A SYSTEMATIC APPROACH FOR IMPROVING CONSTRUCTION MATERIALS LOGISTICS

by

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Abstract

In the 1990s, the UK construction industry directed considerable effort at improving productivity and reducing costs by harmonising relationships among clients, contractors, sub-contractors, specialist contractors and designers. Opportunities to accrue further benefits should be explored and capitalised upon from all areas of construction projects. Management of construction materials on well grounded logistics and supply chain management principles has the potential to yield results and augment efforts being made in other areas at making construction more efficient.

The overall aim of this thesis was to develop a systematic supplier management decision-support process model that contractors can use for both short and long-term management of suppliers in the implementation of construction materials supply logistics. Such a process model would benefit construction companies by identifying essential elements that lead to improved supply of construction materials. The objectives of the research were to:

- assess the extent to which information and communication technologies were being used in materials management in the UK construction industry;
- examine the nature of relationships and attitudes between contractors and suppliers in construction materials supply logistics;
- assess the importance that UK contractors and suppliers attached to logistics performance indicators and the extent to which they assessed the indicators to contribute to improved customer service in the supply of construction materials; and
- assess the importance that UK contractors attached to logistics enablers and the extent to which they took the enablers into consideration when evaluating and selecting construction materials suppliers.

The research findings were based upon a literature survey, two 'mirror-image' questionnaires (one sent to 71 UK contractors and the other to 76 UK construction materials suppliers); structured interviews with nine UK contractors and five UK construction materials suppliers; and a supplier management process model validation exercise with six UK contractors. From these, the research produced the following outcomes:

- a systematic supplier management decision-support process map that contractors can use for short and long-term management of suppliers in the implementation of construction materials supply logistics;
- an understanding of the supply of construction materials into construction processes from the wider perspective of logistics and supply chain management as opposed to traditional materials management;
- the identification of the performance indicators against which the performance of suppliers can be evaluated and the quantification of the relative contribution of the performance indicators to improvements in customer service;
- the identification of factors which enable suppliers to improve levels of customer service and quantification of the relative extent to which the factors enable suppliers to contribute to improvements in their levels of customer service in the delivery of construction materials;
- identification of the extent to which both performance indicators and enablers were used in supplier evaluation and selection;
- evaluation and comparison of the extent to which contractors and suppliers used information and communication technologies in internal and external materials supply logistics processes; and
- evaluation of the nature of relationships between contractors and suppliers.

Keywords: Construction Materials, Contractor-Supplier Relationships, Logistics, Enablers, Performance Indicators

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CHAPTER ONE

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 Background

Within a total quality management (TQM) philosophy, continuous improvement, adding greater value, improving quality, reducing costs and reducing construction schedules are no longer mutually exclusive customer requirements. The call by Latham (1994), targeting 30 per cent cost reductions in the delivery of UK construction projects, increased the search for better methods of procuring services within the industry. The Chartered Institute of Purchasing and Supply (CIPS, 1994) envisioned that the way to reduce costs in the industry was through adoption of collaborative arrangements by parties to the construction process. The introduction of electronic data management technologies also offers further opportunities for integrating inputs of construction process participants, thus contributing to cost reductions and enhancement of efficiency in the delivery of projects. It has been observed that collaboration in the construction industry is more common between contractors and clients (Whitelaw, 1997). All sixteen major contractors surveyed by Construction Manager (1998) had partnering arrangements with clients on significant percentages of their contracts. All the surveyed contractors further projected that the percentage of their contracts involving partnering would increase in the following year. The surveyed contractors reported win-win interactions and major cost reductions as a result of partnering.

Several studies have investigated issues relating to contractor-subcontractor interface management (Allen and Gibb, 1996; Mathews et al, 1996; Sărkilahti, 1996; Haksever et al, 1996; Sözen and Küçük, 1996). Contractors involved in long-term relationships with their sub-contractors are reported to have experienced more indirect benefits such as effective communication, less conflict and risk than direct benefits such as lower costs, shorter construction times and improved quality (Haksever et al, 1996; Mathews, 1996). In one instance, it was noted that tendering costs were higher on the single contractor-subcontractor project specific partnering case study than would have been the case if the partnering approach had not been used (Mathews, 1996).

The value chain concept (Porter, 1985) proposes that logistics management can play a vital role in reducing costs and improving productivity and competitiveness of enterprises. Performing primary activities, which involve the supply of materials, more cheaply and efficiently can help companies meet customer requirements. Even though construction materials can control up to 80 per cent of construction schedules from initial materials acquisition to the delivery of the last item (Kerridge, 1987), little literature exists to suggest that there has been sufficient investigation on the nature of collaboration between contractors and construction materials suppliers. Cost escalation and decline in productivity can be caused by several management deficiencies, poor control over materials being one of them. Lack of materials and tools on a construction project can cause losses estimated at six to ten per cent of work time (Stukhart, 1995). Materials are a major cost element, accounting for 30 to 80 per cent of the total project installed cost depending on the type of project (Kerridge, 1987; Muehlhausen, 1991). Therefore, improvements in the supply of construction materials could make considerable contribution to efficiency and cost reductions. Due to the critical nature of the supply of materials to project success, it has been suggested that the way to control project costs and schedules in construction is via an integrated materials management approach embracing the total cycle of projects (Marquardt, 1994; Berka and Conn, 1994).

The aim and objectives of this research were formulated with the recognition of the importance of construction materials and opportunities for improvements in the management of the resource presented by new management practices and changes in information and communication technologies.

1.2 Research aim and objectives

The main aim of this research was to develop a systematic supplier management decision-support process map that contractors can use for short and long-term management of suppliers in the implementation of construction materials logistics. The specific objectives of the study were to:

- assess the extent to which information and communication technologies were being used in materials logistics in the UK construction industry;
- examine the nature of relationships and attitudes between contractors and suppliers in construction materials logistics in the UK;
- assess the importance that UK contractors and suppliers attached to logistics performance indicators and the extent to which they assessed the indicators to contribute to improved customer service in the supply of construction materials; and
- assess the importance that UK contractors attached to logistics enablers and the extent to which they took the enablers into consideration when evaluating and selecting construction materials.

1.3 Justification for the research

With greater attention in the management of organisations turning to processes and integration of constituent activities and parties to such processes, one way of leveraging greater benefits from materials management is to take the logistical and supply chain management viewpoint of the process. The motivation for taking such an approach derives from the growing awareness that the ability of contractors to control costs by increasing the efficiency of their internal operations has decreased and cost savings need to be found from sources outside the companies (Sărkilahti, 1996).

Logistics management has emerged as an area where considerable improvement in the performance of enterprises can be achieved. The Institution of Production Engineers (1989) sees competitive material logistics as essential for not only gaining competitive advantage but also for sustaining it. Companies, through integrated logistics, seek to effect efficient material flows in their business transactions and processes for the focused purpose of satisfying their customers.

Advances in information and communication technologies make the integration of logistics functions within and between organisations a reality. Even though hurdles have to be crossed before rewards of full integration can be realised, there is agreement that effective integrated logistics can provide a major source of competitive advantage (Turner, 1993). Changes in information and communication technologies are irreversible. These technologies and ever higher customer awareness are creating pressure on businesses to change ways of transacting and producing products of every kind. This is because competitors are seeking to invest in technologies that improve the effectiveness of their supply chains and competitiveness in their business environments (Hammant, 1995).

The construction industry has, in the 1990s, been directing considerable effort at improving productivity and reducing costs by harmonising relationships among clients, contractors, sub-contractors, specialist contractors and designers (Latham, 1994; Building, 1995). As this is happening, opportunities to accrue even greater benefits should be explored and capitalised upon from every available angle. Management of construction materials on well grounded integrated logistics principles has the potential to yield results and augment efforts being made in other areas at making construction efficient. Greater opportunities exist in improving construction efficiency through the use of Just-in-Time (JIT) practices in construction (Baxter and Macfarlane, 1992). Integrated logistics, while being in harmony with JIT principles, goes much further through taking advantage of the efficiency offered by information technologies in communicating and relaying data within and between organisations.

The motivation for undertaking this research arose from the foregoing, with the recognition that efficiency gains in the entire construction process is a sum total of all improvements in all areas, including contractor-supplier interface management.

1.4 Research methodology

The methodology pursued during the course of the research programme is outlined in Figure 1.1. To define the research aim and objectives stated in Section 1.3, a comprehensive literature review was concurrently undertaken with attendance at seminars and conferences. Seminars and conferences attended during the entire research period are listed in Appendix A. Chapters 2, 3, 4, 5, 6 and part of Chapter 11 resulted from the literature review.

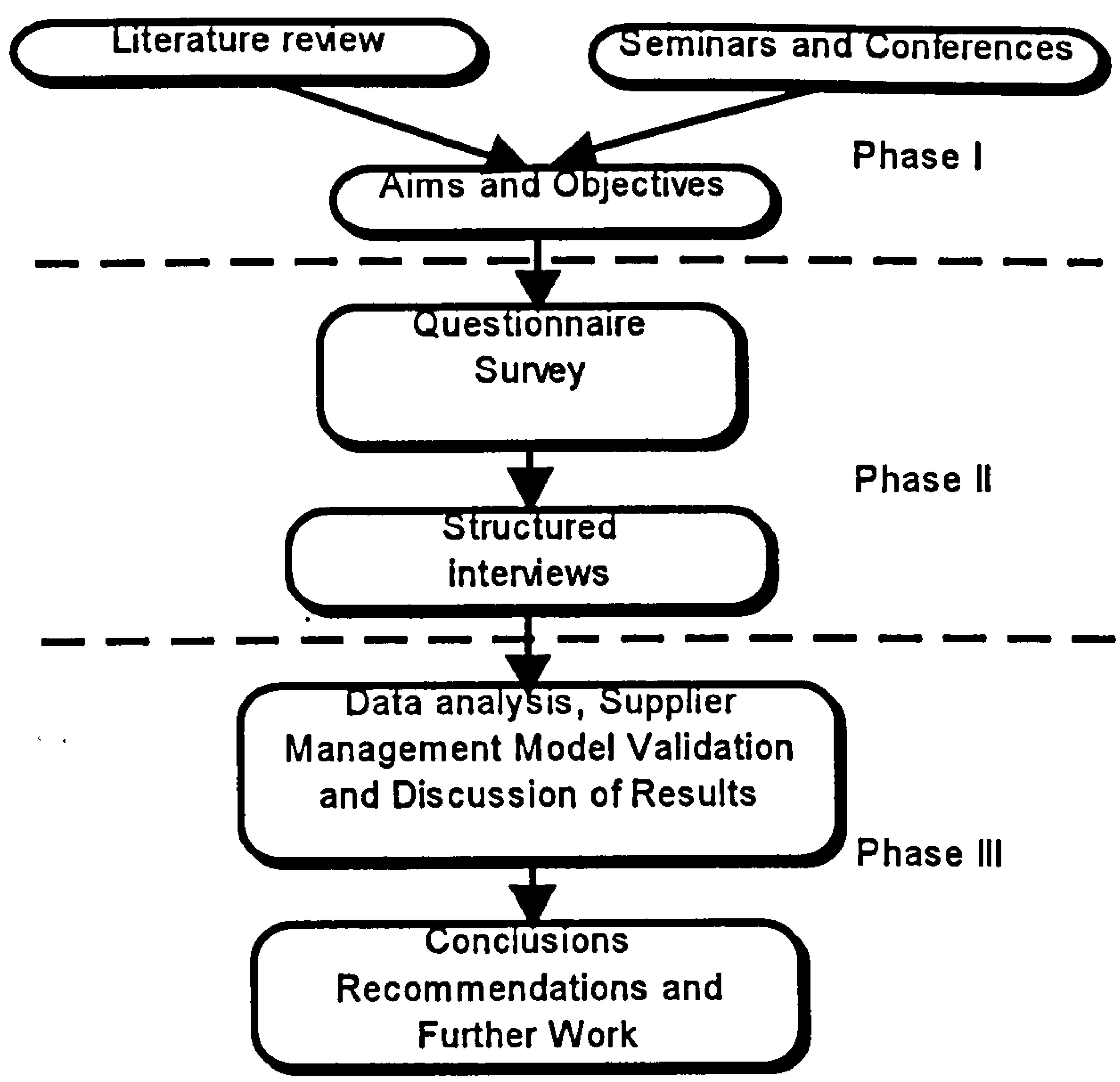

Figure 1.1: The Research Process Diagram

From the defined research aim and objectives, two near 'mirror-image' questionnaires (one directed at contractors and the other at construction materials suppliers) were designed, pre-tested and eventually sent out into industry after the literature review.

Structured interviews were used to complement the results obtained from the questionnaire surveys. The interviews were in two parts. One part involved evaluation of contributions of logistics factors to customer service by contractors and materials suppliers using the Analytic Hierarchy Process. The logistics factors in the analytic hierarchy process (AHP) model were investigated in the earlier questionnaires. The AHP methodology itself was presented in a well received conference paper (Muya et al, 1997). The other part of the interviews comprised open-ended questions. These questions sought in-depth explanations from respondents concerning issues relating to implementation of construction materials supply logistics.

The last phase of the research involved analysis and discussion of the results, validation of the supplier management process model, and drawing conclusions and making recommendations. The main recommendation was the developed and validated supplier management process map in Figure 12.1 of Chapter 12.

1.5 Summary of research achievements

The research produced the following outcomes from questionnaires sent to a total of 147 organisations (comprising 71 contractors and 76 construction materials suppliers); and through structured interviews with 14 companies (consisting 9 contractors and 5 materials suppliers), and a model validation exercise with six contractors:

- a systematic supplier management decision-support process map that contractors can use for short and long-term management of suppliers in the implementation of construction materials logistics;
- an understanding of the supply of construction materials into construction processes from the wider perspective of logistics and supply chain management as opposed to traditional materials management;
- the identification of the performance indicators against which the performance of suppliers can be evaluated;
- the quantification of the relative contribution of the performance indicators to improvements in customer service;

- the identification of factors which enable suppliers improve their levels of customer service and quantification of the relative extent to which the factors enable suppliers to contribute to improvements in their levels of customer service in the delivery of construction materials;
- identification of the extent to which performance indicators and enablers were used in supplier evaluation and selection;
- evaluation and comparison of the extent to which contractors and suppliers used information and communication technologies in internal and external materials logistics processes; and
- evaluation of the nature of relationships between contractors and suppliers.

1.6 Guide to thesis layout

This thesis comprises three parts: background theory; focal theory; and research contribution. Background theory, covered in Chapters 2, 3 and 4, examines logistics and supply chain management concepts and the extension of these concepts to the construction industry. Building on the background theory, the focal theory narrows down contemporary notions on logistics and supply chain management to construction materials supply logistics, particularly supplier management. This is covered in Chapters 5 and 6. The contribution to the area of research is presented in Chapters 7 to 14. Chapter 7 elaborates on the research methodology and Chapters 8 to 11 present analysis of results. Chapter 12 discusses the supplier management process model and its validation. Chapter 13 discusses the results of the research while the conclusions, recommendations and suggested further work have been presented in Chapter 14. The structure of the thesis in chapter form is as shown in Figure 1.2. The summaries of the 14 chapters are given below.

Chapter 1 is an introduction to the thesis. It outlines the aim and objectives of the research and the methodology pursued to realise them. The chapter also presents research achievements and the organisation of the thesis.

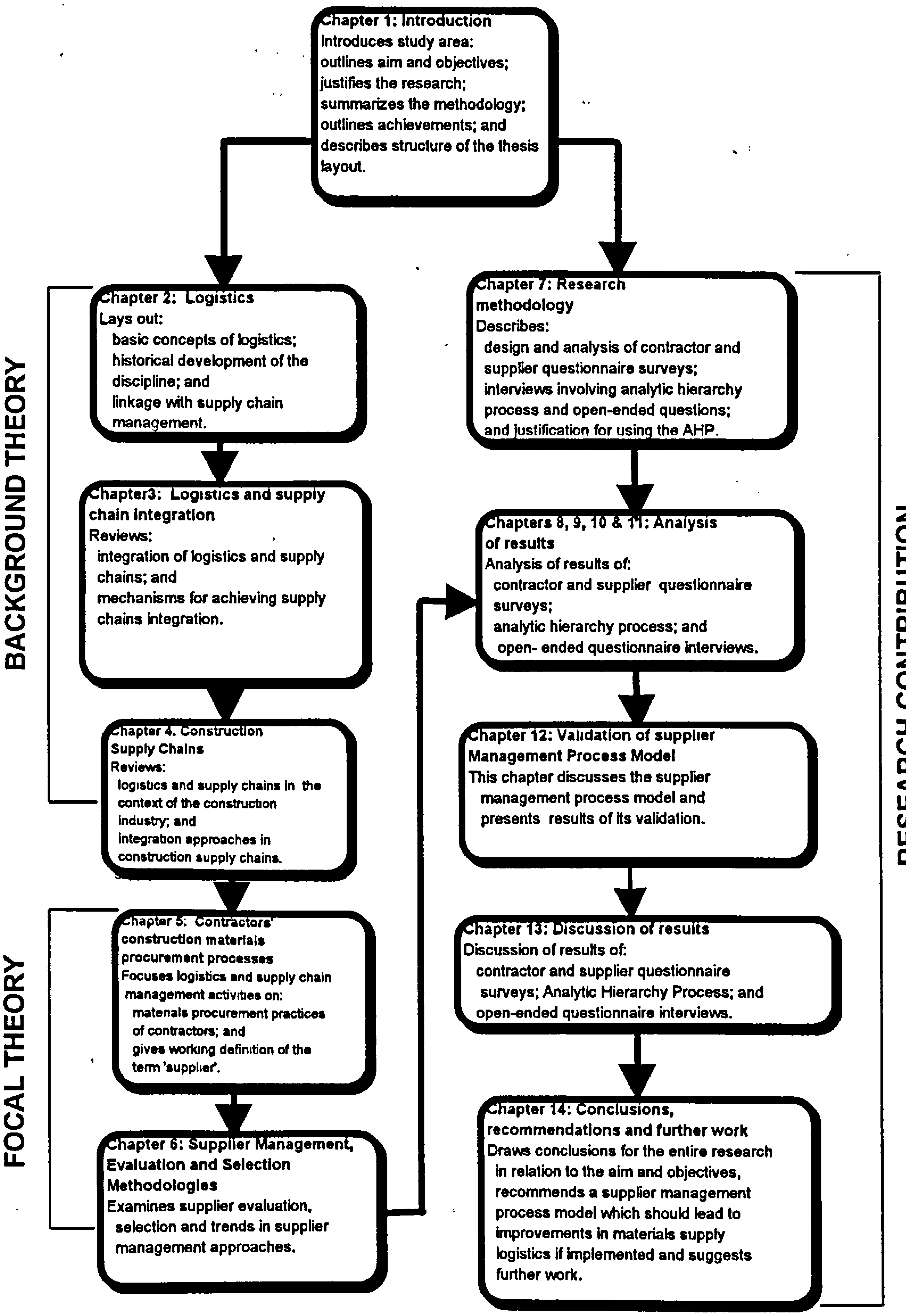

Figure 1.2: Thesis layout

Chapters 2 to 4 provide a review of background theory on logistics and supply chain management. These chapters define logistics and supply chain management concepts and examine their constituent elements and the evolution of the concepts to contemporary paradigms. Chapter 4 specifically examines and extends logistics and supply chain management concepts in the context of the construction industry.

Chapters 5 and 6 focus the theory on logistics and supply chain management so far discussed in Chapters 2 to 4 to materials procurement processes, supplier management, evaluation and selection methodologies of contractors. Chapter 6 also examines traditional factors normally considered in supplier selection and further presents contemporary trends in supplier development and problems posed by introduction of soft factors to traditional supplier evaluation methodologies. Within the context of the research, a working definition of the term 'supplier' has been provided in Chapter 6.

The research contribution is presented in Chapters 7 to 14.

Chapter 7 discusses the methodology adopted in this research, including the development of the questionnaires and structured interviews used to collect the data. Methods of analysis of the collected data have been presented. Reasons for using the Analytic Hierarchy Process in Chapter 11 in preference to other methods have been presented.

Chapters 8 to 11 present analysis of results of questionnaire surveys and structured interviews, including the Analytic Hierarchy Process evaluations.

Chapter 12 discusses the supplier management process model and its validation while **Chapter 13** discusses the results of the research from Chapter 8 to 11 in the context of the aim and objectives of the research and the literature reviewed in Chapters 2 to 6.

Chapter 14 presents the conclusions drawn from the research, recommendations and suggested further work.

Appendices included at the back of the thesis include:

- Appendix A: Workshops, seminars and conferences attended during the research period;
- Appendix B: Contractor questionnaire documents;
- Appendix C; Supplier questionnaire documents;
- Appendix D: Contractor interview documents;
- Appendix E: Supplier interview documents; and
- Appendix F: Supplier management process map validation questionnaire documents.

CHAPTER TWO

LOGISTICS

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LOGISTICS

2.1 Introduction

Chapter 2 examines the logistics concept and its evolution to supply chain management. Various activities which constitute a logistic system have been discussed. Recent organisational paradigms in logistics management which lead to efficiency and competitiveness in operations of companies have been discussed. The chapter also outlines the basic concepts of logistics and supply chain management to which all subsequent chapters are underpinned.

2.2 Logistics concept

Logistics has been defined in many ways, reflecting how the concept applies to different operational areas. The Society of Logistics Engineers defines logistics as *"the art and science of management, engineering and technical activities concerned with requirements, design and supplying and maintaining resources to support objectives, plans and operations"* (Blanchard, 1981). This definition is conceptual and covers all conceivable areas: business, military or otherwise.

Literature indicates that the military was one of the first areas to recognise and practice logistics in art form. This view is reflected in some dictionary definitions, the Oxford English Dictionary (1989) defining logistics as "*the organisation of supplies, stores, quarters, etc. necessary for the support of troop movements, expeditions, etc.*".

The definition of logistics has broadened to cover support activities in the production of consumer and capital goods, and their distribution in manufacturing, and erection of fixed capital infrastructure in construction. Logistics also embraces supply, distribution and other strategic and operational activities in retailing. Most definitions of logistics reflect these non-military operations (NEVEM-workgroup, 1989; The Institution of Production Engineers, 1989; Gattorna et al, 1991; and Wareham, 1991).

The most comprehensive and frequently cited operational definition of logistics is by the Council of Logistics Management (Coyle et al, 1996) which defines logistics as *"the process of planning, implementing and controlling the efficient, effective flow and storage of raw materials, in-process inventory, finished goods, services and related information from point of origin to point of consumption (including inbound, internal and external movements) for the purpose of conforming to customer requirements".* A summary of this definition was given by Wareham (1991) in diagram form (Figure 2.1).

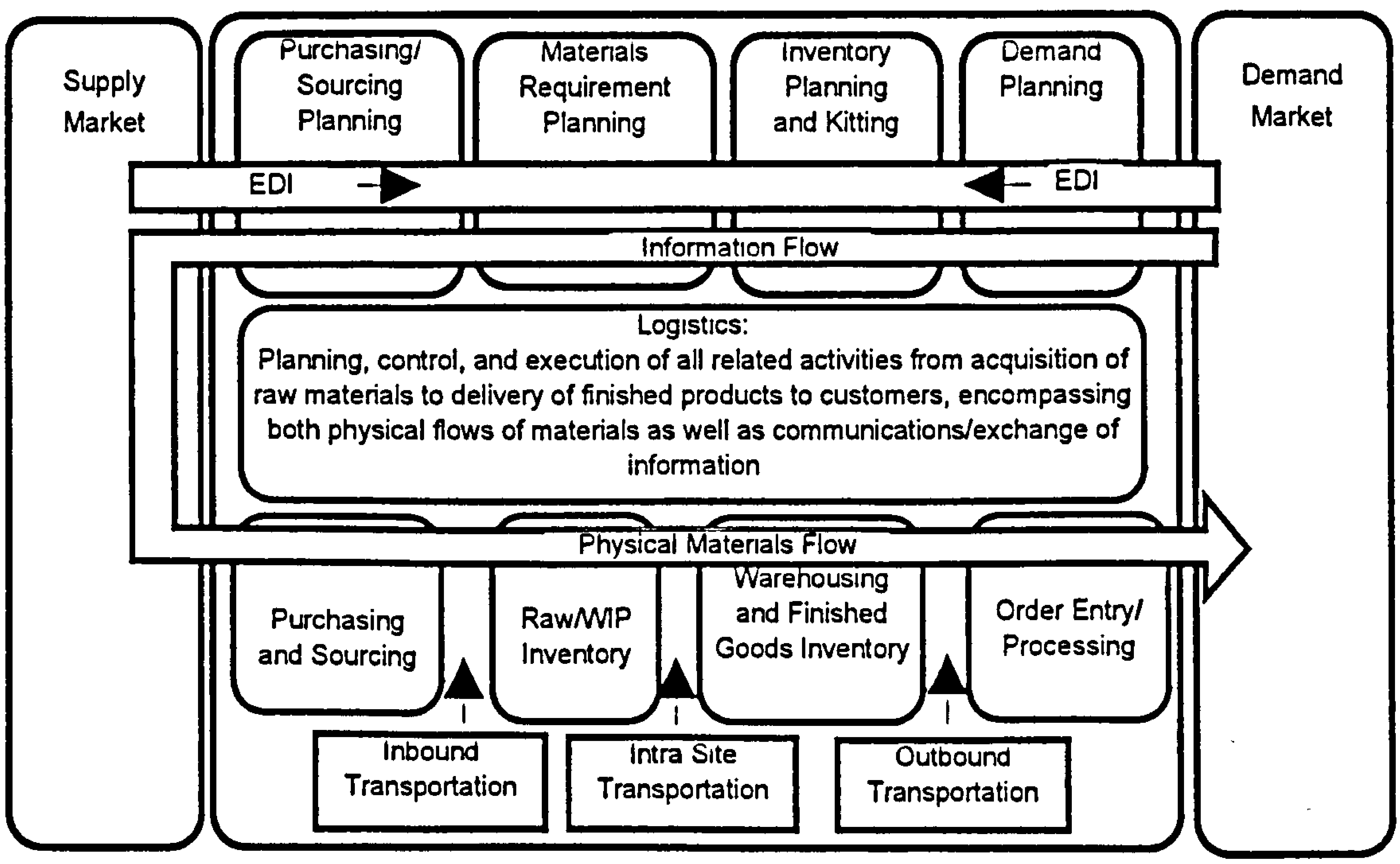

Figure 2.1: Wareham's view of logistics

2.3 Logistics evolution to the supply chain concept

Logistics received the attention of academics in the early 1900's (Lambert and Stock, 1993). Its development and refinement as a field, however, only picked up after World War II (Coyle et al, 1996). During this initial phase of development as an art, logistics was associated more with marketing (Lambert and Stock, 1993). The mass production that followed after World War II far outstripped the capacity to distribute industrial products. As companies sought new markets for their products, the need and search for more efficient physical distribution systems became acute. In the effort to get products to customers, greater emphasis was placed on the transportation element of logistics. The cost of reaching new markets also required economic considerations to be taken into account.

The total cost concept was introduced to logistics in the 1950s (Coyle et al, 1996). Initially, all physical distribution activities were managed as discrete elements. However, during the period 1960 to 1970, companies began placing all the activities involved in distribution: transportation, warehousing, inventory control and materials handling in one management function, namely, physical distribution. The rationalè was to reduce the total cost by managing all the trade-offs between interacting logistics elements. During the same period, companies whose businesses had complex inbound logistics were similarly seeking trade-offs between interrelated elements by putting upstream activities in the materials management function and managing them together in order to optimise the total cost.

From 1970 to 1980, opportunities for further cost saving by integrating materials management with physical distribution were recognised (Coyle et al, 1996). Companies became aware that from the total system perspective, greater operational efficiencies could result if the whole materials and products flow was viewed as a continuum. The 1980s and 1990s have seen the logistics perspective develop to embrace all firms within the total logistics system: suppliers of raw materials, companies engaged in production, products distributors and ultimate customers (Coyle et al, 1996). This concept is based on alliances among the trading partners and is referred to as the supply chain. Refinements in logistics systems and their evolution to contemporary supply chain practices continue (Figure 2.2).

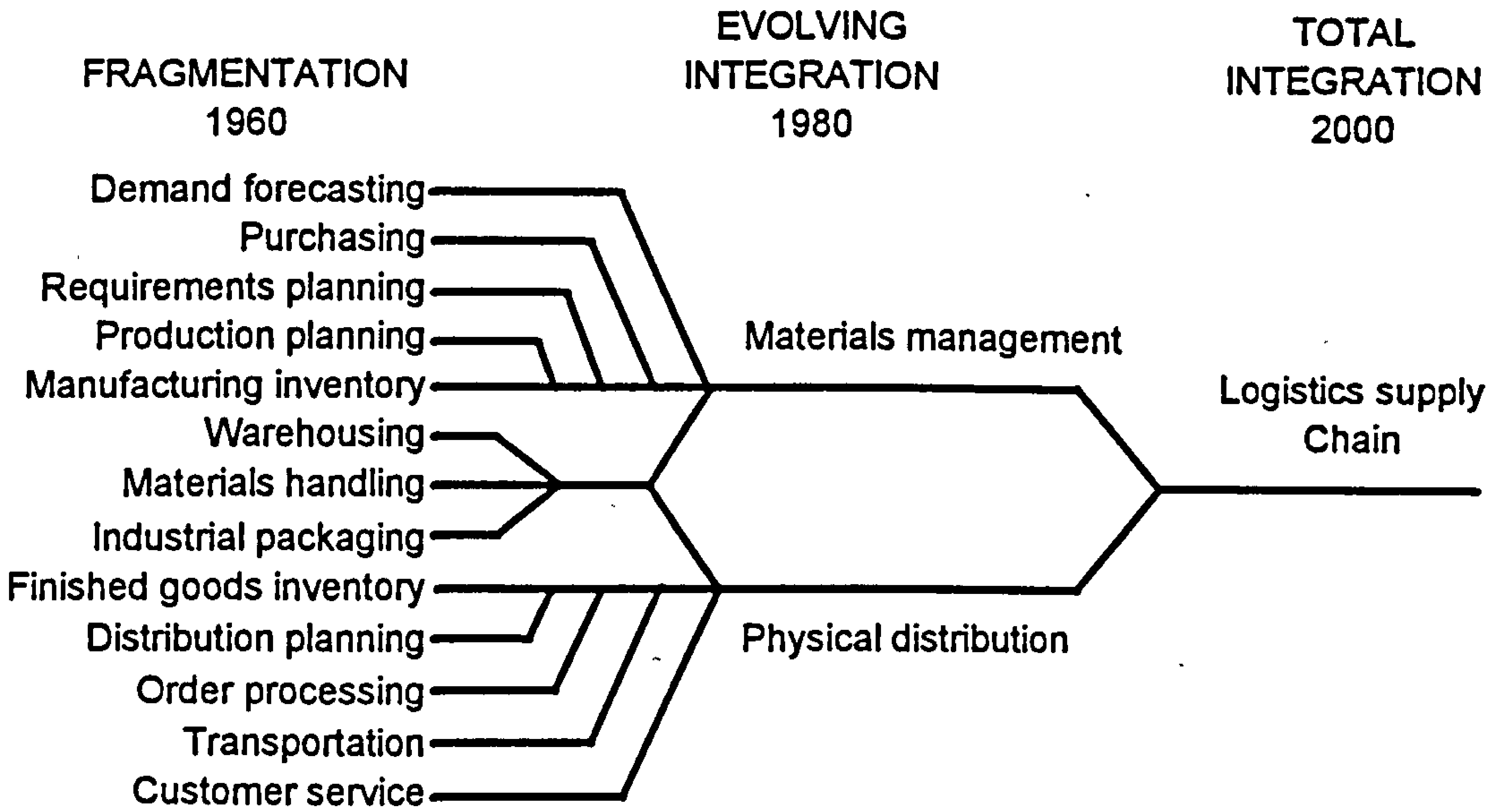

Figure 2.2: The Logistics Evolution

(After Coyle et al, 1996)

2.4 Logistics management

The fundamental purpose of logistics management in a company is to facilitate smooth information, materials and products flow through the organisation to meet customer requirements at an optimal cost. In the manufacturing and service sectors, logistics management involves both materials management and physical distribution at the company level. The accepted view of logistics from these industries was illustrated by Rushton and Oxley (1989) in the relationship:

Materials Management + Physical distribution = Logistics.

