findings of this survey []

Name: .

Company: .

Address:

Tel: .

Fax: .

Thank you for your time and assistance, please return the completed questionnaire by 31st August 1995 to:

Mr Douglas Nisbet,
The Robert Gordon University,
Offshore Management Centre,
Kepplestone Mansion,
Viewfield Road,
ABERDEEN,
AB9 2PW

Tel: (01224) 263116

APPENDIX C
Supplier Survey

LEAD TIMES IN THE OFFSHORE SUPPLY CHAIN

The purpose of this survey is to obtain information about the influences on supplier lead times for equipment manufacturers/service companies serving the offshore oil and gas industry.

- For the purpose of this study **'lead time' is defined as:** the time from receipt of customer order to the time of receipt of the equipment by the customer.
- In order to make the questionnaire as specific as possible, we shall ask you to complete it related to the product with the largest output that you manufacture for the offshore oil and gas industry – in the questionnaire we shall call this the **sample product**

Please note all information shall be treated in the **strictest confidence** and no individual respondent or company shall be identified within the thesis. Questionnaires have been coded to permit analysis of response rate.

If you have any queries on the completion of the questionnaire, please make contact.

If you are not the correct person to provide this information, please pass the questionnaire on to an appropriate colleague.

Please return the questionnaire in the envelope provided by 30th June 1999.

Douglas J Nisbet

Aberdeen Business School,
The Robert Gordon University,
Garthdee Road,
ABERDEEN,
AB10 6JQ

Tel: 01224-317557
E-mail: d.nisbet@rgu.ac.uk

Code:

***Please note all sheets
are double-sided>***

Please answer the questionnaire based on your own production location (thereafter defined 'your plant') rather than for your whole company.

1: Plant Profile

- 1.1 Is the ultimate ownership of your plant: (tick ONE box only)
A Publicly Quoted Company ☐
A Privately Owned Company ☐
- 1.2 Please give the nationality of the ultimate parent company(ies) of your plant
- 1.3 How many plants does the parent company control world-wide?
- 1.4 Please estimate the total area of your plant buildings:
Square Feet or Square Metres
- 1.5 How many people are employed at your plant?
- 1.6 What is your job Title?

2: Nature of Product

- 2.1 Please name the product produced for the offshore oil and gas market with the largest output (at manufacturing cost) in your plant (or system or package of products if that is typically the way your product is ordered):

- 2.2 For classification purposes please give an estimate of the typical cost to the customer of the product, system or package of products noted above (if you are a component supplier please give the cost of a single component not a whole order):

- 2.3 Please estimate what proportion of the plant's orders for the above sample product falls into these four categories:

Sales catalogue item	%
Sales catalogue with customer choice options	%
Customer specific design to repeat orders	%
Unique customer specific design	%
Total	100%

- 2.3 In a typical order for the sample product what proportion of sales value falls into the following categories:

Products	%
Services	%
Total	100%

- 2.4 Please classify the sample product into one of the following categories:

Tick ONE box only

Capital Goods (equipment used by other businesses as capital assets)	☐
Intermediate Goods (components, supplies etc. used by other businesses to produce their products)	☐
Consumer goods (non-capital goods for sale to users)	☐

2.5 With reference to *the sample product*, please estimate the following in a typical order:

Number of individual components in the finished product (as sold to customers)

Number of components or sub-assemblies manufactured by your plant in the finished product

Number of bought in components or sub-assemblies used in the finished product (as purchased from suppliers, but not including raw materials)

Number of raw material items for processing by yourselves used in the finished product

2.6 For the *sample product*, which of the following criteria are most important to the customer in your opinion

*Please rank the following criteria:
(1= greatest importance; 6= least importance)*

	Rank 1 to 6
Quoted Delivery Lead Time	
Reliability of Delivery Date or Service Level	
Product Features or Performance	
After Sales Service	
Brand Image/Reputation	
Price	

3 Lead Times

Answer the questions in this section related to the product which has the largest output (at manufacturing cost) in the plant, (i.e the sample product noted in 2.1 above).

3.1 Indicate your estimate of the *current* lead time over all customers (i.e. time from customer's order to customer's receipt of product):

Tick ONE box on each line

	< 1 month	1-3 months	3-6 months	6-9 months	9-12 months	12-18 months	Over 18 months
What is the shortest lead time?							
What is the average lead time							
What is the longest lead time							

3.2 In the last 2 years indicate the pattern of change in average lead times (if there has been no change go to question 3.4):

Tick ONE box

	1-3 months	4-6 months	7-9 months	10-12 months	Over 12 months
Lead times have reduced by					
Lead times have increased by					

3.3 In your opinion, what has been the main reason for change in lead times over the last 2 years:

3.4 On those orders with a short lead time, rank the following possible contributing factors:

Please rank the following criteria:
(1= greatest importance; 8= least importance)

	Rank 1-8
Standard catalogue item ordered by customer	
Components held in stock	
Capacity easily available at component suppliers	
Short lead times at raw material suppliers	
Low Re-work time	
Specification received on time from customer	
Customer specification not altered since time of order	
Other (state)	

3.4 On those orders with a long lead time, rank the following possible contributing factors:

Please rank the following criteria:
(1= greatest importance; 8= least importance)

	Rank 1-8
Special design required by customer	
Inability to stock special components	
Inability to book capacity at component suppliers	
Long lead times at raw material suppliers	
Changes in customer specification	
High re-work time	
Delay in decisions on specification from customer	
Other (state)	