2.5 Logistics activities

Raw materials, semi-finished and finished products flows in logistics systems are effected through the fragmented activities shown in Figure 2.2. Efficiency and cost-effectiveness in logistics systems are determined by how well these activities are managed and co-ordinated.

As has already been stated, the logistics function has expanded from separate responsibilities involved in materials management and physical distribution to a co-ordinated approach of both these areas. The various activities which may be included within the total logistics function are discussed below.

Traffic and transportation

Traffic and transportation, as a logistic activity, involves managing the movement of goods from supply source to point of consumption. It links materials and products suppliers and their customers. Decision making about this activity is concerned with selecting the appropriate transportation mode, route planning and compliance with transport legislation. The choice of the mode of transport is influenced by numerous factors, the principal criteria being type of material or product and market factors.

Density, storability, ease or difficulty of handling, and liability are product related factors which influence transportation costs (Lambert and Stock, 1993). Market related factors which affect the cost of transport include: the degree of intramode and intermode competition; location of markets; nature and extent of government regulations of transport carriers; balance or imbalance of freight traffic in a territory; seasonal movements of product; and whether the product is being transported domestically or internationally (Lambert and Stock, 1993). Transport is a major cost component in logistics supply chains (Coyle et al, 1996).

Warehousing and storage

A warehouse is for storing inventory. There are two main reasons for using a warehouse. The first is to reduce transport costs. The second reason is to improve service for a production plant or for the market being serviced.

Warehouse and storage systems are designed to hold specified materials in appropriate quantities, in a suitable environment at minimum system overall cost. The systems approach require close co-ordination of stock with all other activities for optimum cost-effectiveness. Reasons for holding stock include the following (Rushton and Oxley, 1989, p. 71):

- *to act as a buffer between supply and demand;*
- *to hold stock for long production runs;*

- *to hold stock between production operations (work in progress);*
- *safety stock to cover unplanned interruptions in supply;*
- *as a cover for seasonal fluctuations; and*
- *as a strategic reserve, e.g. against a planned shutdown.*

Industrial packaging

Packaging can be classified into two groups: industrial and consumer packaging. Industrial packaging protects products during shipment while consumer packaging is designed for sales appeal (Magad et al, 1989). Industrial packaging is determined by mode of transportation and the kind of materials or products involved (Coyle et al, 1996; Lambert and Stock, 1993). Packaging fulfils various functions depending on particular applications (Rushton and Oxley, 1989):

- to protect and preserve from physical, chemical and mechanical damage, deterioration, or contamination;
- to contain;
- to communicate: instructions and hazard warnings; identification of contents; and sales appeal/presentation;
- for convenience, act as a dispenser and as measure, ease of handling, and disposal; and
- for compatibility with packaging machinery.

Trade-off analysis in transportation modes requires management to examine how any changes influence packaging costs. The objective is to achieve the optimum protection level that meets customer requirements at minimum cost (Gattorna et al, 1991).

Materials handling

Materials handling refers to movement of goods through short distances using mechanical equipment. Typical equipment used include conveyors, forklift trucks and overhead cranes. The activity involves all materials from raw to finished products and has critical interfaces with packaging and unitisation. To be performed efficiently, relationships with these elements must be considered. The 'unitisation' concept extends from the basic item unit, through to the pallet or possibly the container (Gattorna et al, 1991).

Movement of goods should be minimised by performing only 'necessary' movements, and combining operations wherever possible (Gattorna et al, 1991). Objectives for efficient materials handling being (Tersine, 1985):

- to eliminate handling wherever possible;
- to minimise travel distance;
- to minimise goods in process;
- to provide uniform flow free of bottlenecks; and
- to minimise losses from waste, breakage, spoilage and theft.

Inventory control

Inventory is material held for future use or sale. It may consist of supplies, raw materials, in-process inventory and/or finished goods (Tersine, 1985).

Inventories isolate supply, production and distribution so that each sub-system operates independently, absorbs errors in forecasting, and allows effective utilisation of resources when demand variations occur. Four reasons why companies keep inventory are (Gattorna et al, 1991):

- to reduce the cost of purchasing;
- it mitigates against variability in both supply and demand;
- it allows longer production runs which may achieve economies of production; and
- it mitigates against the cost of stock-outs which include loss of production time, labour time and possibly expensive interruptions to complex processes.

Inventory holding involves financial risks and potential costs which may result from capital lock-up, interest foregone, obsolescence, damage, pilferage or a combination of these.

Demand forecasting

Forecasting helps to plan and allocate resources, schedule production, and determine demand for products and services. Forecasting is essential for the following two reasons (Lambert and Stock, 1993):

- proper logistics systems require forward planning. Forward planning in turn requires good forecasts. Thus, the need for forward planning is substantial in order to: keep operations running smoothly; adequately prepare for, and meet future conditions and challenges; and minimise present or potential problems in logistics systems of the company; and
- forecasting can provide a fairly accurate picture of the future for management. It is the driving force behind all forward planning activities within the firm.

Accurate forecasting of inventory, materials and parts requirements is essential for effective inventory control. This is particularly true for companies using just-in-time (JIT) or materials requirement planning (MRP) approaches in inventory control (Lambert and Stock, 1993). Among the considerations required to select a forecasting technique, the most important are: appropriateness of the method; cost; and accuracy (Lambert and Stock, 1993).

Procurement

Procurement and purchasing differ in scope. Whereas purchasing refers to the actual buying of materials and related activities associated with the buying process, procurement covers a wider spectrum of activities. Procurement includes purchasing, traffic, warehousing and receiving inbound materials (Lambert and Stock, 1993). Purchasing is the exchange of money for goods or services, while procurement is the total responsibility for acquiring goods and services (Tersine, 1985).

Procurement is of particular importance, especially when purchased materials or semi-finished products account for a high proportion of the unit cost of the product. Tersine (1985) argued that the ability to obtain required materials, equipment, services and supplies at right prices and at right times is key to successful operations.

The goals of purchasing include the following (Lambert and Stock, 1993):

- to provide an uninterrupted flow of materials, supplies, and services required to operate the organisation;
- to keep inventory investment and loss at a minimum;
- maintain adequate quality standards;
- find and develop competent vendors;
- standardise where possible, the items bought;
- purchase required items and services at the lowest ultimate cost;
- improve the organisation's competitive position;
- achieve harmonious, productive working relationships with other activities within the organisation; and
- accomplish the purchasing objectives at the lowest possible level of administrative cost.

Supplier selection and evaluation, quality control and forward buying are among the primary purchasing activities that influence the ability of a company to achieve its objectives (Lambert and Stock, 1993). On the other hand, legalities, management policies, resource limitations, cultural influences and market conditions are the limiting factors that narrow the decision space of acceptable procurement solutions in a company (Tersine, 1985).

Distribution communication

Developments in information technology have focused attention on the importance of good communication infrastructure to support logistics. Information technology is seen as the primary enabler of integrated logistics. The computer has enabled more sophisticated and efficient means of data capture, storage, processing and presentation, and transmission.

Order processing is potentially an area where information technology can considerably improve logistics performance. Order processing systems provide information to employees who assign orders to warehouses, clear customer credit, update inventory files, prepare warehouse picking instructions, and prepare shipping instructions and the associated documentation. The primary function of the order processing system is to provide a network that links the customer and the supplier. Lambert and Stock (1993) encouraged evaluation of various methods of order transmittal. They attributed the inconsistency in manual methods of order transmittal to more handling by individuals which consequently leads to a greater chance for communication errors. Management can evaluate methods of order transmittal on the basis of speed, cost, consistency, and accuracy. Order transmittal should be as direct as possible. Orders transmitted electronically rather than manually minimise the risk of human error. Communication is extremely important because it sets the logistics system in motion.

Plant and warehouse site selection

In this context, plant refers to facilities where operations or processes take place. Warehouses, as seen earlier, are inventory storage facilities. Several factors influence the considered location of both plant and warehouses.

Two main logistics factors normally considered when selecting sites for both types of facilities are sources of materials and semi-finished products and location of customers. The location of a company's markets is a primary consideration. Strategically, proximity improves a company's customer service levels.

The cost of transport is also critical in site selection (Coyle et al, 1996). Other factors include: availability of services (water, energy, sewerage systems), transportation access (road, water, rail, air), land availability and cost, compatibility with surrounding land use (Tersine, 1985); and labour rates, local and state taxes, security, legal concerns and other local factors (Lambert and Stock, 1993). All of these important factors are considered as a total system within which logistics factors constitute sub-systems (Lambert and Stock, 1993).

Return goods handling

Goods may sometimes be returned to source because they are defective, incorrect specifications or they may have expired. Goods may be returned for warranty repair, replacement or recycling. Channelling back of goods is called return goods handling. It is often referred to as reverse logistics.

Most logistics systems are not designed to handle reverse logistics. The effect of this is that the cost of transporting, storing and handling goods back through the system can be much higher. The cost of reverse logistics for an item can be as much as nine times the cost incurred when the same item was moved from the supplier to the customer (Lambert and Stock, 1993).

Parts and service support

Parts and service support as a logistics element is primarily concerned with after sales service. Within the guarantee period, this involves replacement of defective materials/products or provision of labour to correct the defects depending on the terms of the warranty. The logistics emphasis is on quick and decisive service where and when it is required (Lambert and Stock, 1993).

Salvage and scrap disposal

The logistics process generates waste. Such waste may result from excess purchases, abortive work or obsolescence. If such waste can be recycled, then it should be channelled through the appropriate processes. If a company does not need such materials, but others find them useful, then the by-products have value and their disposal can generate income for the company. Scrap which cannot be recycled or sold can be given away. Finally, if no one is willing to take the by-products freely, the scrap must be disposed of as the law prescribes. If the waste is hazardous, environmental regulations in the method of disposal must be observed.

Order processing

The order cycle begins with the customer placing an order and ends with the customer ultimately receiving and accepting the order. Figure 2.3 shows major components of the order cycle.

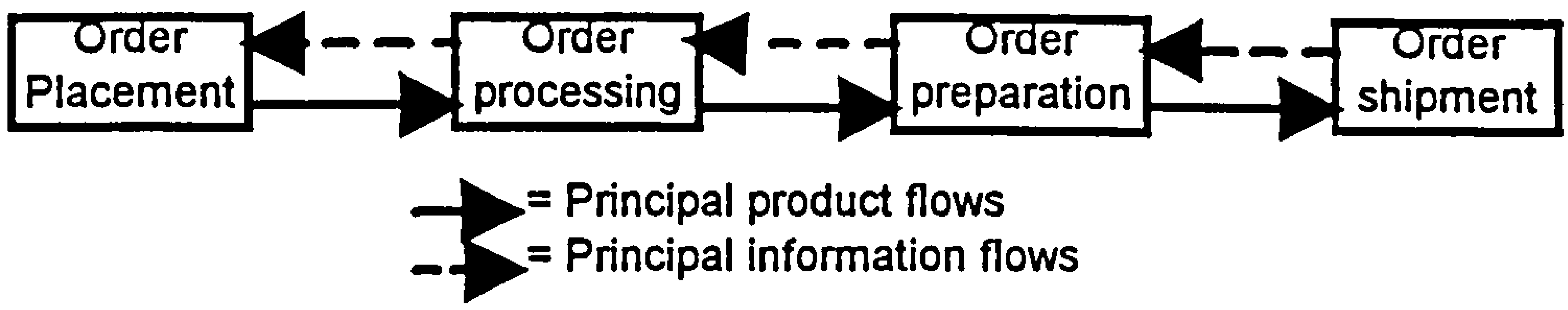

Figure 2.3: Major components of the order cycle

Order processing deals with the information, communication and documentation elements of the order cycle. This usually involves checking customer credit, transferring information to sales records, sending the order to the inventory area, and preparing shipping documents.

Lambert and Stock (1993) broke down order processing components into three groups:

- operational elements; order entry/editing, scheduling, order shipping, set preparation, and invoicing;
- communication elements; order modification, order status enquiry, tracing and expediting, and production information requests; and
- credit and collection elements; credit checking and accounts receivable processing/collecting.

Because of its information and communication based elements, the order processing activity has been identified as the logistics activity with the greatest potential for reducing the order cycle, improving company operational efficiency and enhancing customer service. It has been described as a fabulous hunting ground to seek out and remove non-value-added activities (Christopher, 1992).

Traditional order processing practices involve customers placing orders by hand, post or fax to suppliers who in turn process the order manually or using an in-house computer (Hancock, 1996). Such practices are noted for their inefficiencies arising from human error, delayed response time which subsequently leads to unhappy customers, lost business and poor company cash flow. Modern computer networks and communication technologies which include Electronic Data Interchange (EDI) allow 'real time' interaction between customers and their suppliers. More and more companies are turning to these technologies (Sarich, 1991) as competitive pressure increases.

Customer service

Customer service involves almost all company functions and is much broader than logistics management, but it is the single area that "glues together logistics activities" (Coyle et al, 1996, pp. 46).

The customer service concept has different meanings in different industries; among different companies; and even between companies and their customers. Because of the multivariate nature of customer service and widely differing requirements of specific markets, Christopher (1992) argued that it is essential for any business to have a clearly defined customer service policy. LaLonde et al (1976) had defined customer service as *"a process for providing significant value-added benefits to the supply chain in a cost-effective way"*.

Despite differences in the understanding of the concept, this definition cuts across industries and markets. At the same time, it considers the cost-effectiveness of the level of service provided. Because of the competitive advantage dimension with which customer service is now heavily associated with, Coyle et al (1996, pp. 27) defined customer service as *"a process for providing competitive advantage and adding benefits to the supply chain in order to maximise the total value to the ultimate customer"*. Most companies view customer service in three ways (Coyle et al, 1996):

- as an activity that must be managed to adequately meet customer requirements;

- as performance measures which prescribe acceptable standards of customer service levels; and
- as a corporate philosophy which elevates customer service to company-wide commitment in ensuring superior customer service.

Customer service is a powerful factor that companies can use to differentiate themselves and their products in highly competitive markets. Logistics has been recognised as an area where customer service can be significantly improved. Present day computer networks and communication and information technologies, such as EDI and bar codes, can improve customer service by enhancing efficiency in order processing and other logistics activities. Information and communication technologies also offer capabilities to integrate the management of all logistics activities which can further contribute to improved customer service, thus improving competitiveness and profitability in the long run. Figure 2.4 shows the various components of logistics management. All the logistics activities already reviewed are covered in the logistics management function. In practice, not all of the logistics activities may be placed within the responsibility of the logistics function even in companies with well organised logistics areas (Coyle et al, 1996). The relevance of the activities may also differ from enterprise to enterprise, depending on the nature of operations the company is engaged in.

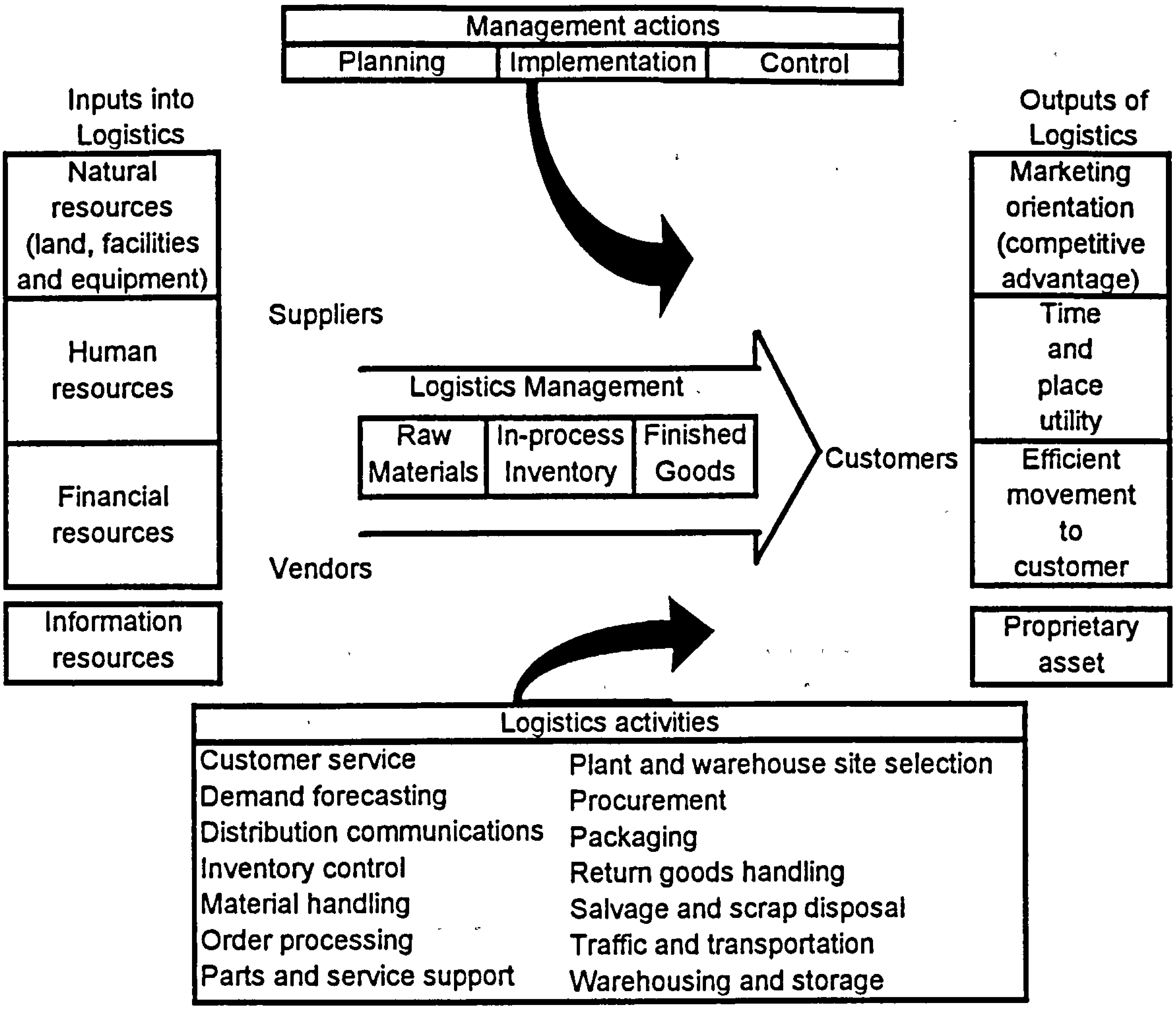

Figure 2.4: Components of logistics management

(After Lambert et al, 1993, pp. 5)

2.6 Contemporary logistics philosophies and trends

The trend of companies to internationalise their operations, in all business spheres, is putting competitive pressure on international and domestic markets. The impact is being felt by both small and large companies. Against the background of organisations facing challenges to remain profitable in increasingly fierce global competition, logistics has emerged as an area that offers a sharp competitive advantage by ensuring efficient customer service (Cooper, 1993). In so doing, it leads to long-term profitability by winning customer loyalty through improved customer service (Figure 2.5).

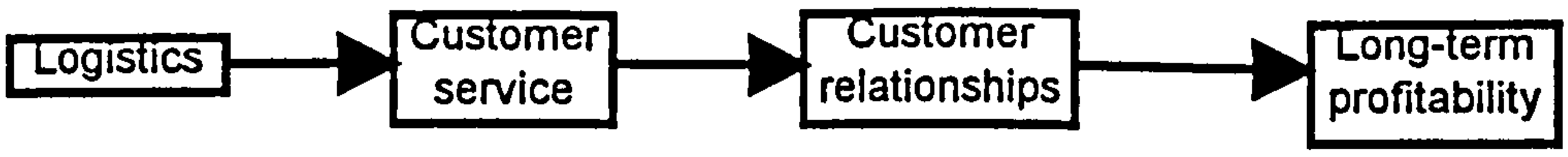

Figure 2.5: Logistics & profitability - the linkages
After Martin Christopher (Cooper, 1993)

2.6.1 Organisational paradigms and competitiveness

Being competitive and cost-effective at the same time depends on the organisational alignment of a company. Porter (1985) is credited for drawing the attention of strategists to the relative nature of competitiveness. Figure 2.6 illustrates the value chain analysis by Porter (1985).

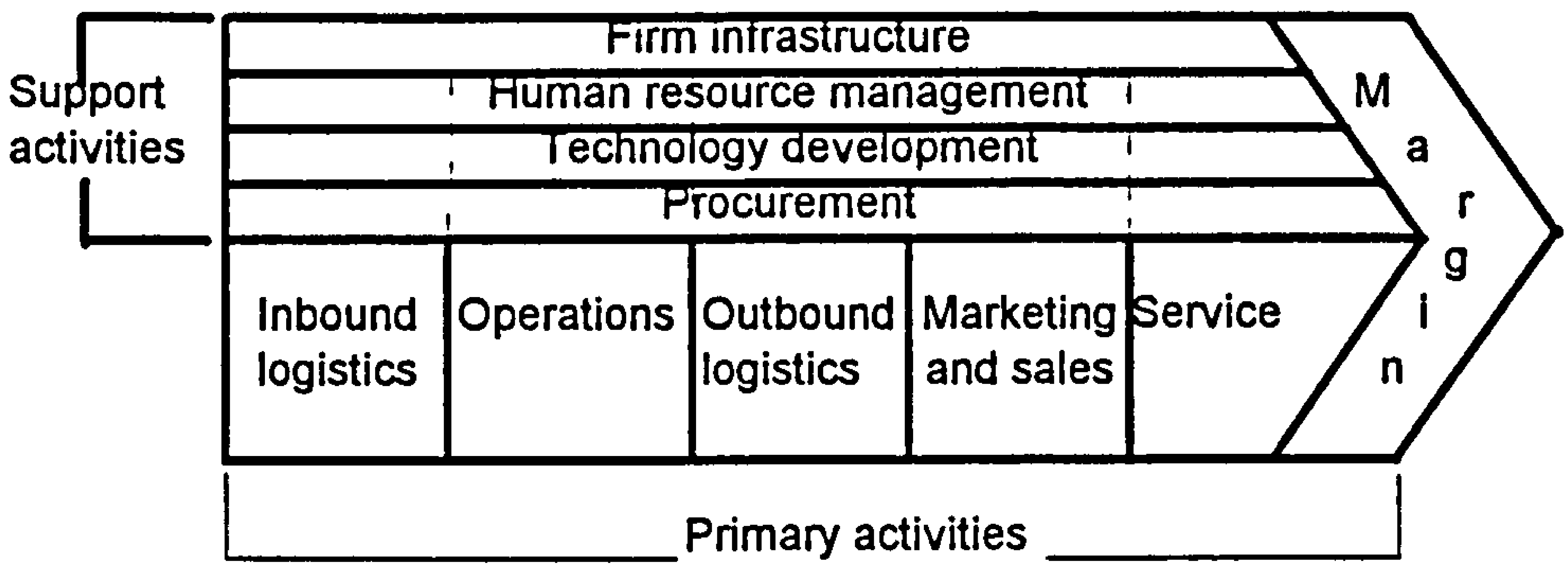

Figure 2.6: Michael Porter's value chain
(After Porter, 1985)

Competitive advantage is gained by strategically performing both primary and support activities in Porter's value chain more cheaply or efficiently than competitors. The realisation from the value chain is that logistics management can create both cost/productivity advantage and value advantage for a company (Christopher, 1992). This awareness is one of the factors influencing changes in logistics management.

2.6.2 Contemporary trends in logistics

Forces driving attitudinal, cultural and organisational changes in logistics and supply chains of companies emanate from: pressure from competitors (Evans et al, 1995); pressure from discerning customers (Gattorna et al, 1996); and developments in information and communication technologies. These are combining to cause cross-market paradigm shifts identified in Table 2.1.

Table 2.1: Skills profile for the logistics manager
(After Christopher, 1992, pp. 213)

Paradigm shift	Leading to	Skills required
From functions to processes	Integral management of materials and goods flow	Understanding of trade-off opportunities between functional areas
From profit to profitability	Focus on resource management and resource utilization	Accounting and financial control techniques
From products to customers	Focus on markets and customers	Ability to define, measure and manage service required by market segment
From transactions to relationships	Co-makership and co-shipper partnership	Network management and optimization techniques e.g. JIT
From inventory to information	Demand based replenishment and quick response systems	Information systems and information technology familiarity

To fully attain the identified logistics paradigm orientation, companies have to change their internal and external organisational business practices. A shift emanating from top management that entails cultural change "in the basic paradigms that have underpinned industrial organisations for so long must take place" (Christopher, 1992, pp. 210). While the importance of logistics management has been recognised by many companies as a concept and organisational philosophy, it still has to be fully embraced (Cooper, 1993).

2.7 Summary

Logistics is a broad concept, which may have different meanings depending on the area being examined. Customer service has been identified to be the element that 'glues' together all the logistics activities. The basic purpose of logistics management is for aiding companies to competitively meet customer requirements at optimised logistics costs. The need to achieve this more effectively has led to the evolution of the logistics concept to supply chain management.

Arguments that logistics management, if performed more efficiently or cheaply can contribute to competitive advantage of companies and, consequently, their long-term profitability are supported by the value chain concept.

Chapter 3 which follows examines logistics integration and supply chain management concepts.

CHAPTER THREE

INTEGRATED LOGISTICS AND SUPPLY CHAINS

CHAPTER THREE

INTEGRATED LOGISTICS AND SUPPLY CHAINS

3.1 Introduction

This chapter examines concepts of internal and external integration of logistics activities and other mechanisms for streamlining logistical operations in companies. Information and communication technologies which aid logistics integration have been discussed.

Integrating logistics activities involves making organisational changes. Two approaches, business process improvement and business process re-engineering, which may be used when implementing organisational changes have been reviewed. The chapter further compares and contrasts push and pull scheduling, two alternative logistics systems which may be chosen to support production. Ultimately, the drive towards efficiency in any type of production system is to reduce waste and the chapter also reviews lean production, a production system which uses pull scheduling in optimising resource utilisation.

3.2 Integrated logistics

Integration has been defined as *"the making into a whole"* (Cassell Concise English Dictionary, 1992). This definition implies existence of discrete elements brought together to make a system. A system is *"a co-ordinated arrangement or organised combination of things or parts, for working together, performing a particular function"* (Cassell Concise English Dictionary, 1992). The systems approach to problem solving is directed at integration of all parts of an operating system to achieve an intended objective. Luck and Newcombe (1996) viewed integration as strategic and that it takes place between subsystems that constitute the unit of analysis - the system. Using the systems approach, various enterprises that come together to execute a project can be integrated to form a project organisation system (and so can the various activities or functions as subsystems constituting each enterprise system).

The various companies in the project system coalition can thus be treated as subsystems which together constitute the whole. Logistics integration can either be internal or external (Bowersox and Closs, 1996).

3.2.1 Internal logistics integration

Internal integration of logistics activities takes place at company level. The various activities which affect logistical flow in an organisation have been discussed in Chapter 2. Isolating and viewing the activities separately is important to gain a better insight into their individual characteristics and how they inter-relate collectively. Inter-relationships exist between and among the various activities. The activities are usually performed in different functions in organisations and are more often fragmented and sometimes uncoordinated in companies where integration has not been achieved (Lambert and Stock, 1993). Managing the fragmented and uncoordinated logistics activities separately can reduce their costs individually, but may not result in reduced total cost of all of them viewed from a total organisational framework. The rationalè underpinning logistics integration is reduction of the total cost. This is achieved by seeking the least logistical cost through trade-off analysis between and among the various logistics costs. Thus, internal integration involves managing all the logistics activities in an organisation together in an effort to minimise sub-optimisation when making logistics decisions.

3.2.1.1 Obstacles to internal integration

Bowersox and Closs (1996) cited organisational structures, measurement systems, inventory ownership, information technology and knowledge transfer capability as barriers to integration of logistics activities within organisations.

Logistics integration requires cross-functional co-ordination. Traditionally, companies organised on the basis of functions vest authority and responsibility in differentiated sections whose structures, budgets, objectives and personnel orientation may preclude cross-functional co-operation. Thus, successful implementation of logistics integration may require significant modification of how an organisation deals with cross-functional matters.

Most traditional cost measurement systems mirror organisation structures and are not designed to optimise integrated logistics total cost. Specific processes should be viewed as parts of functions rather than stand-alone activities. Functions may have to assume increased costs in order to lower costs throughout a process. Therefore, until companies are aligned with the optimised total integrated logistics cost framework, cost measurement systems will impede integration.

The logistics integration philosophy advocates optimised total cost at any given service level. This approach is antagonistic to traditional management styles which view maintenance of sufficient inventory as the way to minimise the risk of stock-outs. Such entrenched inventory policies have related costs which need to change to facilitate optimised total cost principles via total system integration.

Information technology is pivotal to successful logistics integration. This arises out of the need to share information in order to eliminate redundant activities when optimising the total logistics cost through inter-activity trade-off analysis. Until systems with logistics information sharing are developed, stand-alone systems will not facilitate logistics integration.

Logistics integration is further incapacitated by the failure to develop mechanisms capable of cross-functional knowledge transfer. Transfer of such knowledge has been seen as difficult. *"Process work often involves many employees and is not limited to any specific functional area. Transfer of this kind of knowledge and experience is difficult to standardise"* (Bowersox and Closs, 1996, pp. 46). The limitation in the ability to share knowledge and experience is a barrier to integration.

3.2.2 External logistics integration: supply chain management

Internal integration of logistics activities is desirable but may not result in attainment of favourable performance due to uncoordinated supplies upstream and unfocused customer service downstream. For satisfactory logistical performance, integration should be extended to incorporate materials and parts suppliers and customers in the marketplace. External logistics integration is usually referred to as supply chain management. Towill (1995, pp. 15) conceptualised a supply chain as:

> *"a system whose constituent parts include material supplies, production facilities, distribution services and customers linked via the feedforward flow of materials and the feedback flow of information".*

Supply chains usually comprise three flows: two directional flow of information between customers and suppliers; one directional flow of materials and products to customers, except where reverse logistics may arise; and the flow of cash from customers to suppliers, designating completed transactions (Figure 3.1).