- 3.5 For an order with **average** lead time for *the sample product*, indicate your estimate of the time taken within the following stages:

Tick ONE box on each line

	< 1 month	1-3 months	3-6 months	6-9 months	9-12 months	12-18 months	Over 18 months
Design Phase							
Material Procurement							
Component Manufacture							
Final Assembly and test							
Delivery							

- 3.6 With regard to material procurement, indicate which of the following statements apply in your opinion:

Circle ONE number for each statement

Agree

Disagree

	1	2	3	4	5	6	7
Our suppliers are able to significantly reduce the lead times of critical path (pacing) items in an urgent case							
Our component/sub-assembly suppliers have the ability to react rapidly to requests for new products/services							
Our raw material suppliers have the ability to react rapidly to requests for new products/services							
Our component/sub-assembly suppliers are able to rapidly change the level of their production volume to us on request							
Our raw material suppliers are able to rapidly change the level of their production volume to us on request							

4: Information Communication

Answer the questions in this section related to the product which has the largest output (at manufacturing cost) in the plant, (i.e the sample product as noted in 2.1 above).

- 4.1 With regard to the communication of information *from your customer to you*, indicate which statements apply in your opinion

Circle ONE number for each statement

Agree

Disagree

	1	2	3	4	5	6	7
Customers transmit technical specifications in a timely manner							
Customers communicate changes in specification in a timely manner							
Customers provide feedback on our technical performance							
Customers provide feedback on our delivery performance							
Customers involve us in their appraisal of us as a supplier							
Customers involve our people in regular team meetings							
Customers provide us with advance warning of potential orders							
Customers provide us with information on their costs							

- 4.2 With regard to the communication of information *from you to your suppliers*, indicate which statements apply in your opinion:

Circle ONE number for each statement

Agree

Disagree

	1	2	3	4	5	6	7
We transmit technical specifications to our suppliers in a timely manner							
We advise changes in specification to our suppliers in a timely manner							
We provide suppliers with feedback on their technical performance							
We provide suppliers with feedback on their delivery performance							
We involve suppliers in regular team meetings with our people							
We provide suppliers with advance warning of potential orders							
We provide suppliers with information on our costs							

- 4.3 With regard to the communication of information *from your supplier to you*, indicate which statements apply in your opinion:

Circle ONE number for each statement	Agree			Disagree			
	1	2	3	4	5	6	7
Suppliers effectively communicate their capacity constraints to us	1	2	3	4	5	6	7
Suppliers advise us about problems in completing our order in a timely way	1	2	3	4	5	6	7
Suppliers provide us with information about their own performance	1	2	3	4	5	6	7
Suppliers involve our people in regular team meetings	1	2	3	4	5	6	7
Suppliers willingly provide us with information about their costs	1	2	3	4	5	6	7

5: Supplier Relationships

- 5.1 The following information is about your relationship with your customers for the *sample product*.

(Choose either A or B for each pair of statements. Circle the letter beside the statement that most applies to your company, in your opinion – please note that the statements have been RANDOMISED).

- A. We are one of the few companies which can manufacture and supply the products we produce
- B. There are many competitors who can supply similar products as ours

- A. We require to bid for most new and repeat business in an open tender situation
- B. Customers tend to seek a price estimate from us alone, without discussions with other suppliers

- A. Our customers have a long-term commitment to us
- B. The commitment of our customers is on an order-by-order basis

- A. Our contracts with our customers are only a broad trading framework
- B. Our contracts with our customer are detailed, substantive documents

- A. Contingencies in our contracts are written out and followed strictly
- B. We resolve difficulties by agreement mutually on a case-by-case basis

- A. We often start production before a written purchase order is received
- B. We never start production until a written purchase order is received

- A. Our customers use multiple sources of supply for our main product
- B. Our customers depend on us solely for the source of supply for our main product

- A. Our customers rely on our QA system and undertake minimal inspection
- B. Our customers undertake a 100% inspection on delivery

- A. Communication with our customers are infrequent and formal
- B. Communication with our customers are frequent and involve many of our staff

- A. Our customers rarely share their technical expertise with us
- B. Our customers regularly are involved in sharing technical expertise with us

- A. There is much risk sharing between us and our customer
- B. Our customer does little to share risk over cost fluctuations

- 5.2 The following information is about your relationship with your suppliers which supply materials or services related to the *sample product*.

(Choose either A or B for each pair of statements. Circle the letter beside the statement that most applies to your company, in your opinion – please note that the statements have been RANDOMISED).

- A. We have the choice of many suppliers who can supply similar products
- B. We have a limited choice of few companies which can manufacture and supply the products we require

- A. We require our suppliers to bid for most new and repeat business in an open tender situation
 B. We tend to seek a price estimate from a single supplier, without discussions with other suppliers
- A. The commitment to our suppliers is on an order-by-order basis
 B. We have a long-term commitment to our suppliers
- A. Our contracts with our suppliers are only a broad trading framework
 B. Our contracts with our suppliers are detailed, substantive documents
- A. Contingencies in our contracts with suppliers are written out and followed strictly
 B. We resolve difficulties in supply agreements mutually on a case-by-case basis
- A. Our suppliers often start production before a written purchase order is received
 B. Our suppliers never start production until a written purchase order is received
- A. We depend on one source of supply
 B. We use multiple sources of supply for supply
- A. We undertake a 100% inspection on receipt from our suppliers
 B. We rely on our suppliers' QA system and undertake minimal incoming inspection
- A. Communication with our suppliers are infrequent and formal
 B. Communication with our suppliers are frequent and involve many of our staff
- A. We regularly are involved in sharing technical expertise with our suppliers
 B. We rarely share technical expertise with our suppliers
- A. We expect our suppliers to bear the risk of cost fluctuations
 B. There is much risk sharing between us and our suppliers
- A. We tend to undertake repeat business with our suppliers because we genuinely enjoy doing business with them
 B. We tend to undertake repeat business with our suppliers because it would be too expensive for us to change suppliers

5.3 With regard to your relationship with your suppliers, indicate which of the following statements applies to your organisation in your opinion:

<i>Circle ONE number for each statement</i>	<i>Agree</i>				<i>Disagree</i>			
We share both risk and reward with our suppliers	1	2	3	4	5	6	7	
We are able to exert influence and control over our suppliers	1	2	3	4	5	6	7	
We have mutually beneficial goals with our suppliers	1	2	3	4	5	6	7	

5.4 With regard to your suppliers, indicate which factors are in your opinion the most important with regard to maintaining good supplier relations:

<i>Circle ONE number for each factor</i>	<i>Most important</i>				<i>Least important</i>			
Keeping delivery promises	1	2	3	4	5	6	7	
Keeping promises with regard to booking of capacity	1	2	3	4	5	6	7	
Doing a little more than the minimum expected	1	2	3	4	5	6	7	
Performing their tasks competently	1	2	3	4	5	6	7	

- 5.5 With regard to your suppliers overall, indicate in your opinion how well they perform with regard to the following factors:

<i>Circle ONE number for each factor</i>	<i>Good Performance</i>				<i>Poor Performance</i>		
Keeping delivery promises	1	2	3	4	5	6	7
Keeping promises with regard to booking of capacity	1	2	3	4	5	6	7
Doing a little more than the minimum expected	1	2	3	4	5	6	7
Performing their tasks competently	1	2	3	4	5	6	7

6: General Information

- 6.1 Please give a brief description of the *product with the largest output (at manufacturing cost) in the plant*, i.e. the sample product as noted in 2.1 above:

--

- 6.2 Please give a brief description of the main processes involved:

Primary processing stages (e.g. component machining, component assembly)

--

Secondary processing stages (e.g. product assembly, packaging, finishing)

--

- 6.3 If you would like a copy of the results of the survey, please enter the following details (optional)

Name	
Address	
Telephone	
E-mail	

Thank You – please post in reply paid envelope provided by 30th June 1999

APPENDIX D
Secondary
Interview Guide

	Project/Contract Type Questionnaire <i>DATE:</i>
Name	
Company	
Project/ Contract	
Start	
End	
Cost/Value	
Description	
Phases	
Time Reduction	
Reasons	

Pacer 1 & how changed?	
Pacer 2	
Pacer 3	

Pacer 1: Description	
Types	
Modular Packages	
Typical Lead Times	
Manufacturers /Contacts	
Reasons for Lead times	
Product Standardis- ation	
Modularisat- ion	
Functional cf technical	
Re-usability Targets	
% Reduction Targets Types.	

Pacer 2: Description	
Types	
Modular Packages	
Typical Lead Times	
Manufacturers /Contacts	
Reasons for Lead times	
Product Standardis- ation	
Modularisat- ion	
Functional of technical	
Re-usability Targets	
% Reduction Targets Types.	

Pacer 3: Description	
Types	
Modular Packages	
Typical Lead Times	
Manufacturers /Contacts	
Reasons for Lead times	
Product Standardis- ation	
Modularisat- ion	
Functional cf technical	
Re-usability Targets	
% Reduction Targets Types.	

APPENDIX E
Case Research
Interview Guide

TELEPHONE INTERVIEW QUESTIONNAIRE

Supply Environment:

Company:

Name:

Date:

SAMPLE Product:

No	Question	Answer
1.	What is the average lead time for the sample product?	
2.	What is the shortest lead time?	
3.	Why short? standard repeat item components in stock capacity available at suppliers short lead times at raw material suppliers low re-work time spec on time from customer no alterations on customer spec	
4.	What is the longest lead time?	
5.	Why long? special customer design inability to stock special components inability to book capacity at component supp. long lead times at component suppliers long lead times at raw material suppliers high re-work delay in decisions on spec form customer spec changed since order	
6.	Has there been any change in average lead times in the last 2 years? Why?	

7.	What is the most important pacing component to affect overall lead time? (Pacer 1)	
8.	Lead time?	
9.	Reason?	
10.	How many suppliers do you have for Pacer 1?	
11.	Identify main supplier of pacer 1.	
12.	Can this supplier significantly reduce their lead times to you in an urgent case? How?	
13.	Can this supplier react rapidly to requests for new products? How?	
14.	Can this supplier change their production volume to you rapidly? How?	
15.	What is the second most important pacing component to affect overall lead time? (Pacer2)	
16.	Lead time?	
17.	Reason?	
18.	What is the third most important pacing component to affect overall lead time? (Pacer 3)	
19.	Lead time?	
20.	Reason?	