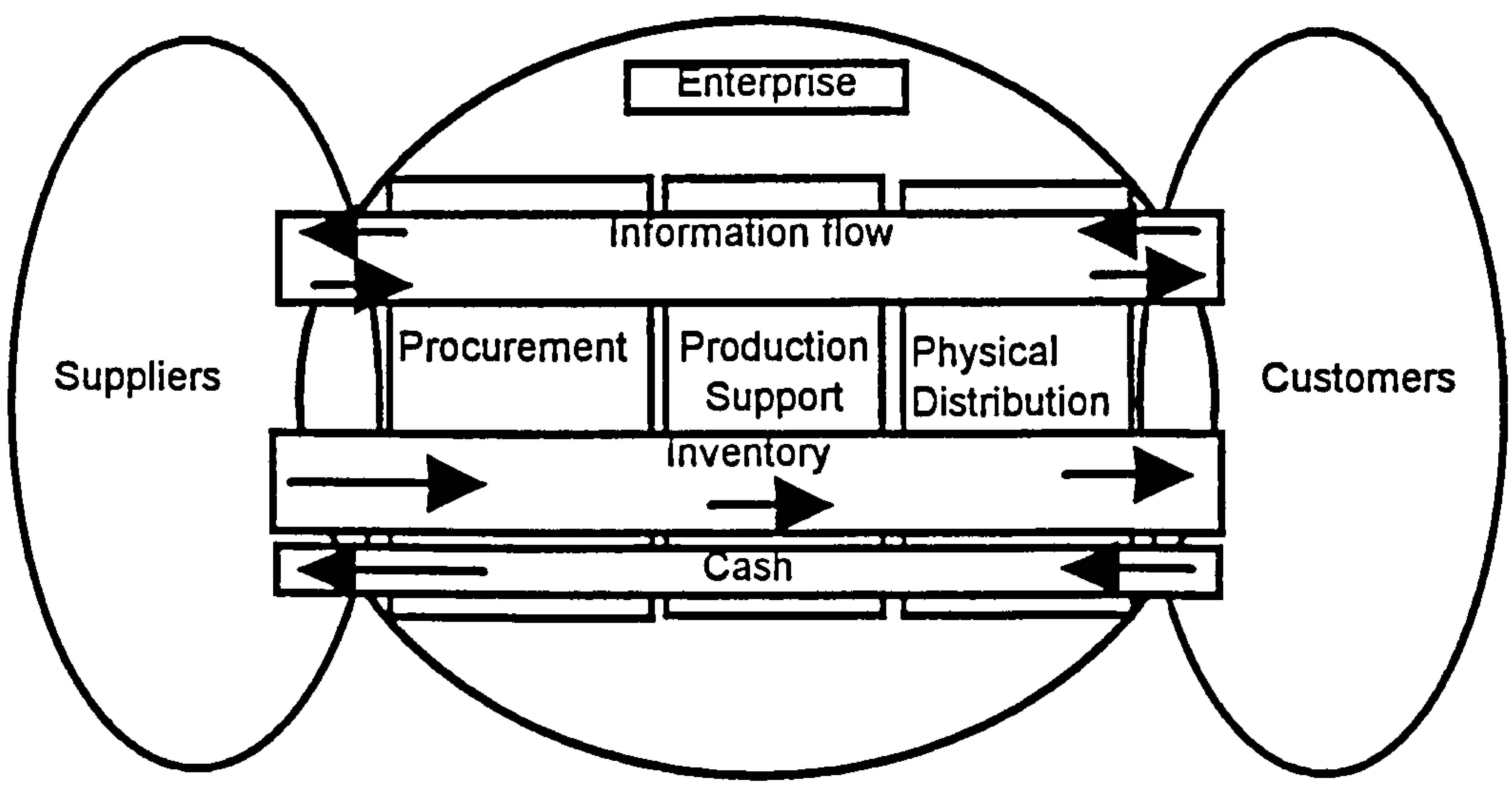

Figure 3.1: The supply chain concept

Traditional product delivery mechanisms via discretely managed enterprises do not characterise a chain (Stewart, 1995). Such supply practices introduce errors and distortion, delay reaction to market changes, underplay strategic decisions and undermine competitive positioning due to discordant linkages between enterprises.

Companies embark on external integration to introduce efficiency, cost-effectiveness and competitiveness in inbound and outbound logistics activities. In combination:

cost-effectiveness, efficiency, and competitiveness require increased management of information among companies in a supply chain. The emphasis on information management arises out of the need to improve inventory visibility along the entire supply pipeline in order to reduce supply uncertainty.

3.2.2.1 Inventory in supply chains

Reducing the cost of inventory in the supply chain, through the provision of timely accurate information, is a key element to successful supply chain management. Two-way information sharing reduces supply uncertainty and lowers safety-stock and its associated cost (Coyle et al, 1996). Figure 3.3 shows factors which lead to companies keeping safety stock.

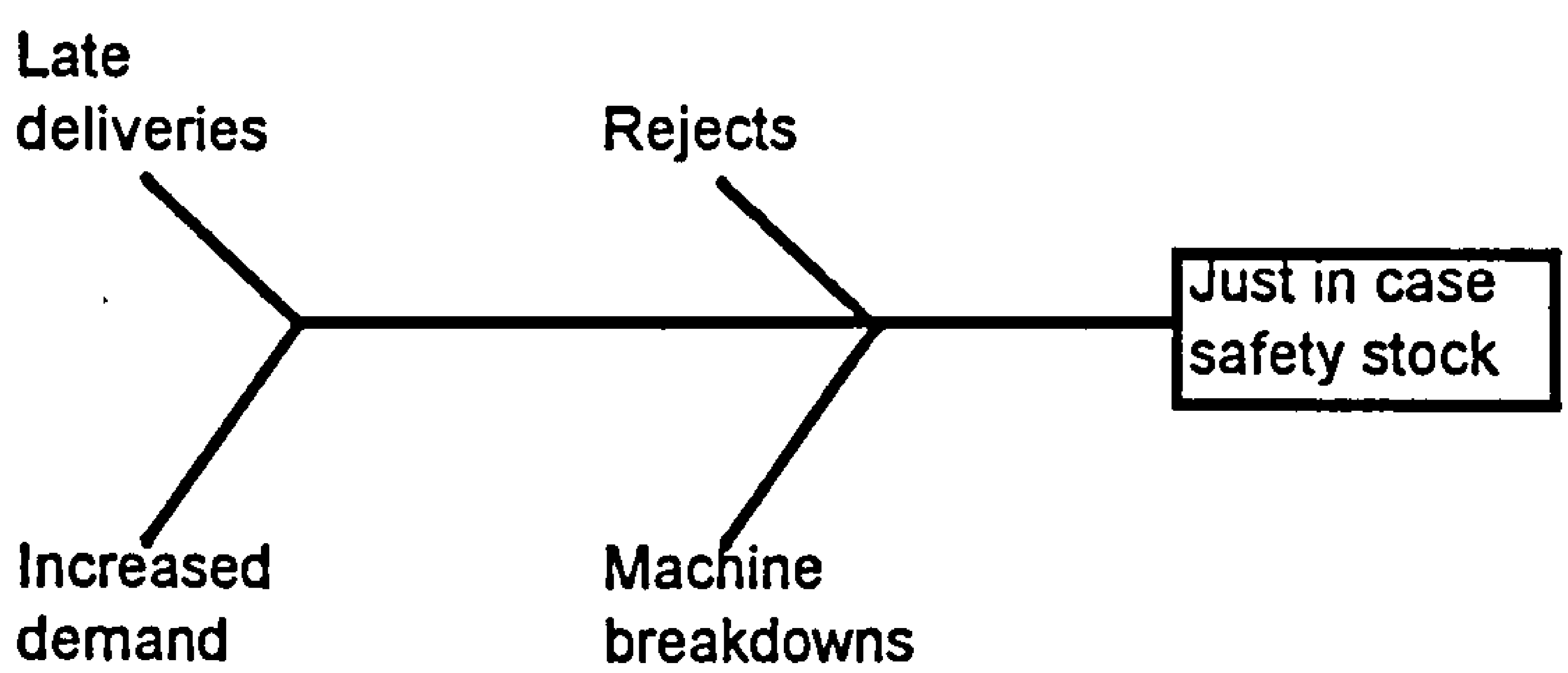

Figure 3.2: Just in case stock in traditional stock control techniques
(After Saunders, 1994, pp. 177)

3.2.2.2 Problems in supply chains

Formation of supply chains is founded on the desire to eliminate waste and duplication of effort, and the belief that co-operative behaviour reduces risk and improves efficiency of the entire logistical channel (Bowersox and Closs, 1996). However, co-operation among companies in supply chains has not been found to be an easy option. Three major obstacles have been identified:

- central to requirements of co-operation is trust. However, progress in building trust between trading partners is a slow process requiring painstaking work and long-term commitment from both sides (Fojt, 1996a);

- secondly, the perceived risk of loss of competitive advantage that may result from competitors finding out 'company secrets' has been identified as a significant obstacle to information sharing. Coyle et al (1996) viewed this as a problem which is likely to continue into the future; and
- one of the biggest obstacles is that obtaining the co-operation of trading partners in the use of information and communication technologies like EDI is difficult (Kappelman et al, 1996).

Notwithstanding the identified obstacles, good reasons exist why companies should be encouraged to form supply chain partnerships. Collaboration should drive investment cost, operating cost, and time out of supply chain processes by minimising non value-added activities and their associated structures among co-operating companies (Stewart, 1995).

The Chrysler-MAGNA alliance (Fojt, 1996b) provides a classical example from manufacturing supporting this argument. The case gives a scenario where acceptance of the lowest bid among suppliers is not a guarantee that costs will not 'shoot up' later. Lowest bids have the potential to have very small profit margins, if at all. The 'cost growth phenomenon' of supposedly lowest tenders after their acceptance is a recipe for sour, adversarial customer-supplier relationships. Target costing considerations in supplier evaluations appears to be a viable replacement for purchase order 'auctioning'. Combined with the help of suppliers in searching for cost reductions, such an approach, while helping to reduce costs and waste without 'eating' into profit margins of suppliers, has the added advantage of improving customer-supplier communications.

The Chrysler-MAGNA case went to show that conducive supply chain management can improve quality, reduce inventory and overall cost. It also showed that the supplier can have increased sales, provide improved value-added service and incur less costs - a perfect win/win result.

3.2.2.3 Information management in supply chains

External integration has been made possible by advances in information technology and changes in business culture. Information and communication technologies can greatly improve inventory visibility. The major problem in using information to manage the flow of goods in the supply chain was expressed by Forrester (1961, pp. 63) who stated that *"Information contains errors and random noise and unknown perturbations from external sources... Since information is the raw material of decisions, information distortions must be included if we are to represent decisions properly"*. Indeed information should be accurate, timely and visible before it can replace inventory (Singh, 1996). Such concerns are quite valid in paper-based information transmittal systems.

Present day information and communication technologies, however, can achieve information integrity. Supply chain management has benefited from developments in information technology (Saunders, 1994). Applications of present day information technology provide new efficient ways of data capture, storage, analysis and speedier transmission within and between organisations. More and more organisations are switching from slow traditional paper-based methods of communicating and processing business data to the expedient new information technology. Kappelman et al (1996) declared: *"Electronic data interchange (EDI) provides new and expanded methods of communication between business partners. EDI is the inter-organisational electronic transmission of business transactions in a standard format. With EDI, companies by-pass the traditional methods of sending physical documents, and instead send electronic ones. EDI is a form of communication which promises productivity"*. Figure 3.4 illustrates the EDI transaction process.

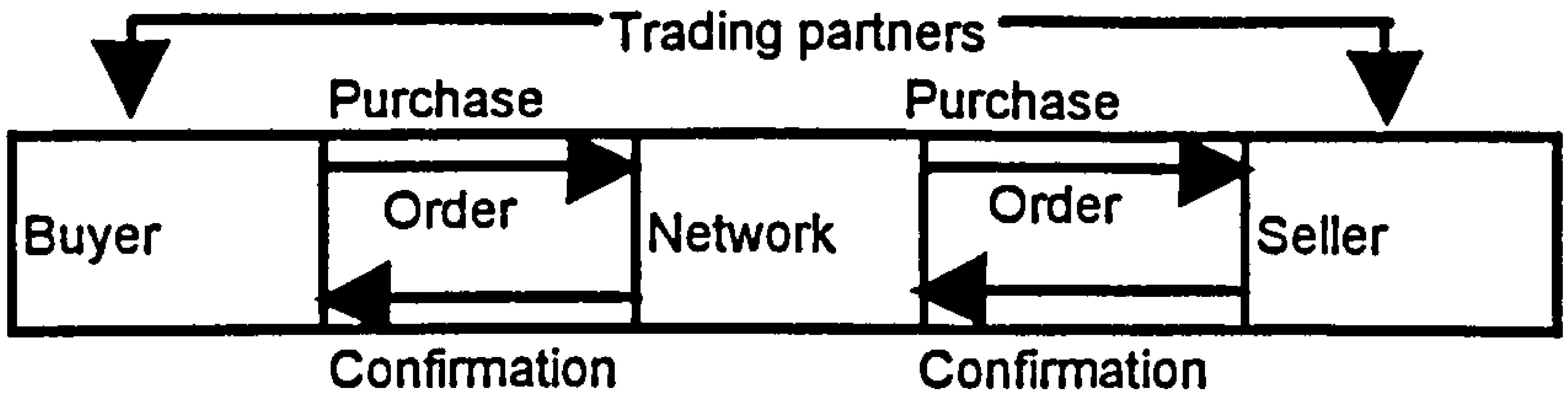

Figure 3.3: Example of an EDI transaction
(After Kappelman, 1996, pp. 13)

3.3 Types of information and communication technologies

Information and communication technologies, sometimes referred to as electronic data management technologies (Back and Bell, 1994), when implemented, facilitate electronic data entry and internal and external integration of logistics activities within and across organisational boundaries. These technologies were reviewed and discussed by Alkaabi (1994), and Back and Bell (1994). Those that can be used for data entry into computers include: bar codes, voice recognition, electronic document imaging, magnetic stripes, optical character recognition, machine vision and touch memory. Integrated database management systems (DBMS) and electronic data interchange (EDI) are integrative or information sharing technologies. These technologies are discussed below.

Integrated database management systems

This is an information based system which allows users to organise, store and manage all data relating to an activity, such as a project, electronically. The data can be entered and stored once and then accessed, transferred, combined, sorted, manipulated and reused by many different users simultaneously for different applications, all without printing and rekeying.

Electronic data interchange

Electronic data interchange (EDI) is the direct computer to computer application of business data in standard format which eliminates the need for the rekeying of information. EDI can be used to electronically transmit standard documents like requisitions, requests for quotations, purchase orders, shipping documents, materials lists, invoices and payment transfers between designers, owners, contractors and materials suppliers.

Electronic mail

This is an internet-based information and communication technology. Initially designed to supply government departments with communication facilities in the event of nuclear war, electronic mail (e-mail) has since evolved to more commercial applications and is said to be one of the reasons many business/domestic users have signed on to the internet (Cleary, 1998). In business, e-mail has found applications for tasks like electronic document interchange or as a rapid text messaging system. The technology can transmit messages on real time basis and is highly cost-effective. For example, data transmission charges are only a fraction of the costs of facsimile technology (Cleary, 1998). As messages, documents, etc. can be read and stored on the computer for later use, there are also savings on the use of printers and paper consumption. Other internet-based technologies are intranet and extranet.

Intranet technology

Due to the huge success of internet world wide web (WWW) pages, companies have begun to employ web pages and browsers to operate in-house information systems referred to as intranets. These are internal corporate computer networks which supply non-public company information in WWW style using internet protocol. The technology connects users to corporate databases thus enabling the pooling of information across the organisation via web browser technology.

Ordinarily, Intranets are equipped with an Internet gateway with a firewall that restricts entry by outsiders. Trading partners maybe permitted limited access via Extranets. Because Intranet communication technology is identical to the Internet, companies can use it for both interior messaging or publishing and as Internet for cost-effective communication links.

The use of the internet is one significant recent development in the use of information and communication technology by contractors. All the contractors that participated in the supplier management benchmarking exercise by Construct I.T. indicated some level of development towards organisation wide intranets (Construct I.T., 1998). The same study also observed evidence of introduction of early forms of extranets among the contractors that participated.

The extranet

The concept of extranet technology is to enable suppliers and customers to establish a walled-off section of the internet (Cleary, 1998). In effect, this is a virtual private network which companies in a supply chain can use to streamline their business activities.

Bar codes

A bar code has been defined as a self-contained message with information encoded in the widths of bars and spaces in a printed format (Bell and McCullouch, 1988). The technology can permit fast and virtually error free data entry into any type of computer system (Bell and McCullouch, 1988) and is an economical data acquisition system which can be used in a variety of applications and environments. In materials management, bar codes can be used to improve storage documentation and effectively generate requirements, document purchases, shipments and receipts (Stukhart and Cook, 1989).

Voice recognition

This technology facilitates a rapid and cost effective way of computer system data entry using direct voice to computer input. The technology has the potential for improving tasks performed in "hands busy, eyes busy" environments or locations remote from data entry terminals (Construction Industry Institute, 1992).

Electronic document imaging

Imaging has been defined as "the ability to capture, store, retrieve, display, process, distribute, and manage business information not already in digital form" (Nolan Norton Institute, 1990). Electronic document imaging allows users to digitise a business document which is in paper form and then move the image of that document electronically from one workstation to another for further processing or more efficient workflow (Back and Bell, 1994).

Magnetic stripes

Magnetic stripes are a read and write technology in which information is encoded onto a magnetic stripe which is attached to a card. Applications of the technology include: credit cards; telephone cards; cheque cards; access control; and time and attendance systems. The technology has been widely used in other industries like manufacturing and banking. Potential use of magnetic stripes in construction may be in head office or site office environment including access control, time and attendance control. The technology is not suitable for use on site for capturing information related to materials because the information stored is vulnerable to exposure from magnetic fields which may occur in the vicinity of electrical supplies or equipment on site.

Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is an automatic read and write electronic encoding data capture technique which uses modulated radio signals. The RFID system consists of three elements: an identification tag; a reader; and an antennae. The identification tag is a transponder that is capable of transmitting a signal of its own when it receives a signal from an external source. Transponder tags can act as receivers, transmitters or both. Radio waves are used to transfer data to the receiver. This eliminates the need for tags to be exposed to the receiver.

The transponder tag is a printed circuit board which has an antenna for receiving and transmitting data and a silicon chip for storing the data. The radio frequency reader is the device that reads the information stored in the tags. The tag receives a signal emitted by the reader via the antenna and after being activated transmits the information to the reader. The information transmitted from the tag is received by the reader and is then filtered to the decoder for decoding before being sent to the data collection computer management system.

This technology is suitable for data collection in environments and conditions where other methods of automatic data collection like bar codes are infeasible because the hardware required for a system is costlier (Alkaabi, 1994). The technology has been used in identifying railway cars and in highway tracking applications. Other applications include valuable cargo shipments and access control for vehicles and personnel for security purposes. Alkaabi (1994) investigated the advantages and disadvantages of the technology and identified its potential application in access control to site and personnel identification in the construction industry. It was, however, found to be too costly to implement with each tag going for approximately £2.

Optical Character Recognition

Optical character recognition is the oldest technique of all the automatic identification technologies (Alkaabi, 1994). The symbology used by this technology can be read by humans and automatically by machines. OCR has been used in retail; in distribution industry for sorting mail by identifying post codes; and for card and cheque processing in banking. OCR has little potential for use as a means of capturing data on site because the technique suffers from high error rates due to presence of dust which is present on construction sites (Alkaabi, 1994). Viable applications of OCR may be found at head office of construction companies for such purposes as invoicing and purchase order.

Machine Vision

Alkaabi (1994) provides a detailed review of this technology. It is an automatic identification technique which has rapidly come into use in the manufacturing industry where it is mainly used for production control, quality control, and security systems. The use of machine vision in construction may be feasible at company head office for applications like access control and security. However, applications of the technique on construction sites is limited because the high costs associated with the equipment may be difficult to justify and also the low accuracy which may result due to similarities in both features and shapes of many materials used in construction (Alkaabi, 1994).

Touch memory

This is one of the latest methods of automatic identification which reads and writes with a torch and transfers information from point to point without wiring (Alkaabi, 1994). The technology has found applications on employee badges which enhances security, especially in restricted areas; in hospitals for identifying patients and all their relevant information; in stores to track and monitor inventory; on trays in manufacturing plants for quick tracking as they move from section to section. The technology has potential use at company head office and also for access control, security, vehicle and materials control. However, by the mid 1990s, the technology was still in its infancy (Alkaabi, 1994). The combined use of the technologies just described can facilitate efficient data entry and transmission within and between companies in their logistics functions, consequently facilitating logistics integration.

3.4 The integration process

The complete route to internal and external integration of logistics was mapped by Stevens (1989). Evans et al (1989) acknowledged that no one has yet suggested an integration model equivalent to that by Stevens. Stevens' model is given in Figure 3.4.

Depending on the level of integration, Stevens (1989) identified four categories in which a company can be classified, i.e., baseline, functionally integrated, internally integrated, and externally integrated.

3.4.1 Baseline

Companies in this category place responsibility for different logistics activities in separate, almost independent departments.

3.4.2 Functionally integrated

Purchasing and material control activities for inbound logistics have been combined into the materials management function. Downstream, sales and distribution activities have been put together in the distribution function. All activities concerned with production have been put together in the production management function.

3.4.3 Internally integrated

At this level, the demand of products downstream has been integrated with the supply of materials and parts upstream within the company. There is co-ordination between and among materials management, production management and distribution; aspects which are directly controlled by the company.

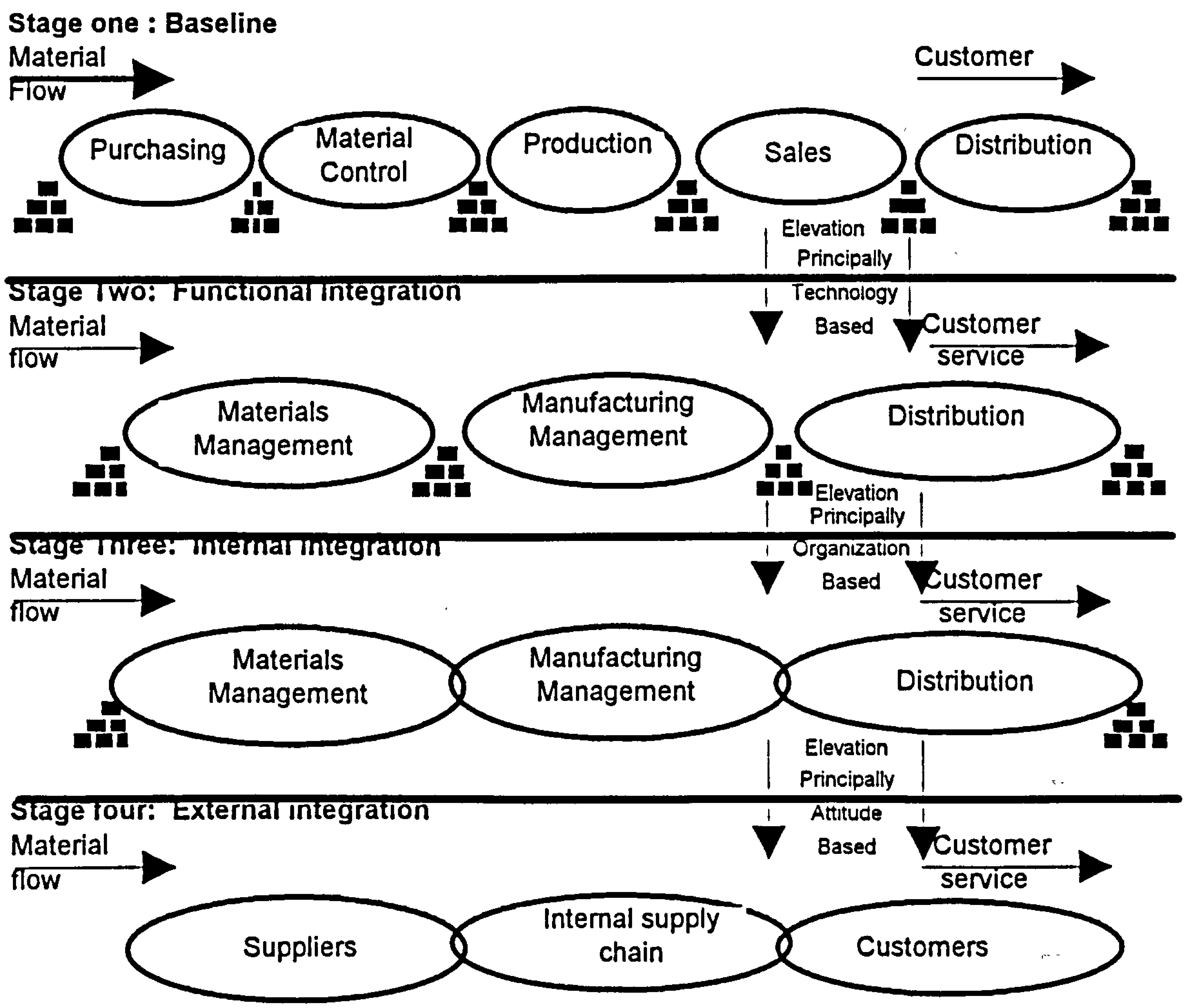

Figure 3.4: Stevens' model for achieving an integrated supply chain

3.4.5 Externally integrated

Companies in this category have achieved full supply chain integration. Integration of logistics activities has extended outside the company to include suppliers and customers. The vision is that supply of raw materials and semi-finished products should be synchronised with production to meet distribution requirements that satisfy customers.

The route to full supply chain integration from the baseline phase takes four steps in Steven's model. Evans et al (1995) argued that the functional integration stage in Steven's model is not essential, rationalising that the effort spent optimising functions to be redesigned later at the internal integration phase is waste. Instead, they championed the business process re-engineering (BPR) route which focuses on redesigning processes.

Integrating logistic activities within and between companies involves making organisational changes. Two contemporary methodologies for implementing organisational changes are business process improvement and business process re-engineering. Both are examined later after a discussion on business processes.

3.5 The process concept

A process has been defined by Hammer and Champy (1993, pp. 35) as *"a collection of activities that takes one or more kinds of inputs and creates an output that is of value to the customer"*. This definition is similar to those given by Davenport (1993) and Harrington (1991).

Processes can be categorised into *production* and *business* processes (Harrington, 1991). A production process is a group of physical activities such as construction or manufacturing which converts input raw materials, components and sub-assemblies into final products for external customers using an organisation's equipment and labour. A business process is a group of logically related activities such as procurement, transport, inventory and distribution employing an organisation's resources to support its production and/or service objectives.

Processes are, thus, mechanisms by which organisations add value to inputs to deliver value-added outputs in form of products and/or services intended to meet customer requirements. Structured processes are measurable in terms of cost incurred and time spent in executing them and the usefulness, consistency, variability and freedom from defects of their inputs can be assessed (Davenport, 1993). The degree to which customers are satisfied with the outputs is an important measure of the effectiveness and efficiency of the process. In contrast, hierarchical organisation structures, cannot, in absolute terms be measured and improved (Davenport, 1993). These are the major reasons why contemporary business consultants argue for process focused company organisation structures (Harrington, 1991; Davenport, 1993; Hammer and Champy, 1993). Implementing process changes requires that affected processes be identified.

3.5.1 Process identification

This involves pinpointing processes that need to be improved or re-engineered. Identification also sets the boundaries of those processes to be worked on. Main activities in identifying processes to be re-engineered are (Davenport, 1993):

- **listing major processes** - Porter's (1985) value chain framework (Figure 2.6) is useful in identifying primary business processes that can help a company achieve competitive advantage. In Porter's value chain, the major activities in an organisation are logistics (inbound and outbound), operations, marketing and sales, and service;
- **determining the boundaries of each process** - this involves determining: the various activities within the process and their sequence; whether the process itself is a sub-process in another process; when customers' involvement begin and end; whether performance benefits will result by combining the process with other processes or sub-processes; and delineating responsibility for the process. Boundary setting is iterative and goes on even after changes have been implemented (Davenport, 1993);
- **assessing strategic relevance of each process** - processes that are central to achieving an organisation's business strategy are favourable candidates to be selected for improvement/re-engineering programmes. Order management and

customer service have been cited as some of the areas many companies focus on (Davenport, 1993);

- **rendering high-level judgements of the "health" of each process** - health refers to whether the process is problematic and needs to be improved/re-engineered or not; and
- **qualifying the culture and politics of each process** - this involves assessing whether there is commitment in an organisation to effect change in a given process. If commitment is not strong, then re-engineering is not suitable (Davenport, 1993) in which case BPI may be resorted to.

Having identified a process that needs changing, business process improvement can be instituted if the objective is merely to improve efficiency and effectiveness of the existing process. If the change is to be radical, business process re-engineering is recommended. To improve their business performances, both Xerox and IBM included logistics among other processes in their re-engineering programmes (Davenport, 1993).

3.5.2 Business process improvement (BPI)

Business process improvement (BPI) is a step change approach. Via BPI, change is implemented by simplifying and streamlining operations, the objectives being that the organisation's processes should: eliminate errors; minimise delays; maximise the use of assets; promote understanding; be ease to use; be customer friendly; be adaptable to customers' changing needs; provide the organisation with a competitive advantage; and reduce excess head count.

Harrington (1991, pp. 21) conceptualised BPI as *"a methodology developed to help an organisation make significant advances in the way its business processes operate"*. Table 3.1 below shows Harrington's 12-step BPI implementation methodology in the order outlined.

Table 3.1: 12-Steps of business process improvement procedure

Step	Action
1. Eliminate bureaucracy	Remove unnecessary administrative tasks, approvals, paperwork
2. Eliminate duplication	Combine identical activities performed as parts of the same process into a single activity
3. Assess value-added role of activities	Evaluate all activities in the business process to determine their contributions in meeting customer requirements
4. Reduce process cycle time	Compress cycle time to meet or exceed customer expectations and to minimize inventory costs
5. Simplify	Reduce complexity in processes
6. Error-proofing	Make it difficult to do an activity incorrectly
7. Upgrade	Make effective use of capital equipment and working environment to improve company performance
8. Simplify language	Reduce complexity in both verbal and written communication
9. Standardize	Standardize ways of doing each activity
10. Supplier partnerships	Improve process performance via development of partnerships with suppliers in order to improve the quality of inputs
11. Big picture improvement	Innovate if the first ten steps have not delivered desired results. Search for bigger ways that can drastically change the process
12. Automate and/or mechanize	Automate/mechanize routine activities to free-up employees for more creative activities

BPI is a general step change improvement approach that is not limited to any specific business process. It is being examined in the light of how it can be used to streamline and simplify integrated supply logistics. More so when operating from the TQM mind set of continuous improvement. However, the procedure has one major weakness if applied to integrated logistics, since automation in the methodology is brought in as the last major change. Automation is the "heart and soul" of the effort to integrate logistics activities, as earlier discussions have revealed. To embark on logistics organisational changes without automation as the forefront objective is to miss the point.

The BPI approach outlined by Harrington to implementing improvements loosely relates to Stevens' (1989) model when, in Step 10, it considers supplier partnerships.

An order-of-magnitude organisational change approach which is next considered is business process re-engineering.

3.5.3 Business process re-engineering (BPR)

The definition of business process re-engineering is more often adopted from Hammer and Champy's (1993, pp. 32) definition who defined re-engineering as:

> *"the fundamental rethinking and radical redesign of processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service and speed".*

From their experience with business process re-engineering programmes, Hammer and Champy (1993) categorised companies that had implemented re-engineering into three groups: those that had faced the danger of going out of business; those whose performance was satisfactory but foresaw serious competition coming ahead; and those companies which were market leaders and saw no threatening competition on the horizon but had the ambition to dramatically improve their business performance. Thus, it follows that any organisation can re-engineer its business processes to align them with state-of-the-art knowledge, leading edge corporate practices, and technological environment to achieve or exceed contemporary measures of performance.