21.	Have you used the same supplier for these pacers over the last 2 years or has there been any change? If so, why?	
22.	Design phase: how long?	
23.	Design phase: actual work?	
24.	Design phase: reasons for difference? <i>wait customer decisions</i> <i>wait internal decisions</i> <i>queue for capacity</i> <i>re-work time</i> <i>other</i>	
25.	Procurement phase: how long?	
26.	Procurement phase: actual work?	
27.	Procurement phase: reasons for difference? <i>wait customer decisions</i> <i>wait internal decisions</i> <i>queue for capacity</i> <i>re-work time</i> <i>other</i>	
28.	Manufacture phase: how long?	
29.	Manufacture phase: actual work?	
30.	Manufacture phase: reasons for difference? <i>wait customer decisions</i> <i>wait internal decisions</i> <i>queue for capacity</i> <i>re-work time</i> <i>other</i>	
31.	Assembly phase: how long?	
32.	Assembly phase: actual work?	

33.	Assembly phase: reasons for difference? wait customer decisions wait internal decisions queue for capacity re-work time other	
34.	Testing phase: how long?	
35.	Testing phase: actual work?	
36.	Testing: reasons for difference? wait customer decisions wait internal decisions queue for capacity re-work time other	
37.	Delivery phase: how long? Why?	
38.	Has there been any change in the extent of product standardisation for the sample product in the last 2 years?	YES / NO
39.	If, so what?	
40.	Has impetus for standardisation come from your company or from your customer?	COMPANY / CUSTOMER
41.	Are there differences to customers' approaches to standardisation?	

42.	What impact has standardisation had on lead times?	
43.	Has there been any change in the extent of a modular approach to production in the last two years?	
44.	If, so what?	
45.	Has impetus for modularisation come from your company or from your customer?	COMPANY / CUSTOMER
46.	Are there differences to customers' approaches to modularisation?	
47.	What impact has modularisation had on lead times?	
48.	Has there been any change in the use of functional rather than technical specs by your customers?	
49.	Has there been any change in the use of functional specs by you with your suppliers?	
50.	If so, what impact has the use of functional specs had on lead times?	

51.	Do you track where the same components are used in different models/orders?	
52.	Do you operate 're-usability' targets?	
53.	If so, what impact have the targets had on lead times?	
54.	Do you operate %age reduction targets on part numbers?	
55.	If so, what impact has this had on lead times?	
56.	Is QA with your suppliers based on your inspection or based on supplier responsibility?	
57.	If not supplier responsibility, why not?	
58.	How often do you undertake meetings with your pacer suppliers?	
59.	What matters are discussed at these meetings?	

60.	In what ways , if any, do you provide support for your suppliers? <i>training consultancy technical/product information quality development supply chain improvement</i>	
61.	Do you provide pacer suppliers with feedback on their technical or delivery performance?	YES / NO
62.	If so, what impact has feedback had on lead times?	
63.	Do you provide pacer suppliers with direct access to your production plans/forecasts?	YES / NO
64.	If so , how? <i>computer to computer access paper schedule verbal</i>	
65.	What impact has access to production plans/forecasts had on lead times?	

66.	What is the nature of your contracts with your main customer for the sample product?	
67.	<p>What innovation/changes has there been in the nature of contracts with your customers in the past 2 years?</p> <p><i>length</i> <i>life cycle costing</i> <i>supply chain requirements</i> <i>open-book costing</i> <i>service level agreements</i> <i>performance measures</i></p>	
68.	Do your contracts with your customers have risk/reward elements?	YES / NO
69.	Have these risk/reward elements influenced change in lead times? If so, how?	
70.	What is the nature of your contract with your pacer suppliers?	
71.	What innovation/changes has there been in the nature of contracts with your suppliers in the past 2 years?	

72.	Have you cascaded risk/reward contract terms to your suppliers?	YES / NO
73.	Have these changes in contract terms with your suppliers influenced lead times? If so ,how?	
74.	To what extent do your customers involve you at the product specification stage?	
75.	What is the nature of the involvement? Are multi-functional teams used?	
76.	To what extent, if any, has early involvement influenced lead times?	
77.	To what extent do you involve your suppliers at the product specification/design stage?	
78.	What is the nature of the involvement? Are multi-functional teams used?	

79.	To what extent, if any, has early involvement influenced lead times?	
80.		
81.		
82.		
83.		

APPENDIX F

Case Environment Background

APPENDIX F

Case Environment Background:

North Sea Oil Development

Exploration for oil in the UK. sector of the North Sea had its origins in the mid-1960's. Earlier activity in the southern North Sea had located significant finds of natural gas and in 1969 the first oil strike came in what was subsequently developed as the Montrose Field. This discovery in the Central North Sea was rapidly joined by the two major fields that formed the backbone of North Sea development: Forties, operated by B.P. and Brent, operated by Shell. This study shall confine itself to the offshore industry that has developed in the deep waters of the Central and Northern North Sea.

The Central North Sea contains the area from 56 degrees North (approximately opposite the Firth of Forth) to 59 degrees North (approximately opposite the mid-point of the Orkney Isles). In addition to the Montrose and Forties field previously mentioned, major fields include the Brae complex, Claymore, Tartan, Buchan, Kittiwake and Gannet fields. The development of the Northern North Sea between 59 degrees North and 62 degrees North has two main concentrations, Bruce and Beryl fields to the south of the sector and the fields to the North East of Shetland including the Brent complex, previously mentioned, and Magnus, Thistle, Hutton and Ninian fields.