Contemporary business re-engineering is focused on redesigning corporate organisational structures so that they are process-focused. Traditionally, hierarchically structured companies are task-focused and have been criticised for not being able to capture the wider viewpoint and maximise the broader objective why companies exist - to meet and satisfy needs of customers - which process focused firms are aligned to (Hammer and Champy, 1993). Business process re-engineering is fundamentally different from business process improvement which implements change through incremental step improvements (Coulson-Thomas, 1995; Hammer and Champy, 1993). Where as BPI is evolutionary, BPR is revolutionary. Evans et al (1995) compared and contrasted BPI and BPR. They viewed BPI as taking the low risk route to the same destination as BPR, but with the likely disadvantage of not being sufficiently rapid to keep pace with fast increasing competition.

Bashein et al (1994) viewed re-engineering *as "a high risk, high reward endeavour"* and cautioned enterprises contemplating the move in this direction to proceed with care. The failure rate among companies that have attempted re-engineering was reported to be in the region of 50 - 70 per cent (Barret, 1994, Hammer and Champy, 1993). Causes of failure in re-engineering projects include:

- failure by BPR teams to consistently get the vision right each time (Barret, 1994);
- lack of sustained management commitment and leadership (Bashein et al, 1994);
- unrealistic scope and expectations (Bashein et al, 1994); and
- and resistance to change (Bashein et al, 1994).

Table 3.2 compares and contrasts BPI (improvement) and BPR (innovation).

Table 3.2: Process Improvement versus Process Innovation
(Adopted from Davenport, 1993, pp. 11)

	Improvement	Innovation
Level of Change	Incremental	Radical
Starting Point	Existing process	Clean slate
Frequency of change	One-time/continuos	One-time
Time required	Short	Long
Participation	Bottom-up	Top-down
Typical Scope	Narrow, within functions	Broad, cross-functional
Risk	Moderate	High
Primary Enabler	Statistical control	Information technology
Type of change	Cultural	Cultural/structural

3.6 Logistics support systems for production

Logistics is influenced by the supply philosophy adopted to support production. The supply philosophy itself is determined by the way inventory is managed. There are two basic types of supply systems: push and pull.

3.6.1 Push scheduling

The main feature of this system is maintenance of minimum inventory as buffer against stock-out of inputs or finished products. Stock is 'pushed' to the next storage point in the supply chain according to plans which may not necessarily match the usage rate. Even though it is designed as a pull system, materials requirement planning (MRP) in practice operates as a push system.

3.6.1.1 Materials requirement planning

Materials requirement planning is based on the master production schedule (MPS). The MPS itself reflects what is to be produced (including the number of units) and when. The MPS is a planning tool for manufacturing and links a company's production capacity to market demand so as to be able to plan for production.

The two main objectives of materials requirement planning are to "determine requirements and to keep priorities current" (Arnold, 1991, pp. 49). As a planning system, MRP generates information required to place orders. To enable a new order to be placed, MRP makes available information about: what items should be ordered; the quantity to be ordered; when the order should be placed with the supplier; and when to schedule delivery (Orlicky, 1975; Arnold, 1991).

A new order action in MRP originates from inventory control where a requisition is placed with purchasing. Purchasing, subsequently places the order with a selected supplier. Sometimes demand and/or inventory requirements necessitate revision of the order previously placed to keep priorities current. A revision of the previous order may be to increase the order quantity; decrease the order quantity; cancel the previous order altogether; bring the order forward; defer the order to a later date; or to indefinitely defer the order (Orlicky, 1975). Harrison (1992) viewed MRP as good at materials planing but poor on timing. Figure 3.5 shows the components of MRP.

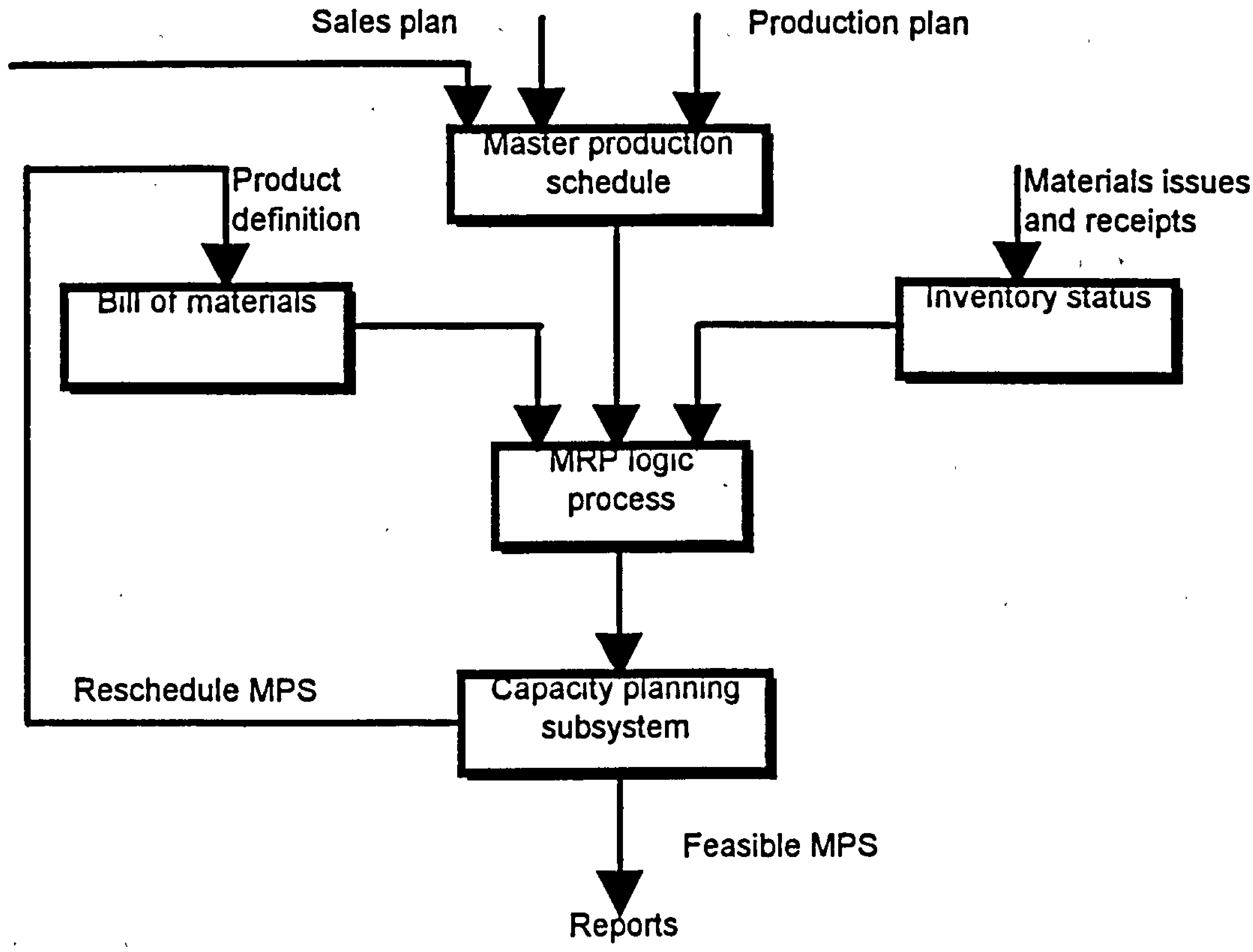

Figure 3.5: Components of MRP
(After Shenoy and Bhadury, 1998))

3.6.2 Pull scheduling

In pull scheduling, materials and parts are supplied at the actual rate they are used by production or demanded by customers as opposed to planned usage rate employed by the push system. The system adjusts to demand variations by responding to the rate of usage of inventory in the supply pipeline. Where the push system maintains minimum inventory as an insurance against stock-outs, the pull system uses the rate of flow of pipeline inventory to react to variability.

There are a number of pull scheduling systems (Harrison, 1992). All use just-in-time (JIT) techniques.

3.6.2.1 The just-in -time philosophy

The just-in-time philosophy of supply was developed and perfected in the Japanese car industry, by Toyota to be specific. Harrison (1992) gave three reasons why JIT stands out elegantly from other approaches to improving business performance:

- it combines various techniques to reduce waste;
- it is process focused and gets everyone to participate; and
- it has enshrined in it the total quality management (TQM) principle of continuous improvement.

Just-in-time production is aimed at elimination of waste. Waste in the JIT environment is defined as any non-value adding activity in the production life cycle of a product (Arnold, 1991; Harrison, 1992). Toyota is credited for having identified seven types of waste in both service and production operations. These are:

- **process** - factors that lead to waste during the process include use of wrong type of equipment, tools and methods. At the end of the process, waste manifests in poor product quality, increased process time and increased scrap. Good quality is achieved if customer expectations are met or exceeded;
- **waiting time** - waiting time occurs in labour and equipment. Waste is incurred when labour or equipment is idle;
- **over-production** - over-production refers to producing more than is needed by the next operation or the market. Over-production increases work-in-process and handling, requires more planning and control, increases inventory and causes quality problems (Arnold, 1991; Harrison, 1992);
- **inventory** - inventory does not add value to the product. It adds cost instead and is thus viewed as waste;
- **defective goods** - defective items disrupt work flow. Such items can, worse still, cost a company its customers. Time spent waiting for defect-free replacements is waste;

- **motion** - motion that increase movement, time and effort for operators to execute tasks add waste and should be eliminated. Work study can help reduce such waste; and
- **movement** - moving goods to storage and from storage to production areas does not add value to products. The labour and equipment involved in the materials handling, storage and record systems all add cost instead of value. Layout planning is also important in reducing this kind of waste.

Just-in-time techniques may be more applicable to repetitive manufacturing (Arnold, 1991). The pull system is founded on just-in-time techniques. Both just-in-time and the pull system depend on long-term relationships based on mutual trust and co-operation between suppliers and the firm engaged in production. Table 3.3 below compares MRP and JIT systems.

Table 3.3:
Comparison between MRP and Pull scheduling
(Adopted from Harrison, 1992, pp. 194)

	Materials Rquirement Planning (MRP)	Pull scheduling/kanban (JIT)
Description	A materials management system aimed at minimum inventory	A system of manufacturing aimed at producing parts which have been withdrawn or sold
Difference in philosophy	Driven by the master production schedule	Driven by factory assembly schedule
Difference in method	Operated as a push system by scheduled orders	Operated as a pull system from the process nearest to the market
Unit of control	Weekly scheduled orders	Achievement of daily factory schedule
Pre-condition	Data accuracy, discipline, training	Balanced levelled schedules, flow, e.t.c.

3.7 Lean production

One method of production which uses the pull system is lean production. The principles of lean production were outlined by Womack et al (1990). In essence, lean production is based on the just-in-time philosophy. As the name suggests, the primary objective, as in JIT, is to eliminate waste.

Lean production calls for closely co-ordinated processes within and between companies in the supply chain. A lean production system is highly customer sensitive. The system produces only what is required by the market. A lean enterprise, the group of companies involved in product delivery encompassing materials suppliers and product producers, has an enterprise leader and functions on principles of: target costing; commitment of the enterprise firms to continuous improvement ideals; commitment to agreed process performance levels; agreed methods of arriving at costs; and agreed methods of sharing costs and benefits (Fojt, 1996b). A lean enterprise operates on the basis of measurable and assessable contributions of individual firms with the view to continuously make improvements.

Supplier selection tends to be based on proven performance record established in past relationships. Assembler-supplier relationships in lean production work because "*a rational framework exists for determining costs, price and profits. This framework makes the two parties want to work together for mutual benefit rather than look upon one another with mutual suspicion*" (Womack et al, 1990, pp. 148). The basic producer-supplier relationship in lean production reflects the desire and commitment to long-term working relationship, setting the agenda for co-operative behaviour. The relationships are based on the co-development and co-makership methodology. During product development, value engineering is used to breakdown costs of each production phase and to identify factors that can aide in lowering costs to arrive at the market price by both the supplier and the assembler. During the production phase, value analysis of each production phase is employed to see where improvements can be instituted to reduce waste and costs.

3.8 Summary

The need to introduce efficiency and cost-effectiveness in logistics necessitates integration of logistics activities both within organisations and externally. The integration of logistics itself has its own obstacles which have been identified in this chapter. To introduce efficiency in logistics and supply chains of companies require implementation of information and communication technologies and making organisational changes which should lead to lean production, a philosophy based on the need to eliminate waste. The next chapter examines logistics and supply chain concepts from the perspective of the construction industry.

CHAPTER FOUR

CONSTRUCTION SUPPLY CHAINS

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CONSTRUCTION SUPPLY CHAINS

4.1 Introduction

The review of logistics and supply chain management in Chapters 2 and 3 focused on primary activities in Porter's value chain and had manufacturing and retailing inclination. The supply chain concept in construction covers a much wider resource base because of the project nature of the industry. Due to the temporary nature of construction and the involvement of many organisations in the supply of resources, supply of all inputs represent flows in the inter-linked chain of companies. This chapter examines the concept of supply chains in the context of the construction industry. Direct resources mobilised by project participants are discussed. The chapter further discusses integrative mechanisms in construction supply chains.

4.2 Resources in construction supply chains

Watson (1988) suggested that construction management is concerned with efficient utilisation of knowledge, money, time, manpower and material resources. Lema (1996) argued that direct inputs into construction processes include expertise, manpower, materials and equipment.

Knowledge, money, time (Watson, 1988) and expertise (Lema, 1996) apply across all resources in the construction process. These are neither physical nor direct inputs. Knowledge and expertise are results of trained and experienced manpower, both are intangible and their efficient utilisation may only be demonstrable through delivery of quality, cost-effective and timely construction products. Other inputs in construction supply chains include land, water, energy and other services provided to the industry by local authorities, utilities and service sectors (Miles, 1996). Direct physical resources managed via construction supply chains, thus, include labour, equipment and materials.

4.3 Types of supply chains

In line with Porter's value chain, Saunders (1994) classified supply chains into two categories - primary supply and support chains. For both types of chains, Saunders recommended that the strategic focus in the development of supply arrangements for any type of material or product should:

- identify the patterns of customer service requirements and expected demand patterns for each product or group of similar products;
- establish a supply chain framework for necessary logistics activities through the involvement of all relevant parties at the planning stage;
- select a planning and control system that enables all parties to plan and manage logistical flows via information sharing throughout the period when supply is required; and
- identify supply chain aspects that require improvement as part of a continuous improvement programme.

4.3.1 Primary supply chains

Primary supply chains deliver goods that become part of the end product for the ultimate customer. In the construction industry, such items include materials, components, sub-assemblies, and mechanical and electrical equipment which are incorporated into the final construction product. Delivery of materials has been estimated to control 80 per cent of the project schedule from initial materials acquisition to the delivery of the last item (Kerridge, 1987) and to account for 30 to 80 per cent of the total project installed cost depending on the type of project (Kerridge, 1987; Muelhlhausen, 1991; Stukhart, 1995). This has led to the recognition that the way to control project costs and schedules in construction is via an integrated materials management approach embracing the total construction materials procurement cycle (Marquadt, 1994; Berka and Conn, 1994).

Despite the high proportion of materials costs and their influence on construction project's schedules, the materials delivery process has been reported to be fraught with problems (Stukhart, 1995; Thomas et al, 1989; Majid and McCaffer, 1996). For example, from a synthesis of literature, Majid and McCaffer (1996) identified late delivery of materials as one of the critical factors that caused construction schedule delays. Other materials related construction delays resulted from, damaged materials, poor planning, poor quality control, poor monitoring and control, and inefficient communications.

From the manufacturing viewpoint, Towill (1996) viewed the primary supply chain as the main arena for reducing bottom line costs through reduction of lead times. Enhancing efficiency in the supply of construction materials can result in major cost savings not only in the resource itself, but also in the utilisation of other construction resources. Poor logistics and supply chain management of construction materials has been noted to lower motivation of operatives on sites and consequently lead to losses in labour productivity. Borcheding et al (1981) observed that non-availability of materials at the workface was ranked highest among the factors that demotivated construction operatives.

In addition to cost savings that can be achieved from the resource, improvements in materials supply could lead to an estimated six per cent increase in labour productivity (The Business Roundtable, 1983). In a single case study of structural steel erection of an office block and car-park structure, Thomas et al (1989) estimated an order-of-magnitude work-hour overrun of 18 per cent, which is three times greater than the six per cent productivity loss estimated by the Business Roundtable (1983) as a result of poor materials management.

Re-engineering materials management through the introduction of best practices such as fewer, high quality long-term supplier relationships, cross-functional involvement of personnel in different departments, purchasing and inventory management during supplier negotiations, Just-in-Time supplier contracts, supplier-owned inventory, introduction of electronic data interchange, payment upon receipt and other practices could help enterprises cut costs, enhance efficiency in their business processes and satisfy their customers (Batorski, 1995).

Simulation of the electronically integrated primary supply chain using EDI and integrated database management systems between contractors and suppliers pointed to potential savings in cycle time of the order of 48 - 76 per cent and cost savings in labour of 24 - 50 per cent in the procurement of construction materials (Back and Bell, 1994; Carter, et al, 1996). Furthermore, a bar coding feasibility study at one company specialising in the manufacture of pre-cast concrete flooring systems in the UK established the following savings (Alkaabi, 1994):

- an 85 per cent time saving in clerical time for entering data on to the company's computer;
- a 70 per cent time saving in checking beams prior to delivery; and
- a 30 per cent time saving in locating a beam within the stockyard.

Work already conducted on primary construction supply chains indicates that tremendous scope exists for reducing lead times and lowering costs in this area of construction products supply. Womack et al's (1990) classic work, The Machine That Changed the World, sets good benchmark approaches from manufacturing towards lean primary supply chains for the construction industry.

The temporary and one-off nature of construction projects also implies that labour and support resources have to be mobilised and possibly outsourced to a greater extent than in other sectors such as manufacturing and retailing. The supply of labour and equipment thus become additional dimensions when extending supply chain concepts from other industries to construction.

4.3.2 Support chains

Support chains deliver materials and equipment for temporary works. Temporary works have been defined as "*any temporary construction necessary to assist the execution of the permanent works and which will be removed from site on completion*" (Illingworth, 1993).

The full range of temporary works encompass provision of: falsework and formwork; support for excavations; scaffolding; temporary works related to operation of equipment; site access; and the provision of site accommodation (Illingworth, 1987). Provision of temporary works can be a significant activity representing a major cost element. Illingworth (1987) gave an example where falsework accounted for 62 per cent of the cost of a bridge.

Poor supply of equipment has an adverse effect on labour productivity. Borcheding et al (1980) cited lack of trucks or cranes, or both, to transport materials to the workface as one of the most frequently mentioned factors which caused loss of labour productivity in their study. They further ranked non-availability of tools second in importance to non-availability of materials in causing labour productivity losses. The labour resource, and especially its productivity, has been of major concern because of the labour intensiveness of the construction industry (Agapiou et al, 1995).

4.3.3 Labour

Human resources on a construction project can be categorised into supervisory staff and manual labour. Of these, the labour component is a direct input to the construction process. Druker et al (1996) noted the high prevalence of sub-contracting and the use of self-employed manual labour in the UK construction industry. Over 50 per cent of construction companies surveyed responded that more than 60 per cent of their workforce was non-manual. This was interpreted as a major shift in the employment pattern from direct employment of craft operatives by UK construction contractors to increased use of specialists or labour only sub-contractors. The 60 per cent figure given by Druker et al corresponds with the 43 per cent quoted by Agapiou et al (1995) as representative of the self employed workforce in the UK construction industry. However, the Industry Tax Scheme which comes into effect on August 1, 1999 favours workers to be categorised as employees rather than self-employed and will likely lead to the decline of the trend towards self-employment (Alderson, 1999).

In craft personnel terms, construction companies, thus, appear to have become leaner. The use of sub-contractors and self-employed labour has become the norm. Increased complexity of projects, especially buildings, implies more construction companies have to depend on sub-contractors where the pool of craft skills has shifted (Ndekugri, 1988; Agapiou, 1995 et al; and Druker et al, 1996). The shift in the craft skills reservoir has led to a greater need for the main contracting organisations to focus increased attention on the management of sub-contractors. This is because increased use of specialist trades working in close proximity has led to a rise in new interfacing problems (Agapiou et al, 1995). As noted earlier, reducing interfacing problems is a major driver for supply chain management.

All the direct resource inputs, labour, equipment and construction materials are supplied and managed by a linkage of companies that can, in aggregate, be termed construction supply chains. Figure 4.3 outlines the linkages of the various suppliers and the resources they supply in construction supply chains.

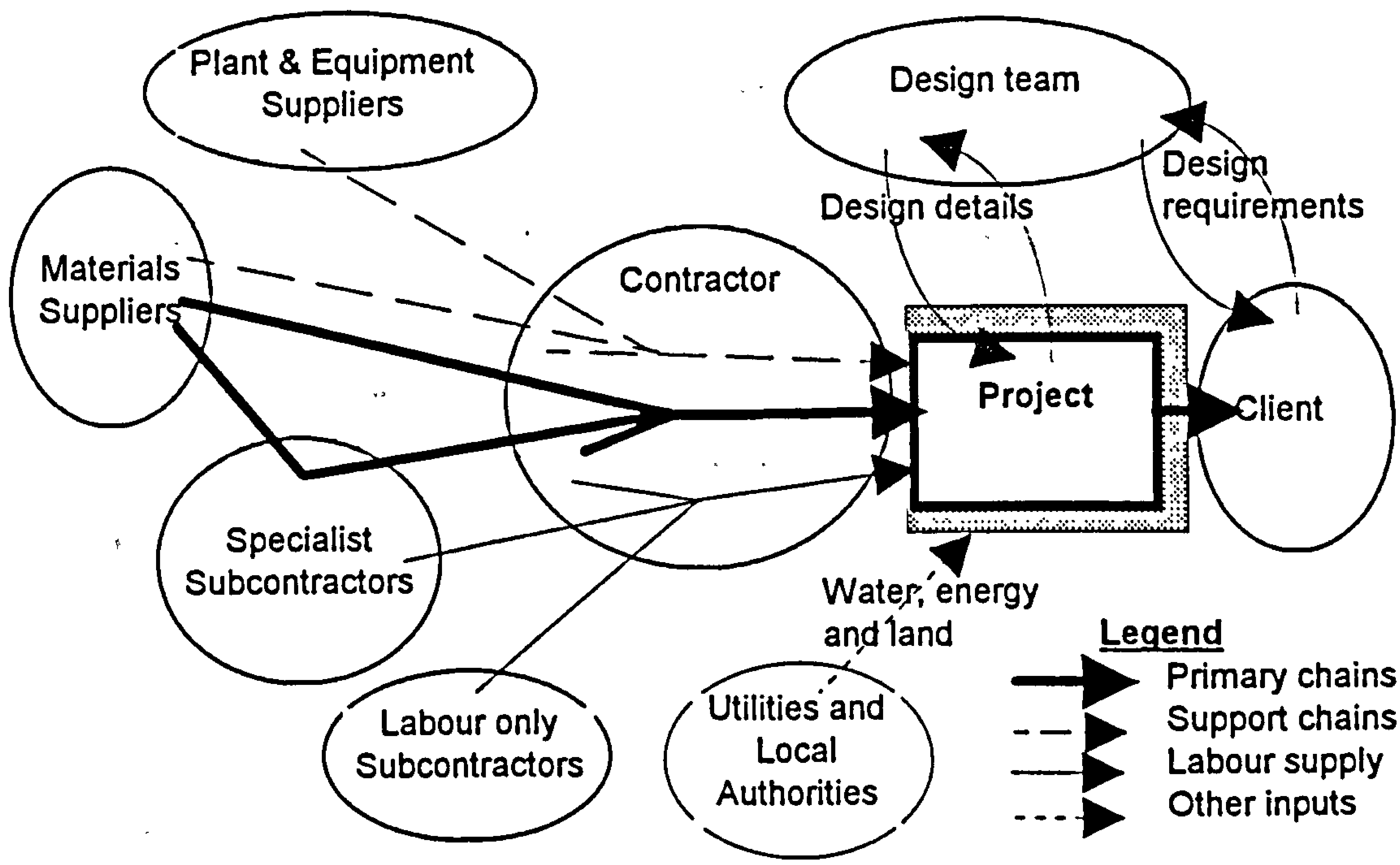


Figure 4.3: Resources supply in Construction Supply Chains

4.4 Parties in construction supply chains

Parties within construction supply chains include clients, designers, contractors, sub-contractors, and materials suppliers. All these provide inputs of one form or another which go towards the realisation of projects.

4.4.1 The client

The client is the owner of the constructed facility, though he/she may not be the end user. The client's procurement decisions, especially of contractual supply partners, should result in high level customer satisfaction. The final selection decision involves consideration of numerous factors which favour this major objective. Irrespective of the final type of contract employed, two general options through which a client can choose a contractor are either by negotiation or through competition (Baldry, 1996).

Circumstances may require a client to obtain the services of a contractor through negotiation. Partnering; the need to start construction early; or a company having unique equipment or techniques could be some of the reasons why the client may opt for this method.

A client may choose to use competition to select a contractor for the following reasons (Smith, 1995, pp. 194):

- *"to obtain a fair price for the work, bearing in mind the general state of the construction market at the time; and*
- *to enter into an agreement with a contractor who possesses the necessary technical skill, resources and financial backing to give the client the best possible chance that the works will be completed within the required time, cost and quality standards".*

Price is a major factor upon which contractors are selected and depending on circumstances, time can also become the controlling factor. The cheapest price, though, may not provide value for money because of the inherent risk of choosing a contractor who may perform poorly (Smith, 1995). Apart from price or the tender sum, Holt el al (1994) identified a number of other selection criteria which if carefully evaluated by clients would help identify the 'most suitable' contractor leading to greater probability of a successful project outcome. These criteria include:

- contractors' current workload;

- contractors' past experience in terms of size of projects completed;
- contractors' management resource in terms of formal training regime;
- time of year (weather being the main factor considered); and
- contractors' past experience in terms of catchment, i.e. national or local.

Procurement through competition may be undertaken through open or selective tendering. Because of the large numbers of firms competing, open tendering is viewed as effort wasting, costlier and presents a greater risk of choosing an unsuitable contractor (Smith, 1986). For these reasons, selective tendering is preferred. In selective tendering, the decision to include a company on the shortlist of companies invited to tender is based on four of the factors identified by Holt el al (1994) above and include (Smith, 1986, pp. 9):

- *"the firm's financial standing and record;*
- *the firm's recent experience of completing similar work within the specified time;*
- *the structure of the firm: technical and managerial staff, workforce and back-up facilities; and*
- *the firm's capability of accepting the work at the required time".*

The decision on which a contractor is chosen is heavily based on the client's assessment of the contractor's ability to execute the project within cost, time and quality requirements whether negotiation or competitive tendering is used. Between the two approaches, negotiation via the client-contractor partnering route has become more dominant in the UK construction industry (Construction Manager, 1998). The cascading effect of this may lead to increased supply chain integration between contractors and suppliers in future.

4.4.2 Designers

Even though they are not direct contractual parties in construction supply chains, designers as consultants to clients have influence on performance of construction supply chains. Clients are usually advised on the selection of main contractors, and nomination of sub-contractors and materials suppliers by project designers.

Designers determine the method of construction and hence site logistics. They also determine to an extent whether standard and prefabricated components are used, though such elements are subject to factors emanating from the client as well. Selection and specification of materials and components are carried out at the design phase. Availability of materials selected and specified during design affects logistics (Ahmad, 1996). Non-availability of specified materials in the local market can require long lead times to acquire such items. Their shortage can cause delays and disruptions to construction schedules. Designers need to foresee problems and mitigate their effect on resource supply logistics. Designers' representatives further ensure that materials incorporated into the facilities comply with specifications (Seeley, 1993).

Clients and designers often introduce variation orders through designers. Such changes in design can introduce new materials and components at short notice and affect supply logistics. Matin (1996) recommended tripartite consultations between clients, designers and experienced contractors when selecting construction materials. Such an approach could reduce materials or/and specification changes during construction. Rutland (1996) identified clients and designers as main contributors of variations caused by deficient contract documents and changes in project requirements during the construction phase. Early contractor involvement through mechanisms like partnering at the projects requirements stage aims and should reduce the frequency of client/designer variations.

Information may sometimes not be available from the design office to enable work to proceed and also materials to be ordered during construction (Hakserver, 1995). Thus, while the designer's main input to the supply chain is informational, his/her influence in supply logistics could be much wider than might be apparent in as far as his/her advice to the client in choosing supply chain participants go. They are also involved in nomination of sub-contractors and materials suppliers.

4.4.2.1 Nomination of sub-contractors

The Aqua Group (1992, pp. 88) defined a nominated sub-contractor in building as one *"whose selection is reserved to the architect, and who may be:*

- *nominated by way of a prime cost sum; or*
- *specifically identified by name".*

Specialist sub-contractors are nominated on behalf of the client by the adviser who is often the designer. Due to complexity of construction projects, it is often necessary for the designer to engage the know-how of specialists during the design process, especially when structural steelworks, mechanical and electrical installations and lifts are involved. Leading from their early involvement and relationship with the client, such specialists normally end up being nominated to enter into sub-contract with the main contractor in order to carry out the specialist work they designed. The following are reasons why nomination may be necessary (Banwell, 1964):

- the designer may require *specialist techniques* which a specialist can offer;
- necessity to place an order for specialist work at an *earlier time* before the main contractor is selected; or
- a *particular quality* of work may be required which a specialist sub-contractor can offer.

To achieve client satisfaction, nomination requires co-operation among the client, the designer, the contractor and the sub-contractor because of the responsibilities the system requires from each of them (The Aqua Group, 1992). Selection of the rest of the sub-contractors is normally the responsibility of the main contractor.

4.4.2.2 Nomination of materials suppliers

Nominated suppliers are usually selected for the main client by the designer (Johnston, 1981). Generally, in contract conditions, a supplier is considered nominated if (The Aqua Group, 1992):

- a prime cost sum is included in the bill of quantities and the supplier is named in the bills or is subsequently named by the designer;

- a prime cost sum is included in an instruction regarding the expenditure of a provisional sum and the supplier is named in the instruction, or is subsequently named by the designer; or
- in an instruction regarding the expenditure of a provisional sum or in a variation order the designer specifies materials or goods which can only be purchased from one supplier.

If no prime cost sum has been included, the supplier is not necessarily nominated even if he/she has been named in the bill of quantities. The designer decides the products for which to nominate suppliers. Such a decision is normally based on the suitability of materials for the design. Nominated suppliers are often consulted by the designer during the pre-contract period (Johnston, 1981). Another type of suppliers are referred to as specified suppliers. These are included in the main contract by the designer but negotiation for supply of goods and settlement of accounts is between the contractor and the supplier.

Nomination of suppliers should be conducted during the pre-contract phase to facilitate proper preparation of the bill of quantities (The Aqua Group, 1992). Even then, contractors may still prefer suppliers who they have worked with previously. If the contractor finds a nominated supplier undesirable he/she can object, though this rarely happens (Johnston, 1981).

4.4.2.3 Free-issue materials

This system involves the client procuring materials for the project and free-issuing them to the contractor during the construction programme. The client may prefer the free-issue system for the following reasons (Glen, 1981):

- being cautious of the safety aspects of the installation and *to ensure reliability*, the client may use a quality assurance officer to procure materials for the project;
- to obtain generous *discounts on bulk purchases* from suppliers, which may not be available to the contractor. Such discounts may offset materials procurement costs; and

- to ensure availability of *specialised equipment* which require one-off manufacturing for which the contractor may not have the time to arrange.

The free-issue system has been criticised for its unreliability in ensuring that materials arrived on site on time (Glen, 1981). This can lead to the disruption of the contractor's construction schedule, which can cause costly claims to the client.

4.4.3 The main contractor

All the three direct resources (namely labour, materials and equipment) in construction supply chains are usually managed by the main contractor. The management of labour and related labour-only sub-contractors was discussed in Section 4.3.3. The contractor is normally responsible for evaluating and selecting all the other materials suppliers, sub-contractors and equipment suppliers not nominated by the client or the client's advisor.

Even though the designer usually selects and specifies materials and components and describes them in the bill of quantities, it is the responsibility of the contractor to evaluate suppliers (those not already nominated), place orders and receive items on site. To ensure availability, sometimes the designer will place a reserve order on certain materials before contractors are invited to tender (Johnston, 1981). When a contractor's bid is accepted, he or she is informed about the materials for which reservations have been made and should place official orders with the supplier at the earliest possible time thereafter.

For the contractor, the function of materials management is to: identify materials requirements; identify appropriate materials suppliers; manage the ordering process; arrange timely delivery of requisite materials to site; and store and dispense those materials on site to locations where they are required.

4.5 Managing construction supply chains

Latham (1994) encouraged the UK construction industry to reduce costs by 30 per cent. The 30 per cent cost reduction can not be achieved by companies acting independently. Improvements have to be found in all the companies in a supply chain. Sigma (1997) likens a supply chain to a virtual company whose sole existence is for designing, engineering and building products which satisfy the demands of customers and suggests that the way to optimise the supply chain to meet customer needs is to change the nature of relationships: company cultures, people attitudes and behaviours. To succeed, it is necessary to have all the companies in the virtual company empowered and aligned to the end goals as are departments in companies which achieve their corporate objectives.

The conceptual and design phases are the best stages for the convergence of ideas of construction supply chain participants in order to reduce lead times, lower costs, improve quality, minimise variations during construction and for starting the partnering process and getting the commitment of all involved. Goucha and O'Connor (1996) demonstrated the importance of the designer-supplier interface in their study of the supply of vendor-data at the design stage of industrial piping. Numerous problems in vendor data delivery which included missing, late or vendor documents containing inaccurate information when they were needed to support engineering designs, were identified. The uncertainty resulting from missing data and documents was incorporated into design documents only to cause problems in succeeding processes, leading to: redesign of piping interfaces and/or transitions; misfabrication of components; rework at the fabrication shop; rework on site; and on-site piping rerouting.

Early integration may be unnecessary and unproductive in some instances due to the difficulties inherent in integration of design and construction. It has been emphasised, however, that due to increasing complexities and competitive pressures in the industry, efforts aimed at integration are necessary and will continue (Puddicombe, 1997).

4.5.1 Integration of construction supply chains

The trend towards the integration of systems supports supply chain management. In construction, integration is required to create a sense and culture for participating firms to identify with the project and is concerned with establishing common objectives for the project organisation system as a whole. From an extensive survey of organisational theory, Luck and Newcombe (1996) categorised integrative mechanisms into three: hierarchies, formal procedures, and informal procedures:

- the hierarchy of a project based organisation is established by the contract signed at the time of engagement of parties. The contract establishes responsibilities of persons or firms in the project organisation;
- formal procedures are administrative mechanisms and are a means of controlling inputs of sub-systems or firms in a project organisation; and
- informal adjustments are non-contractual activities and their introduction is for harmonising the working environment.

A construction project is an inter-firm coalition that has in the past relied on contractual rather than administrative relationships (Winch, 1989). Contracts have, traditionally, been the strongest mode of holding together project participants in fragmented construction supply chains. Construction contracts have, however, proved to be a fertile area for adversarial relationships.

In searching for ways to reduce or eliminate adversity between contracting parties, particularly contractors and clients, the industry has been turning to partnering (Crowley and Karim, 1995; Miles, 1996).

Puddicombe (1997) broadly classified organisational integrative tools into contractual and social psychological and placed partnering into the social psychological category. He then presented the notion that as contractual dimensions proceed from traditional through construction management to design and build they exert a stronger force towards the integration of the contracting parties.

4.5.1.1 Partnering

A partnering arrangement is not intended to be legally binding unless otherwise mutually agreed to, consequently, partnering does not supersede a contract. Partnering is directed at achieving win-win transactions by reducing adversarialism and promoting co-operation between parties (European Construction Institute, 1997). It is based on the willingness of parties to work together and achieve goals they have mutually defined and agreed to.

There are two broad types of partnering arrangements: strategic partnering, which is for a long period of time; and project-specific partnering, which is for the duration of an individual project (European Construction Institute, 1997).

Partnering is one of the key elements of the TQM concepts. Realisation dawned early during the implementation of TQM in manufacturing that the product is the result of all parties involved, from suppliers to manufacturers through to distributors (Miles, 1996). In the continuous search for improved performance in quality, efficiency and cost effectiveness, it was concluded that traditional competitive bidding was working against business objectives, hence the need to develop long-term trading relationships, especially in the form of strategic partnering arose.

The identified elements of successful partnering include (Bingham, 1995; Miles 1996):

- a commitment of parties to endeavour for zero defects, successful execution of project delivery goals, improved reliability of delivery in time and cost, better value, maintenance of satisfactory profit margins, and a willingness to work together;
- equity of all stakeholders during the development of project goals;
- open and honest communications based on mutual respect;
- trust in the sharing of information;
- system for resolving problems at the lowest level, with a mechanism for escalation for those that require the attention of higher management;

- real-time responsive decision-making to issues that require immediate attention of higher management; and
- continuous measurements and evaluation of project milestones and goals.

Companies that have partnered previously report having experienced the following benefits (Construction Industry Institute (CII), 1991; European Construction Instate (ECI), 1996):

- reduced costs associated with disputes and legal proceedings;
- improved information flows between parties leading to reduction in inefficiencies resulting from errors, confusion and misunderstanding;
- shortened schedules and improved profits;
- improved ability of parties to respond to changing business conditions;
- improved quality and safety;
- reduced rework and improved consistency as a result of the continuous improvement effort;
- improved responsiveness, reduced learning curves and greater security of confidential information; and
- improved utilisation of resources.

A CII (1991) report estimated project cost reductions of about eight per cent and shortening of project duration by seven per cent as a result of partnering. The same report quotes improvements in profitability of contractors of about 10 per cent. Miles (1996) cites a case where the use of partnering on an ultra fast-track technologically advanced project, reduced project duration by 30 per cent and design cost by 30 per cent as well.

Reaping the rewards of partnering, however, requires investment in money, time, dedication and perseverance when setbacks are encountered (Construction Industry Institute, 1991). To satisfactorily work, partnering should operate within a correct contractual framework and receive the full support of top management of all the companies in the arrangement (European construction Institute, 1996). Partnering arrangements can also break-up, especially when workloads decline. For example, following a decline in its workloads, BAA embarked on an exercise of laying off some of the contractors it had partnering arrangements with (Hope, 1999).

Reasons for less than successful partnering have been attributed to poor alignment of parties at the beginning of a working relationship, and a less than satisfactory benefit for one of the parties. Hill (1995) argued that disputes will never end in construction even with partnering arrangements. To increase the chance of success and to avoid taking risks, Hill advised that:

- partners should have high standard of conduct towards each other;
- a standard form of contract is still required when partnering;
- partners need to draw up a memorandum of understanding, outlining how they are to achieve intangible benefits from cost savings; and
- disputes be resolved after completion of projects.

Enlightened clients are beginning to require their contractors to partner with companies that supply them with labour, materials and equipment. These are the organisations contractors do business with across a range of projects. Lessons learnt from interactions in supply chains become more useful within the framework of strategic partnering rather than on short-term interactions, even under arrangements like project-specific partnering. Mathews (1996) actually noted that tendering costs were higher on the single contractor-subcontractor project-specific partnering case study he investigated due to increased interaction costs than would have been the case if the partnering approach had not been used.

Very good reasons exist why contractors should manage their sub-contractors and suppliers. Dobler et al (1990) listed the following arguments for long-term customer-supplier relationships, which should also hold true for any type of supply chain relationship:

- it minimises the learning process and the potential for communication difficulties common in transactions between organisations which have not interacted previously;
- adaptation in changing market conditions and technology is less painful in ongoing and mutual beneficial relationships when the parties have been working together for a long time;
- reduction in the probability of quality problems and late deliveries in continuing relationships;
- likelihood to come to each other's aid is greater when organisations' relationships are long term and based on goodwill;
- suppliers are more likely to deliver on time to organisations they have traded with for a longer time than new customers; and
- insufficient capacity or supply problems are more likely to be experienced by organisations that purchase opportunistically than those with continuing relationships with suppliers.

There is an entrenched culture in the construction industry of contractors reaching out to customers while at the same time pushing back at suppliers (Whitelaw, 1997). Adopting the Pareto Principle, O'Connor (1997) approximated that 80 per cent of materials costs are incurred at suppliers' plants. In this context, Pearson and Ellram (1995) viewed supply chain management as very important and argued that *"An organisation's suppliers directly affect the price, quality, delivery reliability and availability of its products - all of which have a profound impact on customer satisfaction."*

In addition to the three integration mechanisms given by Luck and Newcombe earlier, information and communication technologies can be added as a fourth integrative mechanism in supply chains, especially in relation to materials suppliers.

4.5.1.2 Information and Communication Technologies

Partnering is an integrative mechanism more commonly used among the contracting parties - clients, contractors and subcontractors - in the construction process. However, partnering with suppliers is a recognised competitive frontier in other industries (see Chapter 6). From discussions in Chapters 1 and 2, it is also evident that information and communication technologies play a vital role in the integration of materials suppliers in supply chains.

4.6 Summary

The concept of supply chain management in its wider context in the construction industry has been examined in this chapter. Because of the project nature of construction, direct resource flows involve mobilisation of both labour and equipment, in addition to materials and finished products ordinarily considered in steady-state industries like manufacturing and retailing. Supply chain actors include clients, construction contractors, sub-contractors and materials suppliers. Designers play a central role in supply chains as agents for clients.

Identified supply chain integrative mechanisms are the same as those used for integrating project participants (namely, hierarchical contractual arrangements; formal administrative procedures for controlling inputs of actors; and non-contractual informal adjustments as may be evidenced in partnering). Information and communication technologies also play a very important role in integrating inputs of supply chain participants especially materials and components suppliers.

CHAPTER FIVE

CONTRACTORS' MATERIALS PROCUREMENT PROCESSES

CHAPTER FIVE

CONTRACTORS' MATERIALS PROCUREMENT PROCESSES

5.1 Introduction

Chapter 4 examined construction supply chains in the broader context of the construction industry. Literature reviewed in that chapter indicated that interface management between clients, contractors and subcontractors has been investigated in a number of studies. It was further noted from a number of earlier studies that improvements in the supply of construction materials can lead to significant improvements in construction performance. However, it was observed that supply chain management practices between contractors and suppliers have not received much attention in the way of research. This chapter highlights supplier related materials delivery problems and examines traditional contractors' materials procurement processes. A working definition of the term 'supplier' has been given.

5.2 Supplier related problems in contractors' construction materials procurement processes

The discussion in Section 4.3.1 of Chapter 4 highlighted the adverse impact of poor delivery of materials on: construction schedules; use of resources; and productivity. The investigation by Oswald and Burati (1992) into the implementation of total quality management in the USA construction industry further identified that the construction industry's attention to supplier management was rooted in the desire to eliminate historically chronic problems which include:

- late or incorrect supplier drawings;
- late deliveries;
- poor quality;
- no supplier quality assurance or quality improvement programmes;
- inadequate supplier control of lower-tier suppliers;
- poor communications; and
- lack of conformance to requirements.

Minimising these problems requires understanding of how contractors manage their interfaces with construction materials suppliers in their procurement processes. To put contractors' materials procurement processes into perspective, the definition of the term 'supplier' as used in this thesis is required. In searching for a working definition of the term, it is important to clarify the classification of companies that, as well as being subcontracted to execute parts of a project, manufacture and supply the materials they install. Oswald and Burati (1992) encountered a similar difficult while attempting to define the term supplier in the context of supplier management programmes they studied in the construction industry in the USA. The definition in this research was adopted from the one used by Oswald and Burati (1992) who defined a supplier as:

> *any enterprise that enters into a contract with a main contractor, a project manager or a client to: supply, manufacture and supply, or to manufacture, supply and erect or install construction materials, products or components the organisation itself supplies. This definition excludes labour only subcontractors but includes specialist contractors who supply materials, components or mechanical and electrical equipment and install them as well as those organisations that merely supply such goods but have nothing to do with their final incorporation into the facility.*

Several activities are performed by a contractor to procure materials and services for a project before the required project inputs are available. During the tender estimation period, the contractor contacts suppliers for quotations for goods and services described in the specifications and bill of quantities. Certain policies within construction contractors guide relevant functions on how such materials and services should be procured.

5.3 Purchasing policy

In order to effectively procure materials, a company should have a purchasing policy that holds together the materials management function. Such a policy embodies principles that guide the buying function of the organisation. The policy determines, for example, whether or not purchases are made by sites or head office. In relation to supply chain management, the purchasing policy deals with many aspects, including (Newcombe et al, 1990):

- supplier relationships;
- source policies - guiding buyers to particular suppliers; and
- internal policies - these lay down administrative principles which are expressed in procedures.

To be cost-effective and obtain quality materials that give value for money, an organisation should have a thorough knowledge of the products available on the market.

5.3.1 Materials market and making enquiries

Market intelligence is the ability of a company to make enquiries that lead to obtaining appropriate materials at the right cost. Market enquiries should lead to knowledge of quality materials from different sources and order quantities that attract discounts. The combination of printed matter, local knowledge and experience constitute information sources for market intelligence. Questions that a market intelligence report should answer are (Newcombe et al, 1990):

- what material is right for the job?
- where can it be found?
- what price should be paid for it?
- when can it be delivered? and
- is the quality reliable?

Figure 5.1 shows likely decision processes in a traditional purchase transaction.

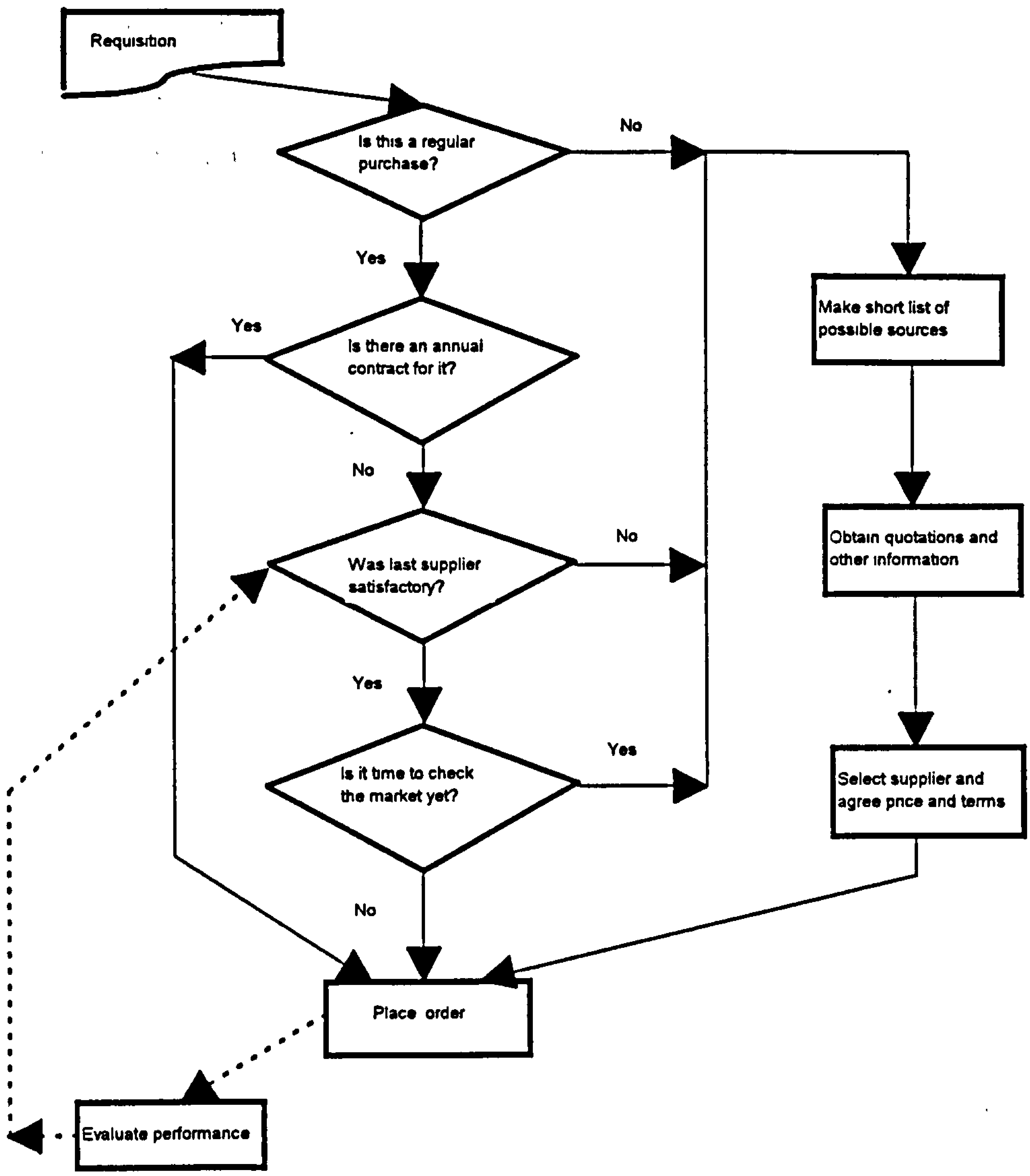


Figure 5.1: Typical purchase transaction
The broken line indicates steps taken after the order has been placed
(Adapted from Bailey, 1991)

Dobler et al (1990) gave various sources from where information concerning suppliers can be obtained by an organisation. Some of these will now be discussed.

Purchasing departments

Purchasing departments of organisations usually keep information on suppliers which may include:

- name of supplier;
- list of materials available from each supplier;
- delivery history of supplier;

- quality record of supplier;
- overall desirability of supplier; and
- general information about the supplier's plant and management.

Since many purchasing operations are repetitive, the need to maintain a supplier list cannot be over-emphasised.

Supplier catalogues

Catalogues are common sources of supplier information which can be used to locate required materials. Catalogues also provide sources of potential supply and price estimates. To avoid excessive loss of time when looking for information in catalogues a good approach is to create a library and use an indexing system to keep the catalogues up-to-date. Libraries in purchasing departments also keep documents such as:

- product file;
- supplier name file;
- trade publications; and
- purchasing textbooks.

Some purchasing departments, especially in electronics and aerospace industries, use indexed microfilm catalogues with information on many suppliers.

Trade registers and directories

Trade registers contain information on addresses, plant locations and any other relevant details of leading manufacturers. Kompass Publications is one such register in the UK. Such publications may also give financial standing of companies.

Trade journals

Suppliers usually advertise their products in trade journals. The journals are good first contact sources of information about suppliers and their products. Purchasing and Purchasing World are two renowned international trade journals. Specialised trade journals include Aviation Week for the aerospace industry; Iron Age for the steel industry; and Building (specially for the building industry in the UK).

Yellow Pages

The Yellow Pages section of local telephone directories provide information on local companies. Information obtainable from Yellow Pages is limited and does not give any indication on size, capabilities of companies, management and financial data in the advertisements. The pages can, nevertheless, serve as a useful starting point when searching for information on suppliers, especially local sources.

Product brochures

Product brochures are worth saving and can be dated, indexed and filed by name and publication number. When new sources or products are needed, the brochures can be referred to. Alternatively, potential suppliers can be asked to furnish information about themselves and their products which may then be entered on a database. Information provided may include:

- company name;
- address;
- company representatives to contact; and
- products.

Trade exhibits

Sources of supply can also be identified from trade shows: both regional and national. Exhibits are a good forum for new and modified old products. Such occasions also provide a good opportunity for new ideas and to meet potential new suppliers.

Purchasing departments of other companies

These are also a useful source of information about suppliers. Affiliation of a company's employees to institutes such as the Chartered Institute of Purchasing and Supply can provide useful information regarding suppliers through association with personnel from purchasing departments of other companies. Association members can help fellow members to locate and evaluate new products suppliers, though on ethical and legal grounds they are not supposed to reveal pricing information.

International sources

As a result of increased international trading, a number of sources are available from where information on potential suppliers from other countries can be obtained, such as Purchasing and NAPM Insights in the USA.

Company personnel

From their professional, civic and social associations, and their attendance at conventions and trade exhibits, company employees can also be a useful source of information about new products, manufacturers and suppliers.

Sales personnel

Through their contacts with other organisations, sales personnel get to know about other products and services and can be a useful source of information on suppliers.

5.3.2 Selecting materials for tendering

Tendering is cumbersome and has an administrative cost associated with it. To reduce this cost, materials which are unlikely to vary much in quality and price, and have little monetary value to the project should not be included on the tender list (Peters, 1981). Dand and Farmer (1970) suggested using Pareto's Rule (Figure 5.2) to identify which materials need detailed supplier investigation. The rule states that 10 per cent of the total number of project materials are worth 70 per cent of the total project materials value, 20 per cent of the number are worth 20 per cent of the value, and 70 per cent are worth only 10 per cent of the total value (Peters, 1981). Using this rule a company can identify the 10 per cent of total materials categories on which it spends 70 per cent of the total cost on materials and concentrate effort on the tendering and management of such materials in order to

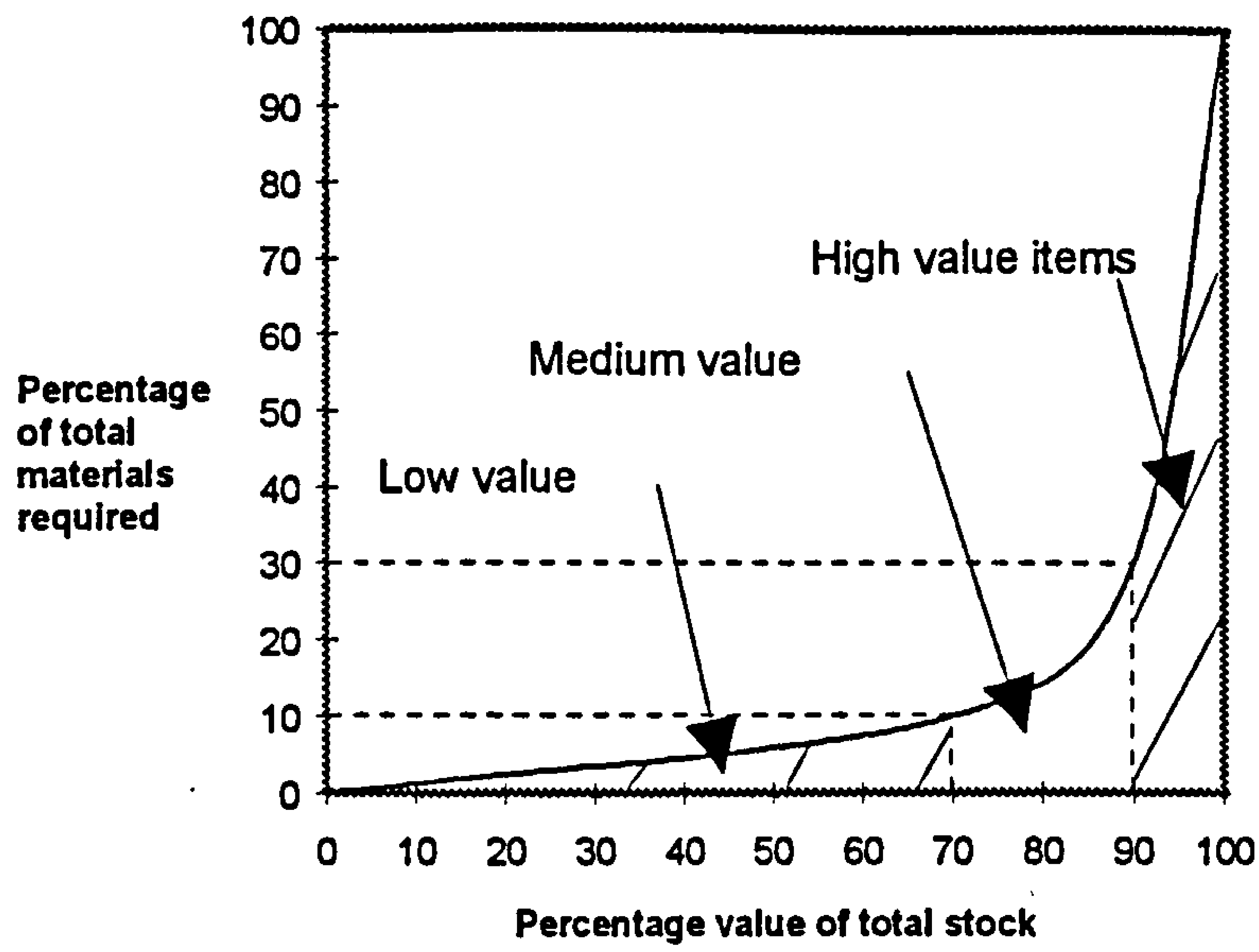


Figure 5.2: Pareto's Rule

control materials cost. Other uses to which the Rule can be put include (Dand and Farmer, 1970):

- analysing the number of sources used for specific materials;
- questioning whether purchasing strength is being put to best advantage;
- examining the possibility of cutting down the number of sources; and
- isolating scheduling problems.

5.3.3 Materials for tendering

Tendering for materials helps keep prices down, improves adherence to delivery programmes and minimises corrupt practices. Advantage of tendering include (Peters, 1981):

- it selects a reasonable price;
- it selects the best delivery programme; and
- it establishes good relationships with suppliers, i.e., no unofficial arrangements which might promote corruption.

To promote fairness in tendering (Peters, 1981):

- the customer should present the same, clear and precise information to all bidders;

- dominant factors on which tenders will be evaluated, whether price, delivery, or an other criteria should be made clear to all bidders; and
- bid opening should be attended by authorised officials and the date of opening should be specified and bidders notified of extension dates, if any.

The described procedure gives confidence to bidders that they will be competing on 'level ground'.

5.3.4 Placement of orders

The contractor establishes contact with suppliers for a particular project when he or she becomes aware of the proposed project and decides to bid. Initially, a list of required materials for the tender is made. Preferred suppliers are then invited to quote their prices for the listed materials. Communication with suppliers is vital at the enquiry stage to address issues of packaging and materials handling.

All bids have to be in a uniform format so that they are comparable at evaluation. Supplier's bids constitute offers which can be accepted or rejected by the contractor. Factors which are taken into account when carrying out the evaluation include (Newcombe et al, 1990):

- basic price, part-load price, transit charges, surcharges and payment structure;
- delivery time;
- location of supplier;
- quality assurance requirements;
- where the goods are required;
- disputes procedures over quality issues; and
- terms and conditions under which the order should be placed.

On being awarded the contract, the contractor assesses quotations from materials suppliers. Prices and delivery dates are very influential factors in the selection of suppliers (Johnston, 1981). Quality of materials should meet specification requirements. From the evaluation, successful suppliers are selected, but before contracts to supply are awarded, terms and conditions of purchase are clearly defined, including delivery dates. After contractual issues have been ironed out, the order can be placed. The order form should have on it the following details (Newcombe et al, 1990):

- name and address of supplier;
- description and quantity of supply;
- specification and workmanship standard references;
- cross-references to relevant drawings;
- agreed price and any discounts and rebates;
- time when goods will be required;
- retentions;
- liquidated damages; and
- responsibility for loss or damage of materials.

5.4 Construction Phase

During construction, supplier management involves furnishing suppliers with necessary information, monitoring quality of supplied items, progress chasing of ordered materials, instituting call-off procedures and receiving ordered materials. Information furnished to suppliers is extracted from the buying and materials schedules.

5.4.1 The buying schedule

After suppliers for various materials have been selected, the buying schedule is developed. The schedule should furnish information on:

- the suppliers of the different materials;
- when the materials should be delivered; and
- the contact person within the supplier organisation.

The schedule should envision shortages or gluts of the various materials and structure purchases accordingly.

5.4.2 The materials schedule

Information from the materials take-off process and the buying schedule enable the materials schedule to be prepared. The schedule is used for monitoring materials flow to ensure uninterrupted construction. It complements the buying schedule and may provide the following information (Newcombe et al, 1990):

- materials to be provided by sub-contractors;
- materials with special requirements or with long lead times;
- materials delivery points on site;
- materials expediting schedules;
- reports on delivered materials; and
- materials reconciliation document.

The Buying Schedule
Names of suppliers for different materials
When the materials should be delivered
Contact person within the supplier organization

Materials take-off

Materials schedule
Materials to be provided by sub-contractors
Materials with long lead times or special requirements
Materials delivery points on site
Materials expediting schedules
Materials reconciliation document

Figure 5.3: Sources of information on required materials

5.5 Site logistics activities

The execution of logistics activities which effect materials flow to site is a shared responsibility between head office and site management (Johnston, 1981). The selection of suppliers, ordering of materials and payment of accounts for materials in large companies is usually performed by head office. All the activities from when the materials are received to final incorporation into the facility are left to site management. Site management also identifies, requisitions, purchases and expedites all those materials not procured by head office (Kirby, 1995). The various logistics management activities on site include: expediting, receiving, materials handling, warehousing and disposal of surplus materials (Figure 5.4).

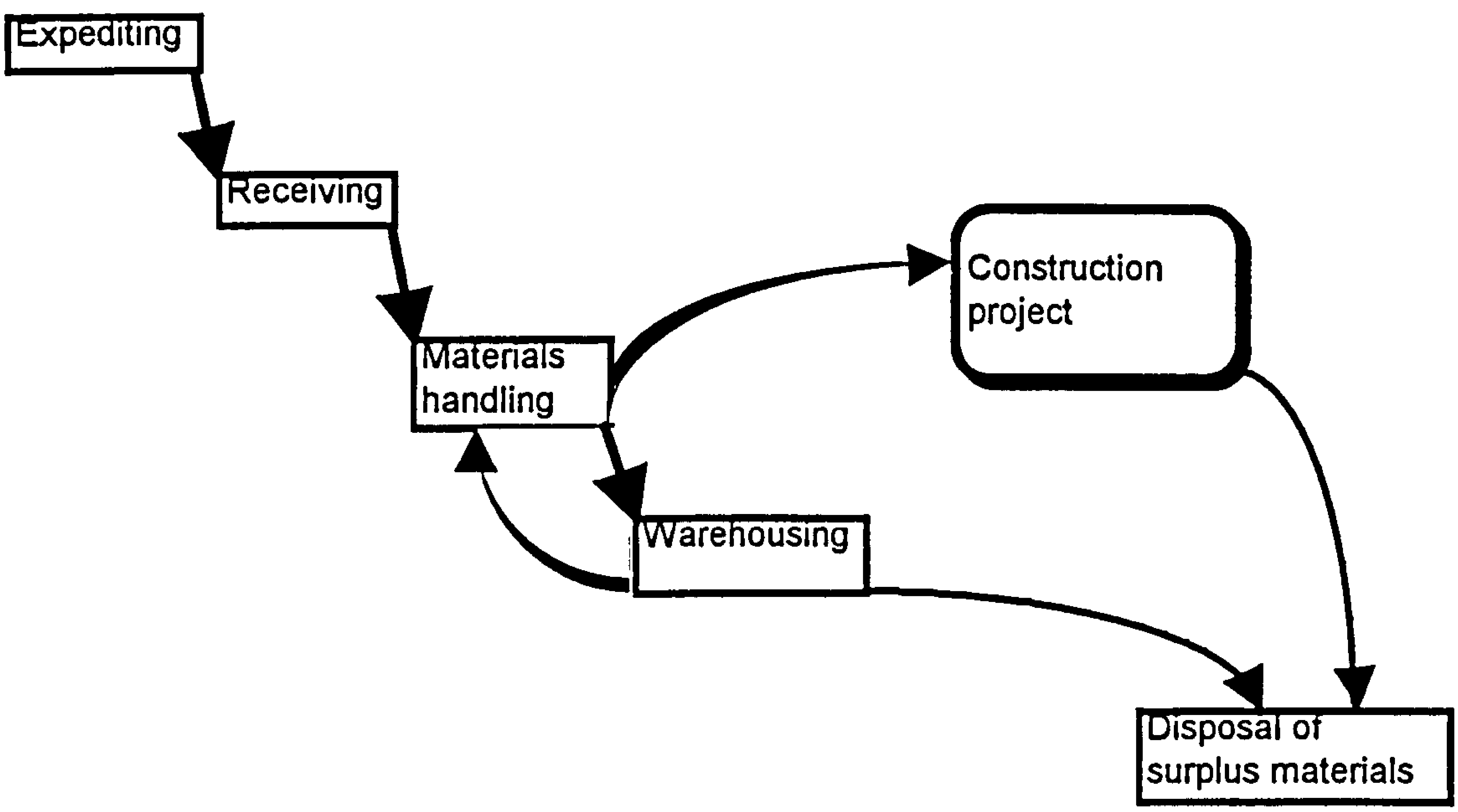


Figure 5.4: Logistics management activities on site

5.5.1 Expediting

Expediting is a continuous control mechanism for ensuring that materials and equipment are supplied in accordance with the purchase contract and to prevent disruption of the construction schedule. There are various types of expediting which can broadly be categorised into: status reporting; reactive expediting; and proactive expediting (Construction Industry Institute, 1987).