There are currently 60 fields on stream producing around 2 million barrels of oil per day. There are still some 13 fields under development in the northern sector, whilst 7 fields have ceased production. Whereas these production figures indicate a massive industry, they must be put into the perspective of world oil production of some 66 million barrels per day. Oil reserves remaining in the North Sea are estimated at around 4,000m barrels. Although the expectation would be that this figure would continue to be reduced year on year due to depletion of the reserves, in previous decades the figure has tended to do the opposite due to increasing exploration activity and new finds adding to the total.

As the North Sea oil province matures, it is clear that reserves are likely to move towards a position of net reduction. Three factors are, however, positively influencing the position. Firstly, new finds continue to be made albeit that they tend to be of a smaller nature and the significance of oil finds West of Shetland have still to be fully quantified. Secondly, improved technology is not only permitting the development of smaller fields due to lower cost sub-sea technology replacing the traditional production platform or allowing the find to be tied in to existing production facilities, but also allowing extension in the life of existing fields due to improved secondary or tertiary recovery techniques. Thirdly, cost reduction techniques are impacting on the capital base of offshore production and extending the field life of mature fields by maintaining an economic rate of return for a longer period than first envisaged.

In 1999 the "upstream" oil and gas sector was estimated as representing an annual £9bn supply market for products and services and provides employment for 300,000 people throughout the UK (Source: LOGIC, 1999).

F.1 The Macroeconomic Background

The supply of relatively inexpensive sources of oil and gas has been a central element in the economic growth of developed nations from the 1970's through to the 1990's. This inevitably brought the provision of reliable and politically stable supplies of oil and gas as a key interest of the UK Government and led to economic regulation and control mechanisms. The aspects of control of the Offshore Industry are related to production control and a variety of fiscal measures related to obtaining taxation revenues from the industry and relief measures to encourage selective behaviour by the industry in line with government objectives.

Production Control

The Secretary of State for Energy has general powers under a system of offshore production licensing to control and influence rates of development and production of oil and gas. Licenses have been issued in batches over time, called licensing rounds. Individual agreements under which licensees operate vary from field to field and production consents may extend for several years. At the same time, UK.

Governments have recognised that the political stability of the U.K.C.S., combined with its proximity to markets for oil, has been a key determinant in foreign investment being attracted to a relatively complex and expensive oil province. The North Sea has been recognised as a hostile environment, mainly due to the deep water characteristics of the fields. The technology for exploiting deep water reserves has essentially been developed in the North Sea, but it has required massive capital investments. UK government policy has thus tended to avoid production controls having an adverse effect on investment and in particular ensuring that production controls did not prejudice the ability of operators to achieve a return on their capital. This return is only generated by marketing the flow of oil in order to recoup investments at the earliest possible stage. The importance of early cash proceeds to massive capital projects can be perhaps paralleled with the difficulties that were experienced by the Channel Tunnel project. Measures included no delays imposed on the development of UKCS oilfields discovered before the end of 1975 under licenses held at the time the statement was made in December 1974 and that no production cutbacks would be made until 1982 at the earliest or until four years after production, whichever was the later. Oilfields discovered after 1975 with pre-1975 licences would not suffer cutbacks in production until 150% of capital investment in the field had been recovered. In addition, production cutbacks in these and any subsequent fields would have full regard to the technical and commercial aspects of the fields in question.

Later government policy in the 1980's emphasised that a key element in its consideration of development and production rates would be the need to ensure good oilfield practice, consistent with optimum oil and gas recovery both in existing fields and with regard to new field development proposals. In 1982, the government announced that it would not require production cut-backs from any field before the end of 1984.

Fiscal Controls

Royalty is paid to the government in respect of oil produced from offshore fields at a rate of 12.5% of the value of oil. The value is calculated as being landed values for

tax purposes and in licenses issued in the first to fourth rounds, the cost of bringing the oil ashore and its initial treatment is included in the calculation. The final valuation of the oil also takes into account agreed abandonment costs. Royalty is not payable on fields gaining development consent after 31 March 1982.

Licensees are also liable to Petroleum Revenue Tax (PRT) payable in respect of profits from oil and gas production on the UKCS and is currently charged at the rate of 75%. Profits of a field for PRT purposes are calculated by deducting development and operating costs, including royalties if applicable, from production revenue. Interest and other financial costs are not deductible in determining profits for PRT purposes, but a supplemental allowance of 35%, known as 'uplift' is available. This qualifies almost all capital expenditure incurred up to 'payback'. There are two other significant reliefs for PRT. First, an oil allowance of one million tonnes of oil per year for all offshore fields given development consent after 31 March 1982 lying outside the Southern Basin. There are cumulative limits of 10 million and 500,000 tonnes respectively. Fields receiving development consent after 1 April 1982 have a limit of 500,000 tonnes per annum subject to a cumulative limit of 5 million tonnes. The second category of relief provides a 'safeguard' provision to limit PRT liability in any chargeable period to 80% of the excess of the adjusted assessable profit over 15% in the early years of a field's life. The adjusted assessable profit is broadly the production revenue less deductions for the period related to royalty and expenditure not qualifying for uplift. Profits for oil and gas production are also subject to Corporation Tax. Royalties and PRT are deductible in computing income for corporation tax purposes.

The Petroleum Act 1987 contained statutory provisions to enable abandonment costs to be carried back for royalty, broadly 70% for royalty paying fields. The 1990 Finance Act included a package of measures designed to improve the tax treatment of future abandonment costs. These included a 100% allowance for abandonment expenditure against corporation tax.