Status reporting can be done either by telephone or communicated by writing. The purpose is to get information on orders and to ensure that suppliers meet the delivery dates.

Reactive expediting involves follow-ups at the supplier's premises by the buyer. It is more effective, but at the same time more expensive than status expediting.

Proactive expediting is more expensive than the first two, but is more productive. It begins before the order is placed and follows the life-cycle production of the ordered item. It may be employed for expensive or urgently required items or both for: programme sensitive items on the critical path; and/or changes in the programme that may require items to be delivered earlier than scheduled (Stukhart, 1995).

5.5.2 Deliveries and receiving of materials

Delivery of materials should be matched with the sequence of construction and arrangements for receiving and storage made before the materials arrive on site. The method and schedule of delivery of materials is usually agreed upon between the contractor and the supplier (Johnston, 1981).

Some materials may arrive on site in bulk, bags, crates or pallets. The materials that are normally delivered in bulk include hard-core, aggregates, pulverised ash, bituminous paving materials, concrete and cement (Johnston, 1981). Nails, screws, door and window components if in large quantities will be in boxes or crates.

Designated off-loading points on site can be sources of conflict between site management and suppliers if site access is poor (Johnston, 1981).

5.5.3 Receiving

Receiving of materials marks the point when the control of materials begins on site. Planning for receiving materials begins before the contractor enters into contract with a supplier (Kirby, 1995). Receiving arrangements during negotiation include consideration of information that should go on identification tags such as materials description and purchase order number. Arrangements for receiving should address communication and co-ordination issues with suppliers and transporters and should have in place means for inspection, offloading, and dealing with accounts payable (Kirby, 1995). Measures for ensuring security of received materials should also be in place.

The site receiving report records shipments received, excess deliveries or shortages and damages and confirms receipt of items to accounts for payment of vendors (Stukhart, 1995). Excess deliveries, shortages and damaged items are also recorded on packing slips as well.

Stukhart (1995) emphasised two points at the receiving stage:

- responsibility for on-site quality must be pre-established. Inspectors must perform this job consistently and knowledgeably; and
- suppliers must be promptly notified of all deficiencies. Shipments should not be returned until suppliers have been notified.

5.5.3.1 Quality control at receiving

Materials and equipment received are normally inspected and site management should closely co-ordinate with site quality assurance or control personnel in this activity (Kirby, 1995). For items failing to comply with specifications and purchase orders, arrangements are made with suppliers for return goods handling or parts and service support. When planning receiving arrangements and co-ordination with site quality assurance or quality control, reports for all materials should be prepared.

Quality Assurance is an inbuilt process beginning from design, through manufacture to installation which ensures that the client's quality standards are adhered to. Quality Assurance requires that as well as meeting the prerequisite quality standards, the processes employed in attaining those standards be documented. Quality Assurance is complied with by ensuring that supplied materials are accompanied by Quality Assurance Certificates. The general trend in quality assurance for suppliers is implementation and accreditation to ISO 9000 whose broad objective is total quality improvement (Stukhart, 1995).

When materials arrive on-site, their line item numbers are compared with purchase order numbers. The details of the transaction are then entered either on a receiving report or directly into a database and the information is then made available to accounting (Stukhart, 1995). If the materials are accepted, it should have been known beforehand what materials handling equipment should be used and where the materials should be delivered on site. Materials labels should specify materials types and quantities, which information should be readily retrieved. Bar codes are an excellent way of identifying items and tracking them down.

Other than quality, other reasons for inspecting items are to ensure that: they are the ordered items; the quantity is correct; and they are not damaged (Arnold, 1991). After inspection the items are either held awaiting further action from the purchasing department if there are issues to be resolved or they are sent to where they are immediately required or to inventory if the order has been accepted. The receiving report is then sent to purchasing. Quality control personnel will also advise purchasing on the status of the items if they had inspected them. When the supplier's invoice arrives at the purchasing department, it is compared with the purchase order and receiving report and all three documents should be in agreement. If the purchasing department approves payment, accounts payable is advised to pay the supplier for the goods received otherwise other instructions or course of action is followed.

5.5.4 Off-loading

There are three methods of unloading materials from transporting vehicles: tipping, manual handling or mechanical handling (Johnston, 1981).

Materials off-loaded by tipping are normally delivered by trucks with elevated sides. These include aggregates, hard-core and excavated materials. Tipping materials where they are to be used is the simplest and probably cheapest way to unload. Most materials will, however, be damaged if tipped. Such materials should be off-loaded manually or by mechanical plant.

Manual unloading is disruptive to other site operations and the trend towards larger packaged deliveries is rendering the method impractical and has almost been phased out and replaced by mechanical lifting such as forklifts, external or lorry mounted equipment (Johnston, 1981).

5.5.5 Materials handling on site

Materials handling equipment may be classified into three categories: conveyors; industrial trucks; and hoists and cranes (Arnold, 1991). Conveyors can move items horizontally, or at an angle or vertically between two spatially fixed points. Industrial trucks move items on horizontal or gentle slopes. Industrial trucks are more versatile and more commonly used than conveyors (Arnold, 1991). Cranes and hoists move items vertically, and are more flexible within their radius of operation than both conveyors and industrial trucks.

The role of equipment in construction supply logistics is to move materials to storage or to the workface. Newcombe et al (1990) viewed the role of equipment management thus: "*to bring to the project that construction plant which can enable construction work to proceed according to programme and to serve the site labour in an appropriate manner*".

5.5.6 Inventory management

The function of managing materials on site encompass all planning, management and implementation activities directed at ensuring that materials do not run out. Inventory is kept on site to mitigate against uncertain deliveries.

In the construction industry, the aim for managing inventory is to meet the production rate in an efficient cost-effective manner. Stukhart (1995) observed that construction companies are more interested in ensuring that materials are available to meet construction schedules, but few exercise inventory control. Inventory management involves keeping records of what is in stock, physical protection from theft and against damage from the elements, and inventory cost control. Inventory management is still a problem on construction sites (Stukhart, 1995). To reduce inventory costs the responsibility for re-stocking may be placed on suppliers

(Stukhart, 1995). Automation of materials records on both large and small construction projects can also be useful. Computer systems have widely become common methods of keeping up-to-date records of the status and location of materials and to forecast shortages on most large projects (Kirby, 1995).

5.5.7 Warehousing and issue of materials

The objective of warehousing is to "*minimise cost and maximise customer service*" (Arnold, 1991, pp. 200). Efficient warehousing:

- achieves timely customer service;
- facilitates efficient tracking of items;
- minimises the total physical effort and cost of moving goods; and
- establishes communication links with customers.

When materials are received, accepted and accounted for, their identification codes will still be useful for storage, issue and installation purposes (Stukhart, 1995). Identification labels help improve controlling and issuing of items from storage and inventory area.

5.5.8 Issue of materials

To be effective the procedure for issuing materials should be simple but well defined. Measures which can achieve effective degree of accountability in issuing materials include (Construction industry Institute, 1987):

- issuing only to personnel authorised to withdraw materials;
- using simple well designed warehouse forms which should be completely filled in by the person requisitioning the material;
- up-dating inventory on a daily basis by entering information each time an issue is made; and
- using an automated system wherever possible.

5.5.9 Surplus materials

Every project will inevitably have some surplus materials at its conclusion. The Construction Industry Institute (1987) estimated that surplus materials can lie between the extremes of 0.1 to 10 per cent of project materials cost and attributed causes of excess surplus to:

- design changes made after materials have been purchased;
- inadequate planning;
- poor materials management procedures and computer systems; and
- poor site materials control procedures.

The best method of controlling surplus is good site materials management. When surplus occurs it is disposed by: using the materials elsewhere within the project; taking the materials to other projects; transferring parts to equipment spares; returning excess materials to suppliers; or selling the surplus for investment recovery. "*The site's ability to control surplus is closely linked to controls which prevent duplicate purchases, overbuying due to improper warehousing and inventory procedures, and identifying materials thought to be required but not actually needed when constructed*" (Construction Industry Institute, 1987, Section 6.4).

5.6 Summary

The focus of this chapter was on contractors' traditional procurement processes, beginning from the tendering process to supply of materials to craftspersons on site. Supplier side problems in the delivery of construction materials were identified from literature and the definition of the term 'supplier' as used in this thesis was given.

To address the problems identified in the supplier side of the delivery of construction materials and to explore collaborative practices between contractors and construction materials suppliers, Chapter 6 takes up the subject of supplier evaluation, selection and management.

CHAPTER SIX

SUPPLIER MANAGEMENT, EVALUATION AND SELECTION METHODOLOGIES

CHAPTER SIX

SUPPLIER MANAGEMENT, EVALUATION AND SELECTION METHODOLOGIES

6.1 Introduction

Chapter 5 discussed Contractors' traditional materials procurement processes. Supplier management, evaluation and selection methodologies have been reviewed in Chapter 6. Traditional factors and introduction of soft factors in supplier evaluation, selection and management have been discussed. The Analytic Hierarchy Process has been presented as an appropriate approach capable of being used to assess the relative importance of factors considered in supplier evaluation and selection because of its capability to handle and quantify both hard and soft data at the same time. The chapter also presents, compares and contrasts other theories similar to the Analytic Hierarchy Process.

6.2 Supplier management

While it has been recognised for a long time that customer goodwill is a valuable attitude on the part of suppliers, businesses have also begun to realise the value of supplier goodwill. Supplier goodwill is developed through open, impartial and fair dealings with suppliers.

Supplier-customer relationships develop when both parties understand the mutual benefit of a continuing relationship. The development of such a relationship allows each side to have insight into operations and problems of the other. The final result of good supplier-customer relationship is the development of joint operations between the trading parties (Dobler et al, 1990).

Supplier base reduction and long-term supplier relationships are some of the reasons which are increasing the importance of supplier selection and evaluation. Reducing the number of suppliers involves a long-term commitment to the exercise leading to greater integration and eventual sharing of resources between suppliers and buyers (Pearson and Ellram, 1995). The increasing need for supplier input at the design stage is also contributing to the importance of supplier selection and evaluation.

Supplier goodwill takes time to develop, but there are benefits that accrue to the customer. Suppliers can help their trading partner achieve superior performance by helping in product development, value analysis and delivery of quality products. Other benefits that accrue from long-term arrangements with suppliers include: *"low all-in-costs; a dependable source of supply, and a partner familiar"* with the customer's needs (Dobler et al, 1990). Greater benefits accrue when the involvement of suppliers is sought earlier before their services are required. Early supplier involvement can lead to improvements in the following areas (Dobler et al, 1990):

- materials specifications;
- tolerances;
- standardisation;
- order sizes;
- process changes in the supplier's manufacturing;
- packaging;
- inventory;
- transportation; and
- assembly changes in buyer's plant.

Early supplier involvement often results in selection of a single source from competitive tendering of utmost three carefully pre-qualified suppliers. Dobler et al (1990, pp. 183) gave the following reasons that support use of one supplier:

- *"better pricing results from a much higher volume;*
- *quality considerations dictate;*
- *the buyer obtains more influence - clout - with the supplier;*
- *lower costs are incurred to source, process, expedite, and inspect;*
- *the quality, control, and co-ordination required with JIT manufacturing require a single source;*

- *the quantities to be purchased are small;*
- *the supplier holds critical patents;*
- *significantly lower freight costs result;*
- *special tooling is required and the use of more than one supplier is impractical; and*
- *a supplier agrees to carry a buyer's inventory (stockless purchasing)".*

However, there are also numerous disadvantages associated with the use of a single supplier. If the volume of business is large, it may be necessary to arrange for more than one supplier. Advantages of this include (Compton, 1985):

- mitigation against stock-out by main supplier;
- minimising monopolistic tendencies of a single source;
- it offers a chance to compare quality, specifications and technical performance;
- increased possibility of new developments; and
- a chance for improved supplies due to special effort by new suppliers to increase their market share.

Customers tend to use a minimum of two to three suppliers as a safeguard against problems that can arise from a single supply source. Supplier development is not a new concept, but the increasing importance of reliable sources of supply is a new phenomenon (Dobler et al, 1990). The road to establishment of short or long-term trading relationship normally begins with evaluation of suppliers by the customer firm.

6.3 Evaluation of suppliers

It is preferable to evaluate potential suppliers before they are included among those selected to tender than to rely on recommendation or their product brochures (Peters, 1981). Details of the evaluation depend on the importance to the project of the materials concerned. Aspects for evaluation include (Peters; 1981):

- product quality;
- technical ability;

- production capacity;
- reliance on sub-suppliers;
- financial standing;
- managerial capability; and
- administrative capability.

An important initial step in evaluating suppliers is to perform appropriate tests on the company's products. These tests could determine whether to evaluate the company further or not. A company's production capacity, technical ability, debt to turnover ratio, target/achieved profit margin, turnover trend and its immediate and long-term plans should be assessed for possible problems that can be encountered with that supplier. A company that is supplied by a number of sub-suppliers is preferred to one that depends on a single sub-supplier because of attendant monopolistic problems. The evaluation should also closely examine the company's liquidity position and other indicators that give clues about its financial strength. A financially weak company is undesirable. An appraisal of how rapidly a company processes orders and settles its accounts can give an indication of its financial strength and administrative efficiency.

At the end, the evaluation should have information on the following (Dand and Farmer, 1970):

- quality control methods used;
- packaging, handling and transportation methods used;
- degree of flexibility in the organisation;
- expansion plans of the company;
- assessment of the current state of the plant and equipment and likelihood of reduction in capacity; and
- supplier's present and projected future workload.

6.3.1 Performance of suppliers

Each time a request for a quotation is prepared, the approved supplier list is reviewed for suitable bidders. The Construction Industry Institute (1987) outlined the following approach:

- to assure the supplier's capability of successfully providing the materials and services being requested, the supplier's current financial and operating conditions are examined. This may be done using an investigative organisation specialised in this kind of work;
- physical visits to supplier's premises to determine production capacity, current and future workloads in comparison with the supplier's normal workload; and
- a review of recent experiences of the contractor or client with the supplier.

On the basis of the findings of the above checks, it may be decided not to include a supplier among those to bid for the current job if it is discovered that the supplier has had: problems in keeping to delivery schedules recently; quality problems in engineering or manufacturing; or any other problems which might have caused poor performance lately.

6.3.2 Supplier performance evaluation methods

The Construction Industry Institute (1987) outlined two approaches used for evaluating performance of suppliers:

- reviewing the performance of suppliers regularly. This may be done annually and is more suited to centralised purchasing where data may be available for such an exercise; and
- when collecting information within a decentralised purchasing arrangement, evaluate each supplier purchase order which exceeds the market value or is of a critical nature.

The criterion for choosing suppliers to be included on the preferred list of suppliers for a particular project is based on: the supplier's level of annual commitment; size of the individual order; and the criticality of that particular order. Ultimately, the purpose of supplier performance measurement is to develop a report on key aspects like capability, price, quality, delivery and service. Eventually, each organisation needs to define parameters for use in its method for assessing suppliers in terms of (Construction Industry Institute, 1987):

- factors to be evaluated;
- relative importance to be applied to each factor; and
- number or type of suppliers to be evaluated.

Benefits of such a supplier performance programme are threefold:

- suppliers soon realise the importance placed by the customer on performance;
- during project execution, a supplier's past performance can be used in planning and supplier bid list development. The supplier's past performance record can also be used to determine the need for expediting and inspecting the supplier's premises; and
- it provides an opportunity to review a supplier's performance as a means of providing constructive feedback between the supplier and the contractor/client.

6.3.3 Types of evaluation

The type of supplier evaluation depends on the nature of the purchase to be made:

- its criticality; complexity and money value involved in the purchase; and
- knowledge of the firm being considered for the order.

Company supplier lists, catalogues and brochures may be sufficient for simple, low-cost items. Critical high value items require detailed evaluation of suppliers (Dobler et al, 1990). Extra investigative measures for the latter items may include:

- surveys by mail, telephone or both, followed by visits to premises of carefully identified suppliers;
- if considered appropriate, detailed evaluations of suppliers' managerial and service capabilities can be conducted; and
- for very critical purchases, evaluation conferences can be organised at the customer's premises to assesses and eliminate those suppliers who do not comprehend the complexity of the order.

Preliminary surveys

Telephone or mail survey can constitute a preliminary survey for obtaining additional information from promising suppliers. The preliminary survey will furnish sufficient information for deciding to include or exclude a supplier for further evaluation. The survey will elicit the following details (Dobler et al, 1990):

- bank references;
- credit references;
- annual history of sales and profit for the past five years;
- referral list of customers;
- number of employees;
- expansion plans;
- current production defects rate for similar products;
- number of inspectors used; date when statistical process control was adopted; and
- list of equipment and tools to be used to manufacture, test and inspect the purchase in question.

Financial condition

An assessment of a supplier's financial and credit ratings can indicate whether or not a supplier can meet customer requirements satisfactorily. A strong financial base is a sign of stability of a supplier (Compton, 1985). Financial stability of a supplier assures continuity of supply and reliability of product quality (Dobler et al, 1990). Financial evaluation should also attempt to establish that suppliers keep to prices they have quoted and that they maintain verifiable price structures.

Plant visits

Some aspects of supplier performance such as plant capacity, condition or age may only be determined by visiting suppliers' premises (Compton, 1985). Visits to supplier's premises give first hand information on the adequacy of a potential supplier's capability to meet customer requirements and the technical know-how of its management. Only a few outstanding potential suppliers would normally be selected for plant visits. Items to be checked on plant visits include (Dobler et al, 1990):

- R&D capability;
- appropriateness of equipment;
- effectiveness of the production control, quality control, and cost control systems;
- competence of the technical and managerial staff;
- morale of personnel in general;
- quality of back orders;
- willingness of the supplier to work co-operatively with the company; and
- the quality of key materials management activities.

Ultimately, a company's capability to meet a customer's requirements depends on that organisation's technical ingenuity, management ability and its financial strength. A plant visit should also establish the plant capacity of a supplier. Depending on the order quantity, the manufacturing capacity of the supplier can become an important consideration in placing an order. A large order quantity requires that the order be placed with a supplier with an equivalent capacity.

Service

While acknowledging that there are variations in the meaning, depending on what is being purchased, good service has been defined as meaning "*delivery on time, treating special orders special, filling back orders promptly, settling disputes quickly and fairly, and informing buyers in advance of impeding price changes or shortages... In the aggregate, good service means that a supplier will take every reasonable action to ensure the smooth flow of purchased materials between the seller and the buyer*" (Dobler et al, 1990). Evaluation of the service level provided by suppliers is important because some suppliers may operate at premium costs due to the fact that they provide an outstanding better service in quality, delivery and value-added support than their competitors (Compton, 1985).

Location

The location of a supplier is an important factor to be considered when selecting suppliers for reasons of speed of delivery, accessibility, communication and low transport costs (Compton, 1985). Sometimes economic factors dictate that goods be purchased locally.

(a) Procuring locally

Advantages for purchasing locally include (Dobler et al, 1990):

- geographical proximity makes co-operation between supplier and customer possible;
- proximity makes delivery dates more certain;
- consolidated transportation and insurance by delivering different customers' orders in one shipment lowers the total "all-in" purchase price;
- proximity reduces lead times and can lead to reduction or elimination of inventory;
- proximity can enhance responsiveness;
- fulfils community social responsibilities; and
- it makes it is easier to resolve disputes.

(b) Procuring nationally

At other times other factors lead to the need to procure nationally. Advantages for buying nationally include (Dobler et al, 1990):

- national suppliers can be more efficient and offer high quality at less cost than local suppliers;
- national suppliers can provide superior technical assistance;
- due to higher production capacities, national companies have greater flexibility to manage fluctuating demand; and
- because of servicing broader markets, shortages are less likely with national companies.

(c) Procuring internationally

Conditions may dictate an organisation to procure internationally. Common reasons for buying internationally include (Dobler et al, 1990):

- quality:- most organisations buy foreign to obtain items of the desired quality;
- timeliness:- organisations buy from foreign suppliers because of their reliability, especially in delivering on time;
- cost:- despite additional procurement costs, sourcing internationally can lead to reduced total materials costs;
- new technologies:- sometimes industries of other countries have advanced new technologies and to maintain competitiveness, it becomes necessary to procure from other countries; and
- broadening supply base:- a broad international supply base can give a company competitive edge over its rivals.

However, numerous problems may be encountered for procuring internationally. These may include:

- erosion of the national production base which can weaken a country's industrial power;
- differences in culture, customs, ethics, language can cause problems in communication and business;
- differences in payment terms and conditions. Whereas the customer would like to receive and inspect the goods before paying for them, the supplier may require advance payment before shipment;
- long lead times: due to many uncertainties; variable schedules; unpredictable time requirements for custom activities and the need for greater co-ordination which can all lead to delays, lead times for internationally sourced items can tend to be very long;
- additional inventories: the need to carry more inventory might arise when buying internationally;
- quality: even though quality is one of the major reasons for purchasing internationally, tolerance problems may sometimes arise and responsiveness in

design changes from suppliers can be poor; and

- higher costs of doing business: the mechanics of doing business with a supplier in a distant country using a different language can be costly. Inadequate communication and transportation systems can cause transaction and interaction complexities.

When potential bidders have been identified, supplier(s) can be selected by:

- competitive bidding;
- negotiation; or
- a combination of both.

Competitive bidding

In the private industry, competitive bidding normally involves inviting three to eight preferred suppliers to compete on price. On the other hand, government departments allow as many suppliers who are considered capable to compete. Competition in the procurement of goods and services in the public sector is mandatory in European Union member states. A number of statutory requirements ensure free movement of goods and services and outlaw practices which prevent, restrict or distort competition within the union (European Construction Institute, 1997).

In both private and government situations, lowest bidders are usually awarded the contract unless a supplier is deemed unqualified. Competitive bidding is efficient when the following five criteria are satisfied (Dobler et al, 1990):

- amount of money for the specific purchase should be large enough to justify the expense to both the customer and the supplier;
- specification of the item to be purchased or the service to be provided should be explicitly clear to both the customer and the supplier. The supplier must also know the cost of producing the item or providing the service from experience;
- an adequate number of suppliers must exist on the market;
- suppliers should be technically competent and be interested to compete on price. If suppliers have backlogs of work, their prices may not be competent should they

participate; and

- time allowed for suppliers must be sufficient for them to obtain and evaluate bids from their subcontractors and perform necessary cost analysis.

Thirty days is the normal time in which bids can be prepared, mailed and evaluated (Dobler et al, 1990). Competitive bidding is most applicable to highly standardised products that are widely used and produced abundantly for stock by many manufacturers and for standard services and is unsuitable under the following four conditions:

- when it is impossible to estimate the costs with a high degree of certainty such as may be the case with long lead time items requiring processes involving high technology under uncertain economic conditions;
- when other factors such as quality, schedule and service may be negotiable variables and the decision to select a supplier does not depend on price alone;
- when the purchasing firm expects changes in specifications or other aspects of the contract. Such situations are easily exploited by unscrupulous suppliers; and
- situations where special tooling or set up costs are considerable and their titles are best resolved through negotiations.

Dobler et al (1990) recommended competitive supplier selection when the nine points above are satisfied and this can result in the lowest price. If the nine pre-requisites are not satisfied, then negotiation may be a better option in the selection processes to arrive at the price. However, in the public sector within the European Union, negotiated procurement within member states can only be used under very limited circumstances provided for in the statutes (Central Unit on Procurement, 1995).

Negotiation

Other reasons given in favour of negotiation over competitive tendering are (Dobler et al, 1990):

- it leads to understanding of issues pertinent to procurement and this reduces subsequent quality and schedule problems; and

- competition puts pressure on suppliers to bid low which can lead to low quality and services provided by suppliers.

Two step bidding/negotiation

This is a modification of competitive bidding, suitable in situations where competitive bidding cannot be used at the outset because specifications have not been developed to an extent where they are fit for supplier selection.

In Step 1 of the process bidders compete on technical proposals concerning materials, products or services without quoting any price.

Step 2 follows after the evaluation of the proposals. Bidders of satisfactory proposals are asked to compete on price for their proposals. There are two approaches which can be used in awarding the contract (Dobler et al, 1990):

- contract can be awarded on lowest price from those bidding; or
- the lowest price resulting from the competition can be used as the starting point for negotiations.

The customer must make it clear at the outset which approach will be used.

6.4 Supplier selection

If, after bidding, one supplier comes out more superior than other competitors, selection becomes easy. However, if the choice is not obvious, evaluation has to go another stage to select the right supplier. The most commonly used approach is the weighted-factor rating system (Dobler et al, 1990). This is an objective rating of supplier performance (Compton, 1985). Using the weighted factor system requires that the following be undertaken (Dobler et al, 1990, pp. 208):

- "*development of selection criteria or factors; and*
- *assignment of ratings*".

Selection criteria and weights are decided upon by persons involved in the purchase.

Assignment of judgements is based on the collective judgements of persons involved in the evaluation of the suppliers after they have had opportunity to study the information on the competing companies and field investigations. Compton (1985) emphasised that the system should be as simple as possible and capable of execution using data available within the company. Such data can be acquired from delivery and inspection reports and further information obtained from items users.

In conclusion, Dobler et al (1990) acknowledged the vitality of purchasing responsibilities but declared that none was more important than selecting the right supplier. With the emergent business culture of long-term customer supplier relationships, selection of suppliers and management of such a relationship is becoming more important than ever before especially in situations where single sources of supply are preferred.

6.5 Contemporary trends in supplier evaluation and selection

Ellram (1990) proposed the model outlined in Figure 6.1 for developing supplier partnerships. To analyse the development of the partnership, it is proposed that a team composed of personnel from major company functional areas especially engineering, quality, production, purchasing and finance or accounting with purchasing as the team leader should be formed.

In Phase 2 of the model, selection of suppliers to partner with begins with determining the selection criteria followed by identification of potential partners. However, previous research in supplier selection focused on "hard" or quantifiable factors such as cost, quality and delivery reliability (Ellram, 1990). While such factors are important and should be considered in supplier selection, "new" and equally important factors which come into play when customer-supplier alliancing is being contemplated should as well be taken into account. The new factors are 'soft' and difficult to quantify. The new supplier selection factors for partnering arrangements while inclusive of traditional selection factors of cost, quality, availability, etc., extend to include (Ellram, 1991, pp. 5):

- "*cultural compatibility of the firms;*

- *long-term plans of the supplier for expansion, contraction, or change in business focus;*
- *financial stability of the firm;*
- *technology/design capability. Does the supplier just build to specification, or does it build for functionality? Is it willing to mutually share technology if desired?;*
- *top management compatibility;*
- *location of production facilities, and willingness to relocate and expand;*
- *with foreign partners: local content laws, tariffs, and other trade issues; and*
- *plant visitation, to verify that facilities meet expectations*".

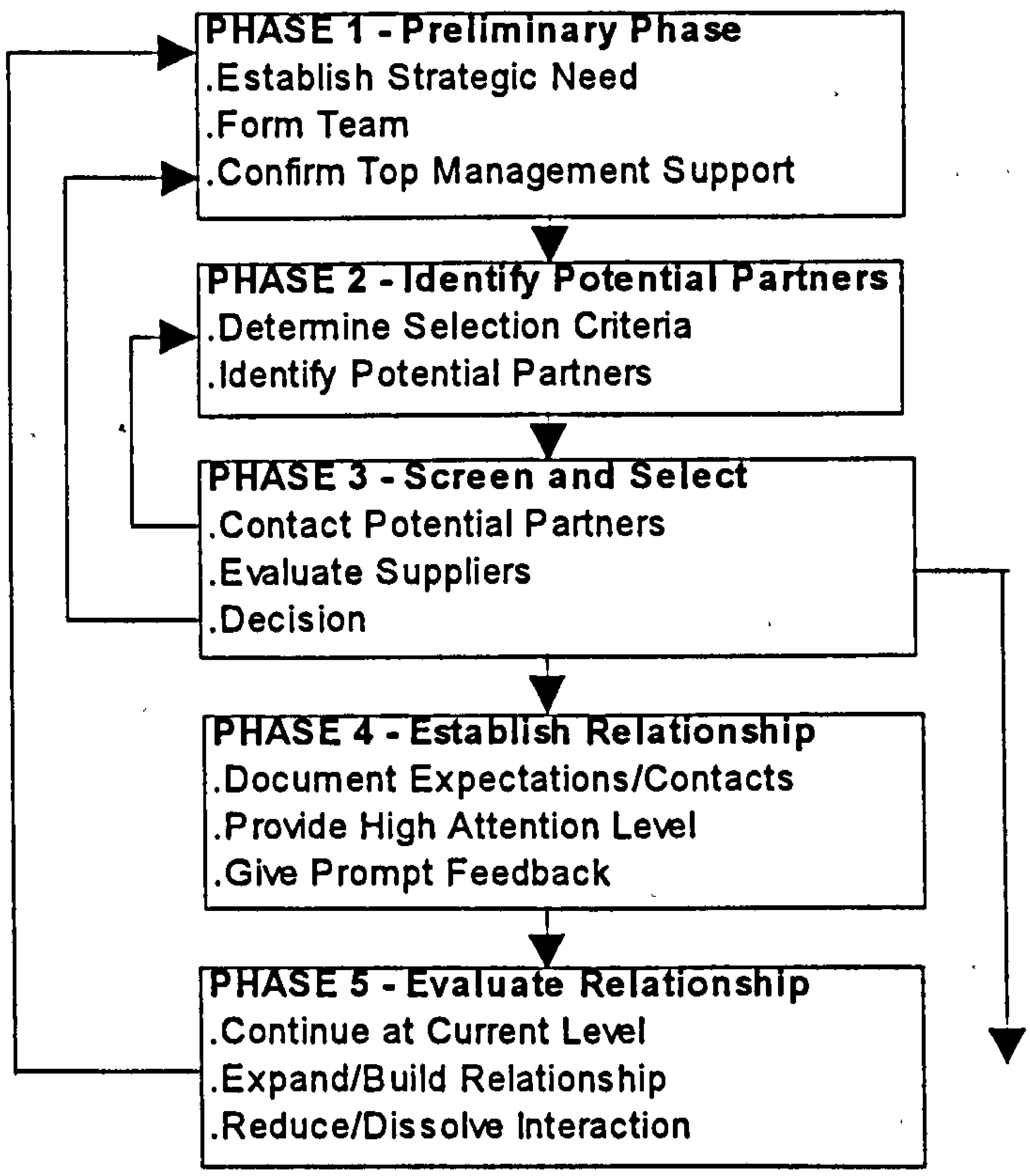


Figure 6.1: Five Phases in the Development and Evolution of Purchasing Relationships

These selection criteria are not exhaustive and not all the factors listed may be considered in all the cases. Ellram (1990) further provides a generalisation of supplier selection approaches and categorised them into two groups: prescriptive or normative and descriptive.

6.5.1 Descriptive models

Descriptive models are empirical descriptions of survey based research. These models describe what their proponents believe is the way decisions are actually made in practice. They suggest that type or category of material influences selection criteria. The 'central theme' in descriptive models is that consideration of supplier selection criteria is important, but the relevance and weighting of these factors is material type dependant.

6.5.2 Prescriptive models

Prescriptive models outline a structured mathematical approach to supplier selection. Most of the prescriptive models use the weighted-factor methodology to score the performance of potential suppliers against pre-determined supplier selection criteria. A number of prescriptive models use computer software packages to simulate or optimise the supplier evaluation process to facilitate decision making. Commonalties between the two generic models include:

- attempting to make supplier selection objective;
- quantification or the use of measurement in the supplier selection criteria; and
- the use of different models or criteria for different supplier selection decisions.

Both generic models do not explicitly accommodate 'soft factors' in their approach to supplier evaluation and selection and have their own strengths and limitations (Ellram, 1990). Even though descriptive models help in understanding supplier selection factors, they fall short of providing full insight into actual practices. On the other hand, prescriptive models do give insight into actual supplier selection practices but can be of little value if their outputs do not produce desirable results.

Ideally, a supplier selection method should overcome the deficiencies of both prescriptive and descriptive methods. Ellram (1990) recommended research into supplier selection methods that would bridge the gap between the two generic models. One method which can handle both 'hard' and 'soft' factors in evaluating supplier selection factors at the same time is the Analytic Hierarchy Process (AHP). The AHP has been reviewed and used for prioritising the importance of logistics factors in contributing to customer service in Chapter 11 and has been compared with similar approaches in Chapter 7.

6.6 Summary

Emphasis in business has traditionally been on customer goodwill. However, businesses have also begun to realise the value of supplier goodwill which is developed through open, impartial and fair dealings with suppliers leading to joint operations between trading partners. The need to form long-term relationships, reduction in the number of suppliers and the need for supplier input at the design stage are all contributing to the importance of supplier selection and evaluation.

Types of supplier evaluation and selection approaches and factors taken into account in the evaluation and selection of suppliers have been discussed in this chapter. In addition to traditional factors, developments in customer-supplier relationships have introduced new and 'soft factors' in supplier selection and evaluation which are difficult to quantify. The new factors have also been identified and discussed in this chapter.

The literature reviewed in this chapter has identified that supplier selection models broadly fall either into descriptive or prescriptive categories. It has been suggested that both categories of models fail to accommodate 'soft factors' in their supplier selection and evaluation approaches. The chapter has proposed the Analytic Hierarchy Process as one method that is capable of quantifying the relative importance of both hard and soft data in supplier evaluation and selection at the same time.

Chapter 7 which follows outlines the research methodology for the entire study and compares and contrasts the AHP with similar approaches. The AHP itself has been reviewed and used to assess the relative importance of logistics factors in contributing to customer service in Chapter 11.

CHAPTER SEVEN

RESEARCH METHODOLOGY

CHAPTER SEVEN

RESEARCH METHODOLOGY

7.1 Introduction

Chapter 6 reviewed contractors' materials procurement processes. This chapter outlines the methodology employed in order to realise the aims and objectives of this research. The self-administered postal questionnaire surveys and structured interviews undertaken are described and rationalised. Modes of analysis of the data collected by both questionnaire surveys and open-ended questions within the structured interviews have been discussed.

The literature reviewed at the end of this chapter compares and contrasts the Analytic Hierarchy Process with similar techniques and justifies the use of this technique for evaluating the importance of logistics factors in contributing to customer service in the supply of construction materials.

7.2 Research activities

The methodology adopted in this research is outlined in Figure 1.1 of Chapter 1. The activities in the methodology were designed to investigate logistics practices in the supply of construction materials in the UK construction industry. The issues investigated were based on the literature reviewed in Chapters 2, 3, 4, 5 and 6. Initial literature review, and seminars and conferences attended in the early part of the research helped in the development of broad aims and objectives which were refined over the research period to those presented in Chapter 1.

After the initial literature review, two near 'mirror-image' questionnaires (one for contractors and the other for suppliers) were developed, pilot tested and sent out into industry. An example of the contractor questionnaire including a list of the contractor organisations surveyed has been presented in Appendix B. An example of the supplier questionnaire with the corresponding surveyed companies has been presented in Appendix C.

The questionnaire surveys were followed by structured interviews comprising two parts. Part one involved evaluation of the Analytic Hierarchy Process model by industry experts from both contractor and supplier organisations to assess relative contributions of logistics factors to customer service. Part two comprised open-ended questions and was designed to complement in greater detail elements that could not be investigated in the questionnaires and part one of the interviews. The third phase of the research involved analysis of data, discussion of results, validation of the supplier management process model, drawing of conclusions and making recommendations.

7.3 Surveys

Two forms of surveys; questionnaires and interviews were used in this research. Both questionnaires and interviews share a number of common features (Fink and Kosecoff, 1985):

- information is obtained by asking people questions;
- for clarity, both need instructions;
- both are concerned with sampling (i.e. who will be asked questions);
- both are concerned with design (i.e. when and how often should the sampling be done); and
- both are concerned with the processing, analysis, and interpretation of the collected data.

7.3.1 Questionnaire survey

The mailed questionnaire technique is suitable for gathering information from a large number of respondents who may be geographically dispersed over the whole survey area. This technique was adopted for the following reasons:

- to enable an appropriate number of experts, who would have been difficult and costly to meet via interviews, throughout the UK to be sampled;

- so that responses were received within a relatively short period of time from the time the questionnaires were despatched; and
- it is a cost-effective method of data collection for the sample sizes dealt in.

The design of the two questionnaires took the format shown in Figure 7.2. The questionnaires were near 'mirror-images' of each other and designed to investigate the same issues from the perspective of contractors and suppliers. Separate questionnaires were used in order to appropriately phrase questions directed at each target group.

The contractor questionnaire had more questions than the supplier questionnaire. Sections 4.7, 5.1 and 5.3 of the contractor questionnaire were left out of the supplier questionnaire because they were considered inappropriate for suppliers.

Table 7.1: Structure of the contractor and supplier questionnaires

Contractor Questionnaire	Supplier Questionnaire
INDEPENDENT VARIABLES	
Section 1 Company Information	
1. Respondent 2. Company 6 Questions	1. Respondent 2. Company 6 Questions
DEPENDENT VARIABLES	
Section 2 Use of Information and Communication Technologies	
1. Internal materials management processes 2. Processes between contractors and construction sites 3. Processes between contractors and suppliers 23 Questions	1. Internal materials management processes 2. Processes between suppliers and construction sites 3. Processes between suppliers and contractors 23 Questions
Section 3 Contractor - Supplier Relationships	
1. Relationships 2. Supplier shortlists 19 Questions	1. Relationships 2. Supplier shortlists 19 Questions
Section 4 Supplier selection	
1. Materials where bidding is used 2. Supplier evaluation and selection factors 3. Quality standards contractors require suppliers to adhere to 4. Supplier assessment factors 5. Supplier evaluation methods 6. Contractors' satisfaction with supplier evaluation systems 43 Questions	1. Materials suppliers deal in 2. Supplier evaluation and Selection factors 3. Quality standards suppliers adhere to 4. Supplier assessment factors 5. Supplier evaluation methods 6. Suppliers' satisfaction with supplier evaluation systems 39 Questions
Section 5 Materials management	
1. Problems in supply of construction materials 2. Improving materials management 3. Responsibility for control of materials on site 4. Any general comments 20 Questions	1. Improving materials management 2. Any general comments 11 Questions

7.3.1.1 Pretesting

In the final stages of development, the questionnaires were pretested before they were finally administered. The purpose of pretesting is to identify construction defects in the questionnaire. This helps improve the clarity of the language used, reveals whether the respondents will understand the instructions and if they will be able to answer the questions, and helps improve the response rate (Fink and Kosecoff, 1985).

Table 7.2 lists the companies that helped in pretesting the two questionnaires. British Airports Authority (BAA), Laing Eastern and Midas pretested the contractor questionnaire. The supplier questionnaire was pretested by Tarmac Heavy Building Materials and ARC Central.

Table 7.2: Companies used in the pretest

Client	Contractor	Supplier
British Airports Authority	Laing Eastern	Tarmac - Heavy Building Materials
	Midas Group	ARC Central

The respondent at Laing Eastern felt that activities between: sites and purchasing departments; and sites and supplier organisations should both be investigated. This led to inclusion of Question 2.2 in both the contractor and the supplier questionnaire. It was also suggested at Tarmac-Heavy Building Materials that benefits of the survey to responding companies be outlined in the covering letter as a strategy towards improving the response rate. This suggestion was implemented. Feedback from the pretesting exercise demonstrated that the questionnaires were clear and easy to follow.

7.3.1.2 Scales

Rating scales avail respondents to judge items and assign specific numeric values regarding their viewpoint about the item along a continuous scale or ordered series of categories. Table 7.3 presents various types of scales used in both contractor and supplier questionnaires.

Table 7.3: Scales of measurement of variables

Item number in questionnaire: Contractor	Supplier	Variable	Measurement	Scales
1.0	1.0	Company type		Nominal
2.1 2.2 2.3	2.1 2.2 2.3	Information and communication technologies	6=Always 5=Very Often 4=Often 3=Occasionally 2=Rarely 1=Never	Ordinal
3.1	3.1	Contractor-supplier relationships	7=Strongly Agree 6=Agree 5=Slightly Agree 4=Neutral 3=Slightly Disagree 2=Disagree 1=Strongly Disagree	Ordinal
3.2	3.2	Shortlist		Nominal
3.3	3.3	Types of construction supplier relationships		Nominal
4.1	4.1	Tendering practices for materials types	Supplier questionnaire	Nominal
			Contractor questionnaire: 6=Always 5=Very Often 4=Often 3=Occasionally 2=Rarely 1=Never	Ordinal
4.2	4.2	Importance of factors considered in supplier selection	5=Extreme Importance 4=Considerable Importance 3=Average Importance 2=Little Importance 1=No Importance	Ordinal
4.3	4.3	Types of quality standards	Nominal	Nominal
4.4	4.4	Factors on which suppliers are assessed	6=Always 5=Very Often 4=Often 3=Neutral 2=Rarely 1=Never	Ordinal
4.5	4.5	Supplier evaluation methods	Nominal	Nominal
4.6	4.6	Satisfaction with supplier evaluation systems	5=Definitely Satisfied 4=Satisfied 3=Neutral 2=Not Satisfied 1=Definitely Not Satisfied	Ordinal
4.7		Departments involved supplier selection	Nominal	Nominal

Table 7.3: Scales of measurement of variables*...continued*

Item number in questionnaire: Contract	Supplier	Variable	Measurement	Scales
5.1		Problems in the supply of construction materials	6=Extremly Common 5=Very Common 4=Common 3=Sometimes 2=Rare 1=Never	Ordinal
5.2	5.2	Approaches to improving materials management	5=Extreme Importance 4=Considerable Importance 3=Average Importance 2=Little Importance 1=No Importance	Ordinal

The scales used in the questionnaires were carefully examined for wide usage (Lim, 1996; Mathews, 1996; Bubshait and Al-Musaid, 1992; Ahmed and Kangari, 1995; de Vaus, 1996) and in relation to how the questions would be analysed. They were also pretested before the final questionnaires were distributed. The different ranges of the response scales were tested and finally adjusted as shown in Table 7.3 based on suggestions of respondents during pre-testing.

7.3.1.3 Final survey

To ensure reasonable response rates, all the companies which were sent the questionnaires were contacted by telephone beforehand to get the consent of respondents and to inform them that the self-administered postal questionnaire was being sent to them.

7.3.1.4 Sampling

Sample selection falls into two broad categories: probability and nonprobability sampling (Henry, 1990). Probability samples are selected in such a way that every member of the population has a chance of being included in the sample. Probability sampling provides a statistical basis for inferring representativeness of the sample to the study population. In probability samples, each unit in the population has an equal chance of being included in the sample. These kind of samples imply the use of random selection methods such as: lottery procedure; extracting a set of numbers from a listing of random numbers; or using a computer program to generate a random list of units from an automated list - mechanisms which eliminate subjective bias in the selection process and underlie the theory used to infer the sample results to the population. Truly random processes, however, are difficult to achieve and are subject to human errors. Furthermore, the costs and time required to conduct a probability sample are often greater than a nonprobability sample (Henry, 1990). Because of these considerations, it was decided to use nonprobability samples in the questionnaire surveys.

Selection of nonprobability samples is based on the judgement of the researcher and is tailored for achieving the objectives of the research at hand. Nonprobability samples are a collection of sampling approaches whose distinguishing characteristic is that subjective judgements play a role in the selection of a sample. They can be chosen on the basis of systematically employed criteria. Subjective judgements are used to determine units of the population contained in the sample. Frequently used nonprobability sample methods have been presented in Table 7.4.

The critical case sampling approach was adopted in the questionnaire surveys in this study. This kind of sampling allows a researcher to select a limited number of cases for which logic permits generalisation to the population.

Table 7.4: Nonprobability sample designs
(After Henry, 1990)

Type of sampling	Selection strategy
Convenience	Select cases on the basis of their availability for the study
Most similar/Disimilar cases	Select cases that are judged to represent similar conditions or, alternatively, very different conditions
Typical cases	Select cases that are known beforehand to be useful and not to be extreme
Critical cases	Select cases that are key or essential for overall acceptance or assessment
Snowball	Group members identify members to be included in sample
Quota	Interviewers select sample that yields the same proportions as the population proportions on easily identified variables

In total, 147 companies comprising 71 contractors and 76 construction materials suppliers were surveyed. The top 100 UK contractors (Construction News, 1996), based on turnover, were initially contacted by telephone and 71 agreed to take part in the survey and were sent the contractor questionnaire. Of the 71 sent out, 35 usable returned questionnaires represented a 49.3 per cent successful response rate from the contractors.

The suppliers were sampled from the top 25 UK construction materials suppliers, based on turnover (Construction News, 1996). These were supplemented, due to inadequacy of the sample size, by another sample of suppliers of comparable turnover listed in the Construction and Civil Engineering CD - ROM (1997). Of the 76 questionnaires sent out, 35 were returned amongst which 30 which were usable represented a successful response rate among surveyed suppliers of 39.5 per cent.

7.3.1.5 Questionnaire data analysis

Analyses of the data involved determining frequencies of responses and central tendencies; statistics commonly referred to as descriptive. This form of analysis was performed using SPSS and was applied in Chapters 8 and 9.

The rank ordering of importance or frequency of occurrence of elements in both Chapters 8 and 9 was performed on the basis of relative indices obtained using the formulae given below. The relative index measure was chosen instead of the mean reponse because the scales in the analysis were ordinal. A relative index measure is more meaningful than a mean score for ranking items assessed on an ordinal scale because this type of scale does not conform to ordinary arithmetic operations.

$$\text{Importance Index} = \frac{5(n_1) + 4(n_2) + 3(n_3) + 2(n_4) + 1(n_5)}{5(n_1 + n_2 + n_3 + n_4 + n_5)} \qquad \text{Equation 7.1}$$

Where Importance Index (IN) was for the response scale where n_1 = the number of respondents that answered 'Extreme Importance', n_2 = 'Considerable Importance', n_3 = 'Average importance', n_4 = 'Little importance', and n_5 = 'No Importance'. The scale ranges from 0.200 to 1.00.

$$\text{Frequency Index} = \frac{6(n_1) + 5(n_2) + 4(n_3) + 3(n_4) + 2(n_5) + 1(n_6)}{6(n_1 + n_2 + n_3 + n_4 + n_5 + n_6)} \qquad \text{Equation 7.2}$$

Where Frequency Index (FI) was for the response scale where n_1 = the number of respondents that answered 'Always', n_2 = 'Very Often', n_3 = 'Often', n_4 = 'Occasionally', n_5 = 'Rare', n_6 = 'Never', the scale ranging from 0.167 to 1.00; and

$$\text{Occurrence Index} = \frac{6(n_1) + 5(n_2) + 4(n_3) + 3(n_4) + 2(n_5) + 1(n_6)}{6(n_1 + n_2 + n_3 + n_4 + n_5 + n_6)} \qquad \text{Equation 7.3}$$

Where the Occurrence Index, (OI) was for the response scale where n_1 = the number of respondents that answered 'Extremely Common', n_2 = 'Very Common', n_3 =

'Common', n_4 = 'Sometimes', n_5 = 'Rare', n_6 = 'Never', the scale ranging from 0.167 to 1.00.

Further analyses in Chapter 10, using inferential statistics, has been performed to uncover differences in group responses modes.

7.3.1.5.1 Inferential statistics

Statistical tests, parametric or non-parametric are determined by the scale of measurement for the survey data. Earlier in this chapter, Table 7.3 presented various types of scales used in both contractor and supplier questionnaires. All the scales were either nominal or ordinal, requiring non-parametric approach of analysis (Siegel and Castellan, 1988).

7.3.1.5.2 Tests of group difference

The two questionnaire surveys solicited responses from two independent groups: contractors and suppliers. Differences in responses between the two groups to dependent variables in Sections 2 to 5 of both contractor and supplier questionnaires were tested on non-parametric basis.

Nine tests were identified that could be used to test for group differences between two independent samples requiring non-parametric analysis (Siegel and Castallen, 1988). Table 7.5 identifies the various assumptions associated with each test.

On the basis that the samples did not meet all the assumptions of: the Fisher Exact Test for 2x2 Tables; the Chi-Square Test for Two Independent Samples; the Permutation Test for Two Independent Samples; and the Siegel Test for Scale Differences; these tests were ruled out.

The choice of which test to use remained among the Median Test, the Wilcoxon-Mann-Whitney Test, the Robust Rank Order Test, the Moses Rank-Like Test for

Table 7.5: Nonparametric test and their assumptions

Test	Assumptions
The Fisher Exact Test for 2x2 Tables	1. Two independent samples 2. Data either nominal or ordinal 3. Small data sets (N less than or equal to 20 for each)
The Chi-Square Test for two independent samples	1. Two independent samples 2. Data either nominal or ordinal 3. Data sets where n>20 . 4. Minimum response for each response category is 5
The Median Test	1. Two independent samples 2. Measurement is atleast on an ordinal scale
The Wilcoxon-Mann-Whitney Test	1. Two independent samples population with same underlying distributions 2. Measurement is atleast on an ordinal scale
Robust Rank-Order Test	1. Two independent samples (Does not assume underlying distributions are same) 2. Measurement is atleast on an ordinal scale
The Kolmogorov-Smirnov Two Sample Test	1. Two independent samples 2. Samples very small, i.e. less than 10 3. Measurement scale is atleast ordinal 4. Random variables assummed to be continuous
The Permutation Test for Two independent variables	1. Two independent samples 2. Measurement atleast on an ordinal scale 3. Small samples, i.e., less than or equal to 10
The Siegel-Turkey Test for Scale Differences	1. Two independent samples 2. Measurement atleast on an ordinal scale 3. Used in instances where it is assumed that one group has higher variability than another 4. Medians of the two groups are the same or known
The Moses Rank-Like Test for Scale Differences	1. Two independent samples 2. Observations are measured on atleast an interval scale

Scale Differences; and the Kolmogorov-Smirnov Two Sample Test. In the end, it was decided to use the Wilcoxon-Mann-Whitney test, the non-parametric equivalent of the independent samples t-test. This was because, among the remaining candidates, it is the most powerful in guarding against differences in location (Siegel and Castellan, 1988). Analysis of results of the questionnaires have been presented in Chapters 8, 9 and 10.

7.4 Structured interviews

Structured interviews were designed to complement the questionnaire surveys. The interviews were in two parts: Part One and Part Two.

The interviewed organisations were part of those surveyed in both contractor and supplier questionnaires. Before the designed interviews were sent, interviewees were contacted by telephone and made aware that designed interview formats were being sent to them and also to confirm if they were still willing to do the interviews. After the formats had been sent and the interviewees had the time to acquaint themselves with the subject matter, telephone calls were again made to fix interview dates.

To save time, interviewees were requested to complete Part One in advance of the interview date. Those who did not do so completed Part One at the end, after evaluation of the model in Part Two.

7.4.1 Format of structured interviews

Copies of both contractor and supplier structured interviews are included in Appendices 3 and 4 respectively. Part One of structured interviews was composed of three sections.

Section 1 elicited data on independent variables. Interviewees were asked to provide: names of their companies, types of businesses their organisations were involved in, and company sizes in terms of turnover and workforce. They were further asked for their own names, their positions in their companies, length and type of experience in the construction industry and any other type of experience outside the construction industry.

Section 2 assesses the use of information and communication technologies in internal materials management processes in the contractor and supplier organisations. Interviewees were asked about benefits their organisations had derived from implementation of information and communication technologies, factors which hindered introduction of information and communication technologies in materials management processes and any general comments they had about implementation of information and communication technologies in the industry.

Section 3 sought to establish factors which influenced supplier-contractor relationships and benefits and difficulties associated with such relationships. Interviewees were also asked to state how contractors gave feedback to suppliers and for any general comments they had about contractor-supplier relationships.

7.4.1.1 Analysis of open-ended questions

Open-ended questions were analysed by initially listing down all the responses to each question. This was done separately for both the contractor and supplier questionnaires. The frequency of occurrence of the responses was noted, mentioning only in passing answers which occurred only once.

Because the sample sizes of both interviewed contractors and suppliers were small, and the fact that the interviews were complementing the questionnaires, the answers were incorporated in the relevant sections of the analysed questionnaire of each group. Open-ended questions relating to implementation of information and communication technologies were analysed at the end of the relevant section of both the contractor and supplier questionnaire in Chapters 8 and 9 respectively. This was the same for questions concerning contractor-supplier relationships.

7.4.1.2 Identification of logistics performance indicators and enablers

The logistics performance indicators and enablers referred to in Chapters 8, 9, 10, 11 and Chapter 13 were identified from literature (NEVEM-workgroup, 1989; Compton, 1985; Stukhart; 1995; Dobler et al, 1990; Construction Industry Institute, 1987). A logistics performance 'indicator' is defined as a metric by which a supplier can be evaluated in satisfying customer requirements and an 'enabler' is a characteristic which makes it possible for a supplier to meet customer requirements.

Logistics performance indicators include reliability, cost-effectiveness, lead time, flexibility and value-added-service. These factors are defined below.

Delivery reliability

This is viewed in terms of the ability of the supplier to provide materials according to schedule requirements: on time, of the right quality, in right quantities, and without damage. High delivery reliability helps reduce inventory holding by the customer company.

Flexibility

Flexibility is the ability to adapt to changing circumstances. Logistically, it is viewed in terms of the supplier's ability and willingness to adjust to changing delivery requirements such as facilitating urgent deliveries, of right products, in right quantities on the customer's requests.

Lead times

This is the elapsed time between placing an order with a supplier and the receipt of that order by the customer.

Inventory level

Inventory level is the amount of stock that a company holds to meet customer demand. The level of stock holding derives from delivery reliability, flexibility and lead times capable of being consistently achieved by suppliers (NEVEM - workgroup, 1989). Inventory level has been left out of the model since it is a function of suppliers' reliability, flexibility and lead times.

Cost-effectiveness and value-added service were two other factors included as performance indicators.

Cost-effectiveness

Cost-effectiveness is the supplier's ability to provide products and level of service at a cost satisfactory to the customer.

Value-added service

This is that level of service provided by a supplier over and above ordinary or basic requirements and may include such elements as improved information processing, improved response to customer queries and general customer care. This performance indicator is intangible.

On the other hand, enablers are those characteristics of a supplier which help a company achieve superior performance as measured with respect to logistics performance indicators. In their theoretical approach to benchmarking distribution effectiveness based on experience from the forest industry, Korpela and Tuominen (1996) included management systems, process integration, information systems, organisation, technology and relationships as enablers in their AHP analysis. The various logistics characteristics which enable a supplier to achieve customer satisfaction which organisations, including construction companies, normally considered when evaluating suppliers include (Compton, 1985; Stukhart; 1995; Dobler et al, 1990; Construction Industry Institute, 1987):

- location of suppliers with respect to projects;
- quality management systems of suppliers;
- capability assessed in terms of financial strength, product technology and operation efficiency, and experience of the supplier;
- management and administrative ability of a supplier;
- quoted price; and
- contractor-supplier relationships.

Information and communication technologies or electronic data management technologies are important for integration of logistics activities within and between companies and have been included among factors upon which suppliers should be evaluated. These technologies are essential in activities like order processing. Integrated database management systems in such activities help reduce non-value-added activities.

After preliminary interviews with one client, two contractors, and one supplier it was also considered appropriate to include environmental, and health and safety records of suppliers as enablers because evidence suggested that these were increasingly being considered important in the evaluation and selection of suppliers as a result of statutory requirements.

7.4.2 Analytic Hierarchy Process (AHP) evaluations

Part Two of structured interviews involved evaluation of the Analytic Hierarchy Process model by the interviewees. A copy of the model and explanations is included in Appendices 3 and 4. The AHP methodology and results of its evaluation and analysis have been discussed in Chapter 11.

7.5 Justification for using the Analytic Hierarchy Process

The rationalè for using the AHP had to be justified. The sub-sections that follow compare and contrast the AHP with other methodologies which have similar objectives.

7.5.1 Comparison of the Analytic Hierarchy Process with similar approaches

In classifying non-market and multicriteria evaluation techniques for public goods and urban plans in relation to the goal that the methods are able to solve, Lombardi (1995) pointed out that there are numerous multicriteria analysis approaches available to help in the decision making process. In the classification, Lombardi observed that the AHP was the only multicriteria technique used in relation to the keyword *strategies* and noted that 80 per cent of keywords *decision-making problems* and 71 per cent of keywords *various kinds* were solved using the AHP. In another article, Lombardi (1997) applied, evaluated, compared and contrasted three decision making methods to urban regeneration plans. The methods in the study were the Analytic Hierarchy Process, Concordance-Discordance Analysis and Regime Analysis.

7.5.1.1 Concordance-Discordance Analysis

This method can be used for decision-making on non-comparable criteria. Based on chosen criteria on which alternatives are being assessed, the alternatives can be ranked and the best among them identified according to how they score to a series of points of views against the set criteria. The method requires quantitative ratio scores on how the alternatives compare against common criteria. It also requires estimation of the relative importance of the criteria used in the assessment of the alternatives. The technique assumes existence of a different suitable method for generation and normalisation of a vector of weights for the criteria and offers no technique of its own for assigning the scores.

The 'heart' of the Concordance-Discordance Analysis is based on computation of concordance and discordance indices. The indices are obtained from the sum of weights of the criteria that respond positively and those that respond negatively to the hypothesis that alternative 1 is preferable to alternative 2 and the summation of all the criteria weightings.

The closer the concordance index to unity and the discordance index to zero for each pair of alternatives 1 and 2, the more preferable 1 is to 2. Lombardi demonstrated that in concordance-discordance analysis, a unique solution on which a decision can outrightly be made is not guaranteed because the final ranking of alternatives is based both on concordance and discordance indices which if looked at holistically can be ambiguous.

7.5.1.2 Regime Analysis

The regime technique is a qualitative multiple criteria approach originating from the soft area of econometrics: that branch of economics concerned with the application of mathematical measures to economic data by the use of statistics.

The advantage of this method is that it uses ordinal rankings of the importance of the criteria either in increasing or decreasing order and it does not require cardinal (hard) data. The technique generates an impact matrix via pairwise comparisons of alternatives against each criteria. The matrix is then used to produce a regime matrix whose elements comprise +, -, or 0 signs only. The regime matrix is a transformation of the impact matrix and if it is multiplied by the weighting vector of the criteria it produces the aggregated success (probability) indices. In the final analysis, an aggregated probability index: equal to unity indicates absolute preference; equal to zero indicates no preference; and between zero and one indicates that the alternative is uncertain.

In contrast to the Concordance-Discordance Analysis, the Regime Method arrives at a unique final ranking, i.e., an unambiguous conclusion. However, its disadvantage is that it is not highly informative about the order of magnitude and degree of preference for alternative solutions.

Both the Concordance-Discordance and Regime methods consider only one set of criteria. In comparison, the AHP can handle more than one set of criteria at different hierarchical levels and is thus more holistic than the other two methods. Lombardi (1997) concluded that the AHP provides a better explanation in priority setting decision making problems where both cardinal and ordinal data are incorporated. Saaty (1983) compared the AHP with a number of other theories. One of these is the Thurstone Model.

7.5.1.3 The Thurstone Model

Like the AHP, this model also uses pairwise comparative judgements of objects to the extent that one is more preferred or greater than the other. The technique, however does not quantify by how much the preference of one item is over the other. Another disadvantage of the Thurstone technique is that it imposes a number of restrictions in the way information is obtained over the stimuli through the assumptions it uses on the formality of the judgements. Another method which has been compared to the AHP on numerous occasions is the Multiattribute Utility Theory.

7.5.1.4 Multiattribute Utility Theory (MAU)

One distinguishing feature between MAU and the AHP is that MAU seeks to generate utilities on an interval scale. Instead, priorities in the case of the AHP belong to a ratio scale. Another point of departure of the two techniques is that the AHP elicits judgements directly and then uses them to synthesise priorities whereas MAU initially derives a utility function through asking questions and then uses the function to analyse the given decision problem.

7.5.1.5 Fuzzy Set Theory

Edum-Fotwe (1995) reviewed various techniques which can assist in strategic decision-making. The difficulty in classifying options whether in strategic decision-making or indeed supplier evaluation and selection methodologies in precise terms arise from the fact that boundaries of various choice situations cannot be clearly demarcated. This is because real-life options are not clear cut and simple. They involve varying degrees of vagueness. Kickert (1978) defined inexactness, ill-definedness or vagueness to be fuzziness.

Fuzzy relationships serve to model imprecise concepts which pervade the real world (Nola et al, 1989). The Fuzzy Set Theory is more useful as a decision situation moves in the direction from certain to uncertain and onwards. Major applications of fuzzy sets are fuzzy control (in logic circuits), artificial intelligence and fuzzy databases (Miyamoto, 1990). In these applications, subjective human judgements or expressions in natural language must be interpreted in terms of numbers or distributions in a space of measurements. Fuzzy sets provide an appropriate framework for modelling of such systems. However, literature on the use of Fuzzy Set Theory in priority setting and evaluation of alternative decision options is scant, an indication that the technique has not found wide application on the subject even though it holds great potential.

Finally, Peniwati (1996) gave an account of an evaluation of group decision making methods in which the AHP was compared and contrasted with other approaches to problem structuring, ordering and ranking. The 16 criteria over which the approaches were compared were:

- group maintenance through leadership effectiveness;
- group maintenance through learning;
- problem abstraction through definition of scope;
- problem abstraction through development of alternatives;
- breadth of structure as represented by the number of distinct elements which can be assumed to be independent of each other;
- the depth of the structure through decomposition of elements into sub-elements, sub-elements into sub-sub-elements and so on;
- faithfulness in the analysis of judgements;
- breadth and depth of analysis;
- fairness in the quantifiable separation of alternatives;
- fairness in the prioritisation of group members;
- fairness in the consideration of other actors and stakeholders;
- scientific and mathematical generalisability;
- applicability to intangibles;
- physiophysical applicability; and
- validity of the outcome.