The stability of the fiscal regime was fundamentally altered in the 1993 Budget. The government's stated philosophy was to adapt the North Sea tax regime to the requirements of a mature oil province. Broadly the shift was to encourage methods of

extending and reducing the cost base of existing oilfields. Unfortunately this was undertaken at the expense of the abolition of PRT tax relief, whereby the cost of exploring for and appraising future fields may be set against the PRT profits of existing fields. This led to a substantial reduction in exploration activity reducing rigs operating in the Central and Northern UKCS from 48 in 1991 to 28 in 1993. Reviewing the UK sector following the 1993 budget changes Hughes (World Oil, Aug. 1993) expressed the concern that funds saved on PRT payments may not be routed to exploration and development projects and the danger of re-routing of funds by the international oil operators to other parts of the world was also noted as a growing concern. These concerns were, however, tempered by the advantage that exists in the ability of current infrastructure to support the commercial viability of marginal fields. Balanced against this are, of course, the immediate cash flow benefits accruing to mature fields and the benefits accruing to newly-developed fields, particularly the large fields. As an example of the benefits, a group of nine companies, led by BP, accelerated plans for a \$2.25 billion oil/gas development project in the Central North Sea as result of the budget changes. The project, Eastern Trough Area Project (ETAP) linked four major and five smaller fields located east of Aberdeen.

Following the downturn in exploration activity after the 1993 budget, exploration and appraisal drilling activity returned in 1995 almost to pre-1993 levels. According to Scottish Enterprise forecasts within the UKCS, overall annual spending was estimated to be £7.8 billion with some £1.12 billion committed to exploration and appraisal and £3.3 billion to development. The Atlantic frontier, west of Shetland is an area of great expectation.

F.2 The Microeconomic Background

As a standard product in commodity markets the price of oil is substantially influenced by supply and demand. The price of North Sea oil is based on a commodity referred to as Brent Blend. At the start of North Sea development up to 1978, prices were reasonably stable around \$12-13 per barrel. The period from 1979 until the dramatic oil price collapse of 1986 saw prices around \$30 per barrel. From

1986 to 1999 prices tended to be relatively stable once more, but at a level somewhat below \$20 per barrel. In 1999 another rapid price collapse brought the price of oil to below \$10 per barrel. In 2000 the price has climbed once more to over \$30 per barrel. Supply factors tend to dominate the price of oil, worldwide collusion by producers such as through OPEC substantially dictating supply.

Demand factors such as manufacturing decline in western Europe, environmental pressures on hydrocarbon emissions and alternative energy sources such as electricity perhaps can be regarded as a long term backdrop rather than a major influence factor. Energy demand does, however, continue to exhibit growth, but the rate of growth is slowing. This growth, even in recessionary times in USA and Western Europe, indicates that market conditions will not be a substantial limiting factor to the North Sea oil industry. Even taking into account non-UK sectors of the North Sea and other Western European fields, the reserves are estimated at 18,400m barrels, only 1.8% of world-wide reserves. As a world player, therefore, the North Sea is relatively small. Competition within multi-national oil companies for funds for capital development of more marginal fields, together with the ongoing support for more mature fields is thus seen as an important influence on the future of the industry in the UKCS.

The UKCS has reached a mature phase in its development. Most oilfields are in a decline phase and it will be increasingly difficult for lower volumes of throughput to profitably offset operating costs. There are opportunities to use 'tie-ins' of new subsea developments to existing platforms and utilise current transportation facilities. The opportunity to undertake tanker-loading direct from offshore facilities, in order to reduce the capital costs of pipelines for low-volume, short-life fields, is a solution, but one which the environmental lobby regards with horror. It is clear, therefore, that opportunities must be sought for cost reduction. Whereas, this was previously regarded as an engineering and technological domain, increasingly management aspects have been emerging as more, if not the most important considerations.

F.3 The Technological Environment

The technological response to the development of new, smaller oilfields is centred on the ability to advance subsea solutions. Current technology is based on developments

in water depths of less than 180 metres, using divers for development and subsequent maintenance work. The opportunity to continue these developments is based on a limitation of a safe diving depth of 300 metres. This is not a limiting factor on the UKCS and although development of diverless technology is limited by lack of standardisation of equipment, there are opportunities for contributions by diverless methods.

The low cost solution for these 'satellite' fields is clearly based on the ability to tie back to host platforms. The technological problem is to achieve this at greater depths and over longer distances from the host. Current distances are in the range of 15 kilometres, depleting the reservoir naturally or by artificial lift. Artificial lift is achieved by injecting gas or water into the reservoir to displace depleted fluid volumes and maintain flow pressures. The ability of the reservoir to produce is fundamentally dependent upon having enough pressure to drive the product from the reservoir, up the well bore, along a seabed pipeline and up to the surface of the host platform. The more remote the platform, the greater the pressure loss in the system and thus the limits on distance. Technological developments have included the introduction of subsea pumps to improve this situation and increase distances.

Improved geological survey techniques are also improving the possibility of finding oil in more complex geological structures and reducing exploration drill time. An example of this is Amerada Hess's Scott field in blocks 15/21 and 15/22. The geology of this area is extremely complex and characterised by tilted fault blocks where conventional geological approaches and standard 2-D seismic surveys would not have provided the leads to oil and gas accumulations. 3-D seismic technology provided the answer, but only part of it according to a profile on the field development by Euroil (July 1993). Euroil comment that it was only due to Amerada Hess's management ability to accept risk that allowed Scott to be the success story that it has become. Mirroring the unexpected success of Hamilton Brothers of bringing the first oil ashore from the North Sea, in advance of the major player BP, Amerada's plans for exploration drilling were rejected by the partners on block 15/22. Monsanto Oil operated adjacent block 15/21 and had discovered oil in the Ivanhoe and Rob Roy structures, but in small quantities. Amoco, as operator of block 15/22 had found oil in a thin lower zone within this block, but had not considered the find of much interest.

In 1985, Leon Hess made the brave decision to buy Monsanto oil, based on an assessment by Amerada Hess's management of the potential indicated by their geological team. The subsequent exploration drilling discovered more than 600 million barrels of oil and 300 billion cubic feet of gas. Time reduction in the development of the Scott field was also achieved by "pre-drilling" 16 wells before the platform was built and located on site. "Pre-drilling" tends to be regarded as another risky strategy, with problems only coming to light after production has taken place. Amerada Hess reduced this risk by an extensive programme of exploration and appraisal wells to allow better understanding of the reservoir. At plateau production Scott wells are expected to produce oil at a minimum rate of 194,000 barrels per day, sustaining this rate for 5 years and then gradually declining to give the field a life of 15 to 20 years.

F.4 The Managerial Environment

The emphasis within the offshore oil industry on the UKCS has reflected the world-wide position. It has essentially been an engineering-led industry, based on a capital intensive strategy and project managed activities. Influenced by knowledge from refineries downstream, the oil production platform was regarded as essentially a fixed cost continuous process, where the only real cost influences can be applied at the design stage. The cost of developing North Sea oil has historically been high, highlighted by a comparative study carried out by BP which calculated development cost at double or more for similar fields in the Gulf of Mexico (LOGIC, 1999b). Clearly in the past these differences have been explained by the various technical and environmental differences between the two provinces. There is a suggestion (LOGIC, 1999b) that differences can be put down principally to the way business has traditionally been conducted in the two provinces. An example provided was that a solution to decrease failure rates was to invest large capital sums in the duplication of equipment. Another feature of the North Sea offshore industry is an apparent inbuilt desire to seek the ultimate technical excellence for any specific application. This has led to time and costs in producing one-off specifications, when perfectly adequate solutions were available 'off the shelf' at realistic cost savings of 25% (LOGIC, 1999b).

There are indications, therefore, that managerial aspects will gain in importance within a mature UKCS offshore industry. Furthermore, informed comment suggests that the emphasis for this change is very much strategy-led. The list of strategic items includes: low-cost production operations; long-term investment based on focused research; personnel management policies to motivate, develop and appropriately reward staff; carefully managed relationships with suppliers to ensure the availability of suitable raw materials; often, nowadays, on a 'just in time' basis in order to minimise inventory costs. There is an industry view that value is being created more successfully in some companies than in others, but that there are very few in which the basic strategic processes cannot be improved.

The link between advancing technology and practical management in a mature oil province is starting to be evidenced within the industry. Based on Quality Management considerations, 'Fit for Purpose' solutions have been considered a key issue within the industry for some years. Due to the lead time involved in the design and build of new production facilities it is only in the present decade that these solutions can be seen as being put into effect. An example of the twinning of technology with managerial objectives of suitable cost in line with the industry environment is Foinaven Phase 1, on BP's west of Shetland field. This development is utilising a £550m floating production platform, instead of a conventional steel or concrete structured anchored to the sea bed.

Concentration Convergence

The companies involved in North Sea exploration and production are large corporate organisations engaged in multi-national markets and to the casual observer could be regarded as very similar. An interesting feature about the companies is that they are geographically concentrated in their locations in the various oil provinces world-wide. This concentration is particularly obvious in the North Sea, with the location of decision-making in Aberdeen, a regional market town with a population of around one quarter of a million. Industry observers thus suggest that as an industry, it acts very much like a club. Swift communication lines within the concentrated locations lead to managerial trends and ideas being adopted and rapidly spread throughout the companies. Often led by the larger players such as BP and Shell, the industry has adopted many of the current managerial approaches such as quality assurance of

suppliers through BS/EN/ISO 9000 (although surprisingly few oil companies actually embrace the standard themselves); total quality management; learning companies; business process re-engineering; outsourcing; partnering and alliances; have all been adopted and spread rapidly. The substantial involvement of the companies in consortia for bidding for acreage, development and production for oil has also led to an unusual closeness between companies that would be unlikely in a manufacturing environment, for example. In a particular development, one company, normally the one with the largest share investment, will be appointed as the operator for the development. This company will then become fully operationally involved and be responsible for all phases of subsequent developments, the other shareholding companies essentially becoming 'sleeping' partners. The latter term is perhaps misleading in an offshore industry context, as the partners take an active interest in the ongoing development. Occasionally this can be at such a level of detail as to be stifling to the management of the operator. Many of the control mechanisms, financial and operational, stemming from operational partners have caused substantial bureaucracy and a control culture that is somewhat adrift from most current managerial styles.

National Culture

Whereas similarities can be observed within the industry there are also a number of factors leading to differences. Although the companies are international in their activities most are based on ownership within one nationality. Thus there are the USA nationals such as Marathon Oil, Phillips Petroleum, Conoco and Chevron. Considering the lack of success in oil exploration in the French sector, French companies have substantial involvement in the North Sea including Total Oil Marine and the French-led Elf Enterprise consortia, including the previous Occidental, who chose to exit North Sea activity following the Piper Alpha disaster. Merger activity has since seen the creation of the Franco-Belgian Total-Fina-Elf. The Anglo-Dutch company Shell is a long established organisation with British credentials and operating in partnership with US giant Exxon (Esso in the UK), who decided not to be involved on their own account right at the start of oil activity in the North Sea, a decision that has now been reversed with a small independent North Sea presence. Then there is the British pedigree of BP Exploration, founded by merger with the originally government-owned British National Oil Company (BNOC), and now

merged with US giant Amoco to create BP Amoco. Oil industry observers have been aware for some time of the differing cultural approaches of the different nationalities.

Appendix G
Case Research:
Data Sources

G2

Alphabetical List of Companies

ABB Vetco Gray
ABB Control Valves
ABB Kent Intro
Amec
Amerada Hess
Baker Oil Tools UK Ltd
Baker Hughes Inteq Ltd
BP Exploration and Production/BP Amoco
Brown and Root Plc
Camco Ltd
Conoco UK Ltd
Cooper Cameron Plc
Ferguson & Timpson Ltd
Fomas
FMC Corporation
Greene Tweed Ltd
Hallite Ltd
Howco Ltd
Ingram Cactus Ltd
Maintool Ltd
Hansen Springs Ltd
Marathon Oil UK Ltd
Masterflo Plc
Merpro Ltd
McEvoy Ltd
McKellar Engineering
Petroleum Engineering Service Plc
Rubber Atkins Ltd
Shell UK Exploration and Production
Texaco UK Ltd
Total Fina Elf
Tronic Ltd
VCL Ltd

Schedule of Respondents

<i>Code</i>	<i>Name</i>	<i>Functional Perspective</i>	<i>Date</i>
CA1	G Johnston	Purchasing Manager	22/11/99
CA2	P Murdoch	Wellhead Purchasing Mgr	22/11/99
CA3	J Robertson	Wellhead Engineer	13/12/99
CA4	E Guthrie	Drilling Manager	15/12/99
MA5	A Bradley	Sales Project Manager	24/11/99
MA6	A Lindsay	Supply Chain Manager	08/06/99
MA7	P Ash	Sales Project Manager	01/10/99
SA8	G Aitken	Sales Manager	08/12/99
SA9	D McKellar	Managing Director	10/12/99
SA10	D Arniston	Divisional Manager	08/12/99
CB1	T Collins	Purchasing Supervisor	15/10/99
CB2	G Watson	Supply Chain Manager	14/12/99
CB3	S Nuttall	Supplies Manager	22/01/99
CB4	G Clutterbuck	Strategic Purchasing Mgr	22/01/99
CB5	P Compton	Project Manager	20/07/99
CB6	B Summerfield	Project Manager	22/07/99
MB7	M Robinson	Sales Project Manager	14/07/99
MB8	A McIntyre	Materials Manager	05/02/99
MB9	S Roberts	Materials Manager	20/09/99
MB10	K Lowley	Operations Manager	05/02/99
MB11	M Rolland	Purchasing Manager	05/02/99
SB12	D Stewart	Oil Products Manager	19/11/99
SB13	S Proietti	Project Sales Manager	06/12/99
SB14	A Wyper	Operations Manager	06/12/99
CC1	K Hart	Operator Well Engineer	17/11/99
CC2	D McPherson	Purchasing Supervisor	19/11/99
CC3	R Smith	Supplies Manager	19/11/99
MC4	J Wilson	Sales Project Manager	22/11/99
MC5	M Wright	Manufacturing Manager	30/11/99
MC6	D Minnett	Procurement Manager	24/11/99
SC7	R Brown	Sales Manager	05/07/00
SC8	E Tusker	Oilfield Sales Manager	06/07/00
CD1	D Donald	Operator Well Engineer	11/10/99
CD2	D Gordon	Contractor Well Engineer	11/10/99
CD3	J Brooks	Drilling Manager	25/03/99
CD4	D Jones	Supply Chain Manager	30/11/99
MD5	J Cadger	Operations Manager	19/10/99
MD6	I Emslie	Materials Planner	22/07/99
MD7	J Stephens	Purchasing Manager	21/07/99
MD8	M Smith	Customer Services Mgr	22/07/99
SD9	I Gavill	Sales Manager	11/07/00
SD10	D Davidson	Stock Manager	13/07/00
CE1	A Tait	Purchasing Manger	30/09/99

CE2	E McLean	Wellhead Engineer	30/09/99
CE3	N Emslie	Wellhead Engineer	07/10/99
CE4	H Stewart	Operations Manager	23/06/99
ME5	K Martin	Completion Products Mgr	21/06/99
ME6	N Strachan	Wireline Manager	21/06/99
ME7	J Algeroy	Area Sales Manager	21/06/99
ME8	K Cantlay	Manufacturing Manager	30/09/99
SE9	N Pike	Sales Manager	18/07/00
SE10	J Warrell	Operations Manager	25/07/00
CF1	R Seniland	Well Engineer	24/02/99
CF2	M Christie	Purchasing Manager	17/02/99
CF3	P Galbraith	Strategic Purchasing Mgr	17/02/99
MF4	G Maitland	Marketing/Operations Mgr	26/01/99
MF5	M Boyle	Sales Project Manager	26/01/99
MF6	A Paterson	Materials Manager	08/08/00
SF6	N Atkins	Managing Director	02/08/00
SF7	J Jeffries	Operations Manager	04/08/00