The methods in the evaluation were divided into two groups. Approaches to problem structuring included:

- Analogy and Attribute Association;
- Boundary Examination;
- Brainstorming;
- Morphological Connection; and
- Why - What's Stopping.

Approaches to ordering and ranking included in Peniwati's analysis comprised:

- Voting;
- The Nominal Group Technique (NGT);
- The Delphi Method;
- Disjointed Incrementalism;
- Matrix Evaluations;
- Goal Programming;
- Conjoint Measurement; and
- Outranking.

Peniwati (1996) concluded that the AHP was the most comprehensive in the basket of techniques in structure, analysis, mathematical validity and in producing truthful results. The decision to use the AHP in evaluation of the relative importance of logistics factors in supplier management, evaluation and selection was arrived at after the forgoing review of literature. Details of the data and analysis have been presented in Chapter 11.

7.6 Development of the supplier management process map

From the reviewed literature, the questionnaire surveys and interviews with contractors and suppliers, a supplier management process model shown in Figure 12.1 in Chapter 12 was mapped out and validated by six contractors.

The questionnaire in Appendix F was used to validate the model. To determine the five per cent level of significance of responses to elements with a Yes or No answer, the one-tailed Binomial Test was used. The Binomial Test was chosen because the data were in two discrete categories and the design was one-sample type. The level of significance for this test was set at $\alpha=0.05$ as was the case with the Wilcoxon-Mann Whitney test discussed earlier and used in Chapter 10.

7.7 Summary

This chapter has outlined the activities undertaken to formulate the aims and objectives of the research; the instruments used to collect the data; and how the data were analysed. Two questionnaires, one directed at contractors and the other at suppliers, were initially used to collect data on materials supply logistics practices in the UK construction industry. The structure, mode of construction, scales used and methods of pretesting the questionnaires have been described in this chapter.

The supplementary open-ended questions part of the structured interviews have also been described and methods of analysis outlined. Results, review of, and method of evaluation of the AHP models have been presented in Chapter 11. The rationalè for using the AHP has been described in this chapter. The Chapter has also briefly touched on the development of the supplier management process model and its validation. Details of the model and its validation have been presented in Chapter 12 as the main recommendation of the research. Results of the analysed questionnaire responses and structured interviews are presented in Chapters 8, 9, 10 and 11.

CHAPTER EIGHT

ANALYSIS OF CONTRACTOR QUESTIONNAIRE AND OPEN-ENDED INTERVIEW QUESTION RESULTS

CHAPTER EIGHT

ANALYSIS OF CONTRACTOR QUESTIONNAIRE AND OPEN-ENDED INTERVIEW QUESTION RESULTS

8.1 Introduction

This chapter has five sections and presents analysis of responses to the questionnaire sent to contractors and open ended interview questions addressed to nine contractors. Section 8.2 discusses independent variables: types of respondents and surveyed contractor organisations. The remaining sections and sub-sections present analysis and discussions of contractors' responses to dependent variables which include: the use of information and communication technologies; contractor-supplier relationships; importance of logistics factors in supplier evaluation and selection; the extent to which contractors considered logistics factors in supplier evaluation and selection; and perceived importance of materials management practices. Complementary in-depth data on information and communication technologies and contractor-supplier relationships from the open-ended questions of the interviews phase of data collection has also been analysed in their respective sections in this chapter.

The analysed responses to dependent variables in this chapter formed the basis for comparisons in Chapter 10 of opinions and practices of contractors concerning construction materials logistics elements with those of suppliers presented in Chapter 9.

8.2 Independent variables

Independent variables comprised data on types of respondents and surveyed contractor organisations. The analysis of surveyed organisations gives the various categories of responding contractors. Analysis of types of respondents simply identified functions performed by individuals that responded and verified whether or not they were the appropriate persons to have completed the questionnaires.

8.2.1 Types of surveyed contractor organisations

Figure 8.1 displays the percentage breakdown of the 35 contractors that responded to the contractor questionnaire: 26 per cent were building contractors, 30 per cent civil contractors, 26 per cent were both civil and building contractors, six per cent were general contractors and 20 per cent were classified as 'others'.

General contractors engaged in all types of work ranging from building, civil, process plant construction and any other type of work within the realm of the construction industry. Contractors in the 'others' category comprised companies that could not be classified in any of the other groups identified above and included those whose work was either limited to property development or construction of process plants, or those that had not indicated the nature of their business activities.

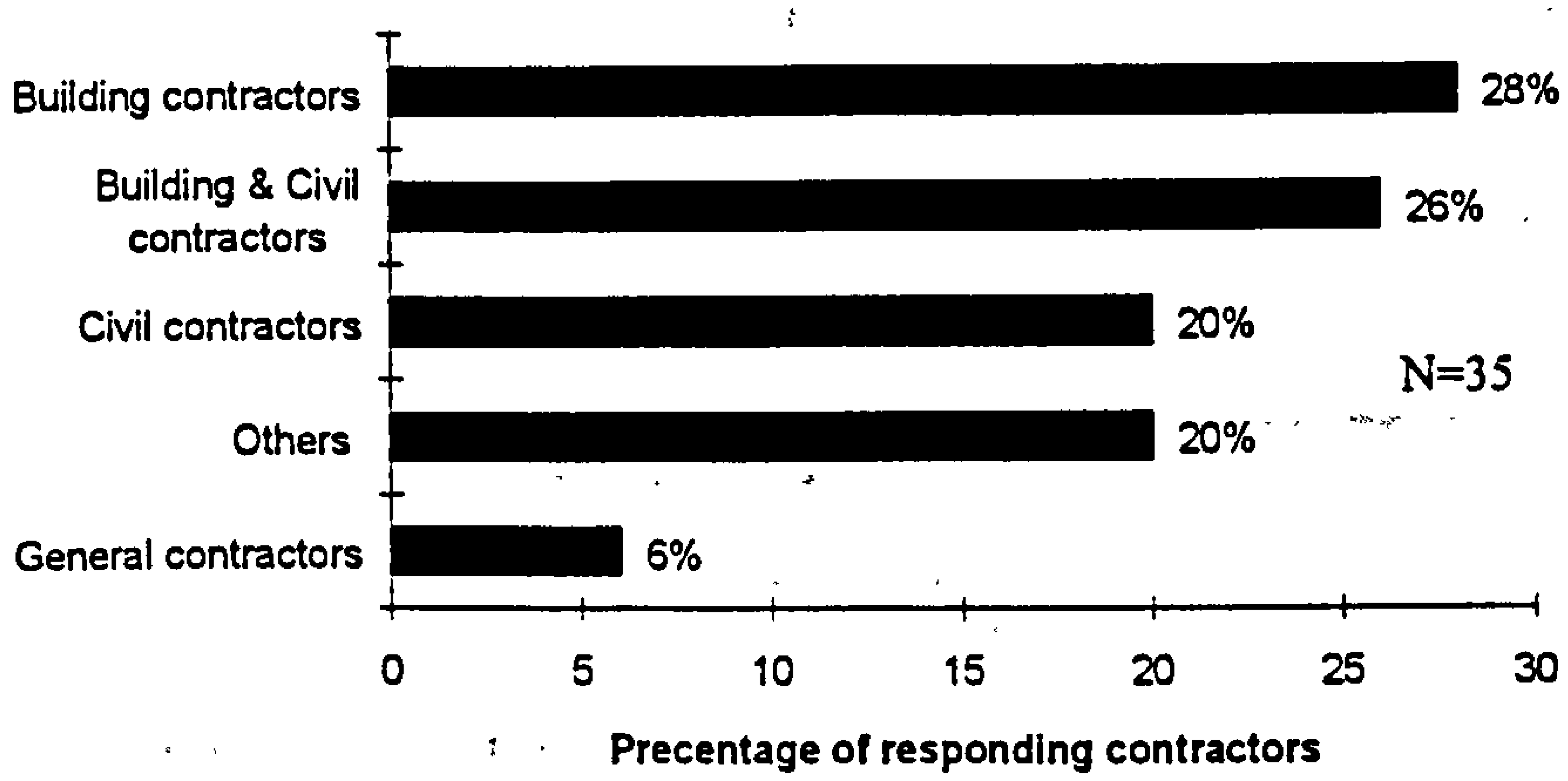


Figure 8.1: Percentage breakdown by type of responding contractors

8.2.2 Types of responding individuals

Respondents to the contractor questionnaire comprised individuals from purchasing, estimating (quantity surveying) and marketing. From the total sample, 74 per cent were from purchasing, 11 per cent from estimating, six per cent from marketing and nine per cent were directors over-seeing overall operations of their companies. Figure 8.2 shows percentage breakdown of types of respondents by functional areas in their companies. The list of surveyed companies including titles of responding individuals has been presented in Appendix B.

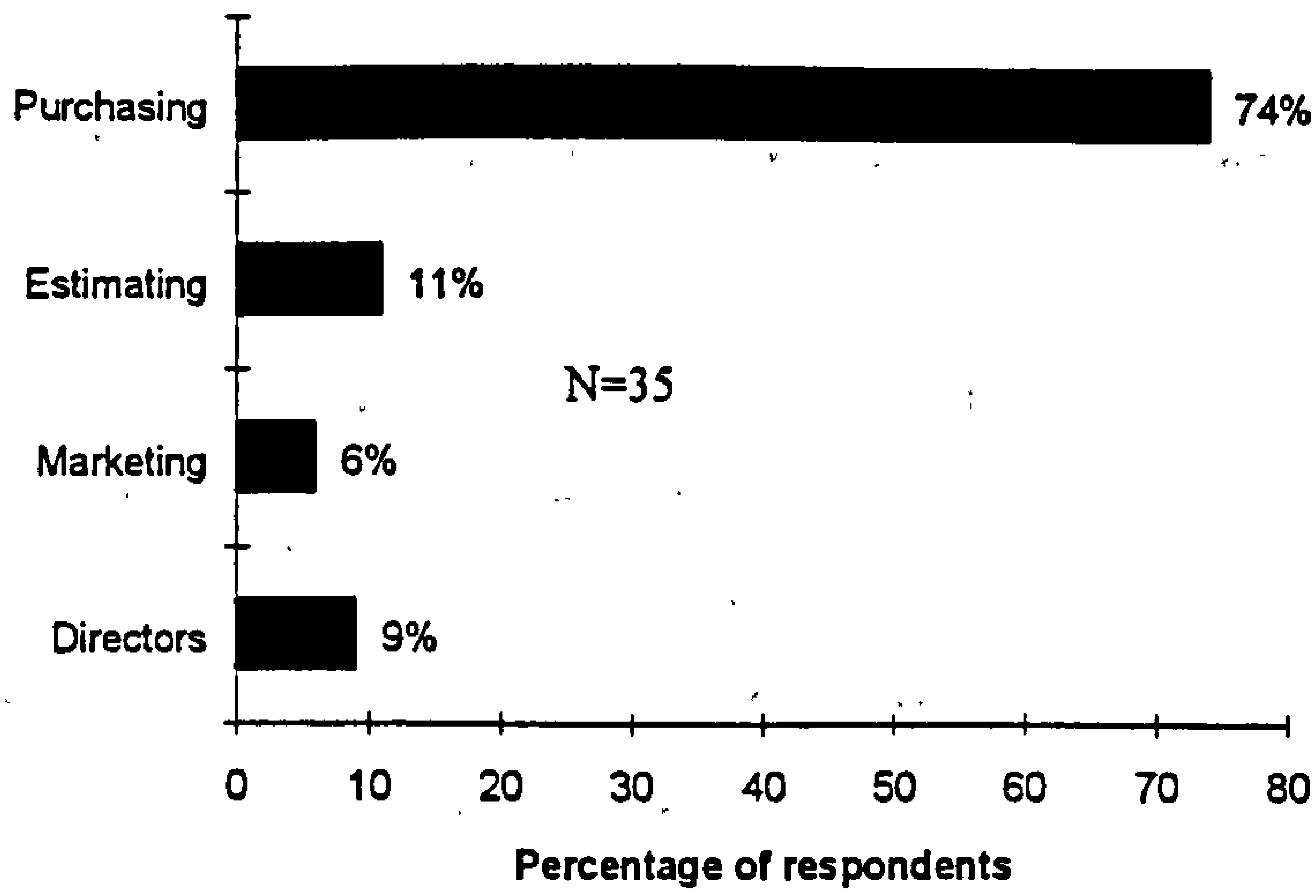


Figure 8.2: Percentage breakdown of respondents by function

To verify whether respondents were involved in supplier evaluation and selection, departments from where individuals responsible for selecting suppliers came from were also identified. Figure 8.3 displays the responses indicating that purchasing and estimating were the main departments responsible for supplier selection.

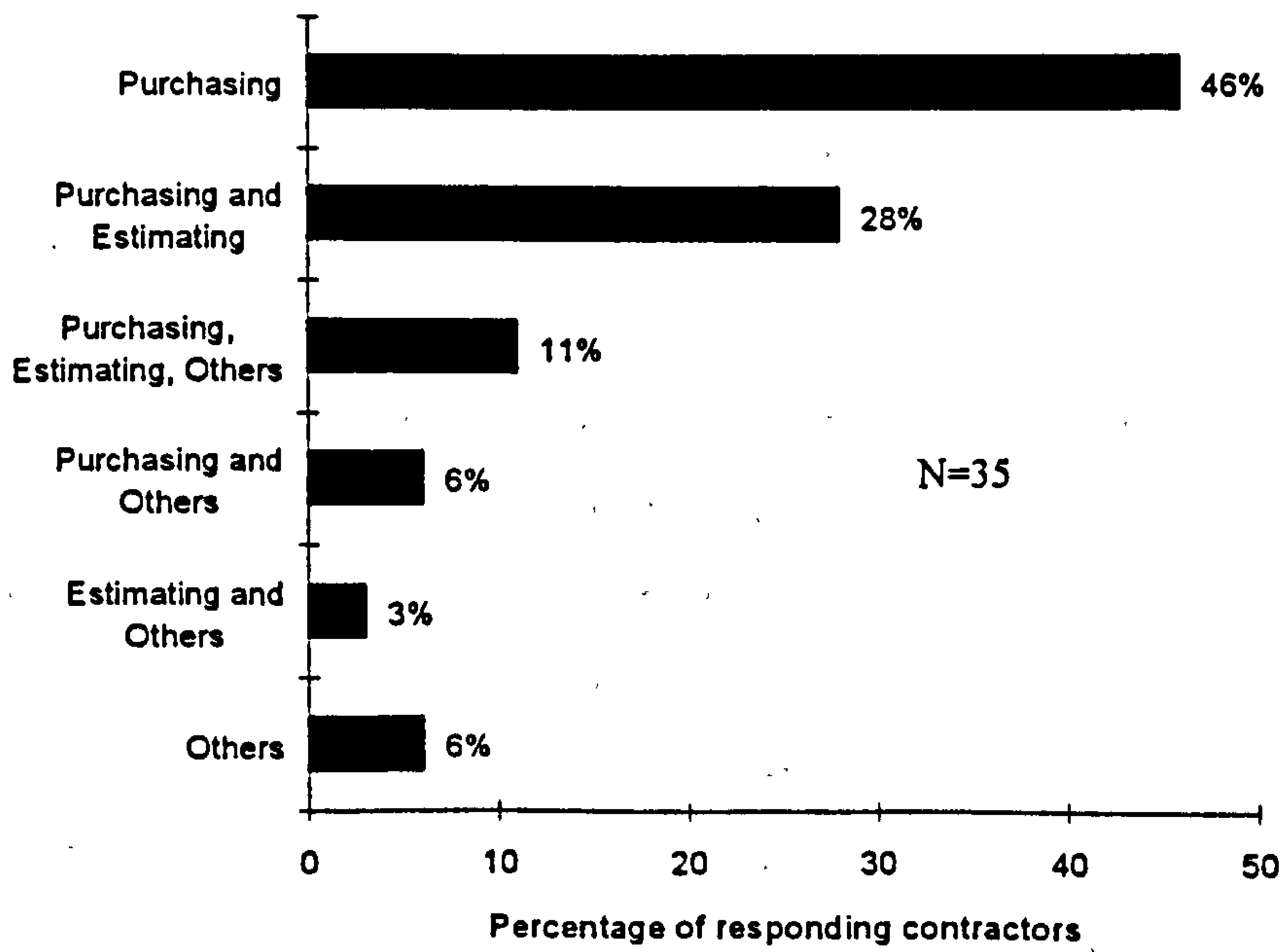


Figure 8.3: Departments involved in supplier selection by percentage of responding contractors

Responses of surveyed contractors to dependent variables are analysed in the following sections.

8.3 Use of information and communication technologies (ICTs) in materials logistics processes by UK contractors

The use of information and communication technologies was investigated with respect to: internal materials management processes; materials management processes between administrative offices of contractors and construction sites; and between contractors and suppliers. Equation 7.2 in Chapter 7 was used to calculate the rank orders of the frequency of usage of the technologies by surveyed contractors.

8.3.1 Usage in internal materials management processes

The extent to which surveyed contractors used various types of information and communication technologies in their internal materials management processes was established. Table 8.1 shows the extent of usage of the identified technologies in internal materials management processes of contractors.

Integrated database management systems were the most frequently used of the identified technologies, with 65.7 per cent (23 out of 35) of the respondents indicating that IDBMS were 'Occasionally' to 'Always' used in internal materials management processes within their organisations. The next most frequently used technologies in internal materials management processes were electronic mail, electronic document imaging, electronic data interchange and voice recognition in that order. Of the total sample, 42.9 per cent (15) of the respondents stated that they used e-mail 'Occasionally' to 'Very often', 22.9 per cent (8) used electronic document imaging 'Occasionally' to 'Very often', 20 per cent (7) used electronic data interchange 'Occasionally' to 'Very often', and 8.6 per cent (3) used voice recognition 'Occasionally' to 'Very often'. Only 5.7 per cent (2) of the surveyed contractors used bar codes 'Rarely' while the rest had 'Never' used this technology. None of the contractors had ever used radio frequency tagging and magnetic stripes.

Table 8.1: Extent contractors used ICTs in internal materials management

Response modes	Information and communication technologies															
6=Always 5=Very often 4=Often 3=Occasionally 2=Rare 1=Never	Integrated Database Management Systems		Electronic mail		Electronic Document Imaging		Electronic Data Interchange		Voice Recognition		Bar codes		Radio Frequency Tagging		Magnetic Stripes	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
6	5	14.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	3	8.6	3	18.6	2	5.7	1	2.9	1	2.9	0	0.0	0	0.0	0	0.0
4	6	17.1	4	11.4	1	2.9	3	8.6	0	0.0	0	0.0	0	0.0	0	0.0
3	9	25.7	8	22.9	5	14.3	3	8.6	2	5.7	0	0.0	0	0.0	0	0.0
2	2	5.7	5	14.3	2	5.7	3	8.6	1	2.9	2	5.7	0	0.0	0	0.0
1	10	28.6	15	42.9	25	71.4	25	71.5	31	88.6	33	94.3	35	100.0	35	100.0
Valid (total & %)	35	100.0	35	100.0	35	00.0	35	100.0	35	100.0	35	100.0	35	100.0	35	100.0
2 - 1(Rarely to Never)	12	34.3	20	57.2	27	77.1	28	80.1	32	91.5	35	100	35	100.0	35	100
3- 5(Occasionally to Always)	23	65.7	15	42.9	8	22.9	7	20.1	3	8.6	0	0.0	0	0.0	0	0
Frequency Index (FI)	0.523		0.381		0.276		0.271		0.209		0.176		0.167		0.167	
Factor Ranking (FR)	1		2		3		4		5		6		7		7	

8.3.2 Usage between contractors and construction sites

Table 8.2 shows that contractors ranked the telephone as the most used communication technology in materials supply logistic processes between administrative offices of contractors and their construction sites, followed in the second and third places by facsimile and post respectively. Over 90 per cent of the contractors indicated that they used each of these technologies 'Occasionally' to 'Always'.

Use of electronic mail, integrated database management systems and electronic data interchange between contractors and their sites was still in its infancy. After the post, e-mail was the next most used, followed by electronic database management systems and EDI in the last position. Of the total sample, 38.2 per cent (13) of the contractors used e-mail in materials supply logistics processes between their administrative offices and construction sites 'Occasionally' to 'Always', 28.6 per cent (10) used IDBMS 'Occasionally' to 'Always' and only 11.8 per cent (4) used EDI 'Occasionally' to 'Often'.

These results suggested that traditional paper-based and verbal information modes of communication were still more commonly used than electronic data management technologies in materials supply logistics processes between contractors and their construction sites.

Table 8.2: Extent of usage of ICTS in materials management between contractors and construction sites

Responses	Information and communication technologies and methods											
Response modes 6=Always 5=Very often 4=Often 3=Occasionally 2=Rare 1=Never	Telephone		Facsimile		Post		Electronic mail		Integrated Database Management Systems		Electronic Data Interchange	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
6	13	37.1	9	25.7	6	17.1	1	2.9	1	2.9	0	0.0
5	20	57.1	21	60.0	16	45.7	2	5.9	5	14.3	0	0.0
4	1	2.9	3	8.6	6	17.1	6	17.6	2	5.7	2	5.9
3	0	0.0	1	2.9	4	11.4	4	11.8	2	5.7	2	5.9
2	0	0.0	0	0.0	2	5.7	4	11.8	3	8.6	1	2.9
1	1	2.9	1	2.9	1	2.9	17	50.0	22	62.9	29	85.3
Total valid	35	100.0	35	100.0	35	100.0	34	100.0	35	100.0	34	100.0
2-1(Never-Rarely)	1	2.9	1	2.9	3	8.6	21	61.8	25	71.5	30	88.2
3-6(Occasionally-Always)	34	97.1	34	97.1	32	91.3	13	38.2	10	28.6	4	11.8
Frequency Index (FI)	0.871		0.833		0.748		0.377		0.348		0.22	
Factor Ranking (FR)	1		2		3		4		5		6	

8.3.3 Usage between contractors and suppliers

Table 8.3 shows that the telephone was the most commonly used information and communication technology in materials management processes between contractors and suppliers, followed by the facsimile and the post in the second and third places respectively. All the contractors, 100 per cent, stated that they used the telephone, facsimile and the post 'Occasionally' to 'Always'.

E-mail was the fourth most used technology, followed in the fifth and sixth place by IDBMS and EDI, respectively. Only 17.6 per cent (6) of the contractors indicated that they used e-mail 'Occasionally' to 'Often', 5.8 per cent (2) used IDBMS 'Often' to 'Very often' and 5.7 per cent (2) used EDI 'Rarely'.

Again results show that traditional paper-based and verbal information and communication technologies were the most used methods in materials logistics activities between contractors and suppliers. The use of electronic data management technologies was still very low.

Table 8.3: Extent ICTs were used in materials management between contractors and suppliers

Response	Information and communication technologies and methods											
Response modes 6=Always 5=Very often 4=Often 3=Occasionally 2=Rare 1=Never	Telephone		Facsimile		Post		Electronic mail		Integrated Database Management Systems		Electronic Data Interchange	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
6	16	45.7	11	31.4	13	37.1	0	0.0	0	0.0	0	0.0
5	17	48.6	23	65.7	17	48.6	0	0.0	1	2.9	0	0.0
4	2	5.7	0	0.0	5	14.3	1	2.9	1	2.9	0	0.0
3	0	0.0	1	2.9	0	0.0	5	14.7	0	0.0	2	5.7
2	0	0.0	0	0.0	0	0.0	7	20.6	7	20.0	7	20.6
1	0	0.0	0	0.0	0	0.0	21	61.8	26	74.3	25	73.5
Valid (total & %)	35	100.0	35	100.0	35	100.0	34	100.0	35	100.0	34	100.0
2 -1(Never- Rarely)	0	0	0	0	0	0	28	82.4	33	94.3	32	94.1
3-6 (Occasionally-Always)	35	100	35	100	35	100	6	17.6	2	5.8	2	5.7
Frequency Index (UI)	0.9		0.876		0.871		0.265		0.233		0.22	
Factor Ranking (UR)	1		2		3		4		5		6	

8.3.4 Analysis of contractors' responses to open-ended questions

Open-ended questions during interviews with nine of the contractors in the second phase of the research sought further insight into the implementation of information and communication technologies by the interviewed companies. Responses to the questions are analysed below.

8.3.4.1 Benefits from the implementation of ICTs in materials management processes

From the experiences of the information and communication technologies that the nine contractors had implemented, the most frequently cited benefit was fast access to data and quicker information flows between sites, administrative offices and among personnel. Of the nine contractors, eight of them cited these benefits. All the mentioned benefits were in intra-organisational materials management processes.

Other identified benefits included increased work output, improved quality and efficiency in communication and less number of errors in data entry. One notable observation was that none of the interviewed contractors associated the technologies with lowering costs.

8.3.4.2 Factors hindering introduction of ICTs in materials management processes

In order of the most frequently mentioned, factors identified to hinder introduction of information and communication technologies in materials management processes included:

- incompatibility of technologies in use. Out of the nine interviewed companies, four identified this factor. Companies using their stand-alone databases, incompatibility of information between departments, technology format incompatibility between contractors and suppliers, and problems in the design of bespoke systems were the various problems cited;
- high cost of the technology leading to lack of investment or expenditure on software and hardware. This factor was mentioned by four of the companies; and

- fear of change, lack of confidence in using the technology and non-availability of people with the expertise were the other hindrances that were cited.

8.3.4.3 General comments about implementation of ICTs in materials management processes

Even though the interviewed companies recognised that information and communication technologies could help in achieving competitiveness, they generally admitted that the industry had been slow in implementing the technologies. The identified main obstacle for this was that designers, suppliers, contractors and subcontractors were not agreed on standards. One company pointed out that unlike in manufacturing and retailing, each construction project is unique and it is difficult to use similar information and communication solutions or approach each time.

8.4 Contractor-supplier relationships

Table 8.4 displays surveyed contractors' opinions to statements relating to relationships between them and suppliers. Each of the statements is analysed separately below.

We know which of our suppliers are vital to our business

Among the contractors, 97.1 per cent (34) agreed with the statement that they knew which of their suppliers were vital to their businesses. Both modal and median responses to the statement were 'Agree'.

We buy on the basis of lowest price alone

The majority of the surveyed contractors disagreed with the statement that they purchased materials on the basis of lowest price alone. Of the total 35 responding contractors, 60 per cent (21) disagreed with the statement, 14.3 per cent (5) were neutral, and only 25.7 per cent (9) agreed with the statement.

Table 8.4: Contractor - supplier relationships

Legend of response modes: Agree (5 to 7), Neutral (4), Disagree (3 to 1)
where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree

Practice		Combined responses			Responses							Total	Mode	Median
		Agree	Neutral	Disagree	7	6	5	4	3	2	1			
Knowledge: We know which of our suppliers are vital to our business	Frequency	34	1	0	11	20	3	1	0	0	0	35	6	6
	% of total	97.1	2.9	0	31.4	57.1	8.6	2.9	0	0	0	100		
Purchasing policy: We buy on the basis of lowest price alone	Frequency	9	5	21	0	3	6	5	8	11	2	35	2	3
	% of total	25.7	14.3	60	0	8.6	17.1	14.3	22.9	51.4	5.7	100		
We try to reduce the number of our suppliers to a minimum	Frequency	20	4	11	2	8	10	4	2	9	0	35	5	5
	% of total	57.2	11.4	31.4	5.7	22.9	28.6	11.4	5.7	25.7	0	100		
Relationships: To obtain the best deal, we change our suppliers frequently	Frequency	7	3	25	0	3	4	3	4	19	2	35	2	2
	% of total	20	8.6	71.4	0	8.6	11.4	8.6	11.4	54.3	5.7	100		
We attempt to obtain mutually beneficial relationships with our suppliers	Frequency	31	4	0	4	23	4	4	0	0	0	35	6	6
	% of total	88.5	11.5	0	11.4	65.7	11.4	11.4	0	0	0	100		
We seek to obtain a unique advantage over our competitors though our relationships with our suppliers	Frequency	31	4	0	5	19	7	4	0	0	0	35	6	6
	% of total	88.6	11.4	0	14.3	54.3	20	11.4	0	0	0	100		
We do not believe that sharing our strategic plans with our suppliers is in our best interests	Frequency	8	13	14	1	2	5	13	4	7	3	35	4	4
	% of total	22.9	37.1	40	2.9	5.7	14.3	37.1	11.4	20	8.6	100		
We give feedback to suppliers on their delivery performance	Frequency	23	7	5	5	11	7	7	3	2	0	35	6	5
	% of total	65.7	20	14.3	14.3	31.4	20	20	8.6	5.7	0	100		

Table 8.4: Contractor - supplier relationships...... *continued*

Legend of response modes: Agree (5 to 7), Neutral (4), Disagree (3 to 1)
where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree

Practice		Combined responses			Responses							Total	Mode	Median
		Agree	Neutral	Disagree	7	6	5	4	3	2	1			
We expect our potential suppliers to deliver exactly what we specify without question	Frequency	25	4	6	6	16	3	4	4	2	0	35	6	6
	% of total	71.4	11.4	17.1	17.1	45.7	8.6	11.4	11.4	5.7	0	100		
We check every delivery - it is the only way to ensure consistent quality	Frequency	26	5	4	8	12	6	5	1	3	0	35	6	6
	% of total	74.3	14.3	11.4	22.9	34.3	17.1	14.3	2.9	8.6	0	100		
We always seek the commitment of our suppliers to achieve project delivery goals of cost, time and quality	Frequency	33	1	1	11	18	4	1	1	0	0	35	6	6
	% of total	94.2	2.9	2.9	31.4	51.4	11.4	2.9	2.9	0	0	100		
We always involve our suppliers when tendering for projects	Frequency	32	2	1	6	19	7	2	0	1	0	35	6	6
	% of total	91.4	5.7	2.9	17.1	54.3	20	5.7	0	2.9	0	100		
Communication between us and our suppliers is open, honest and based on mutual respect	Frequency	30	3	2	7	18	5	3	2	0	0	35	6	6
	% of total	85.7	8.6	5.7	20	51.4	14.3	8.6	5.7	0	0	100		
There is trust in the sharing of project information between us and our suppliers	Frequency	31	4	0	5	15	11	4	0	0	0	35	6	6
	% of total	88.6	11.4	0	14.3	42.9	31.4	11.4	0	0	0	100		
We always give ample time to our suppliers to prepare bids for supply of materials	Frequency	13	8	14	1	9	3	8	10	4	0	35	3	4
	% of total	37.2	22.9	40	2.9	25.7	8.6	22.9	28.6	11.4	0	100		
We pay our suppliers in time for materials already delivered	Frequency	22	7	6	7	14	1	7	4	2	0	35	6	6
	% of total	62.9	20	17.1	20	40	2.9	20	11.4	5.7	0	100		

We try to reduce the number of our suppliers to a minimum

The majority of contractors, 57.2 per cent (20) agreed with the statement that they try to reduce the number of their suppliers to a minimum, 11.4 per cent (4) were neutral and 31.4 per cent (11) disagreed.

To obtain the best deal we change our suppliers frequently

The surveyed contractors disagreed, in majority, with the statement that to obtain the best deal they change their suppliers frequently, recording 'Disagree' for both modal and median responses. Of the total responding, 71.4 per cent (25) disagreed with the statement, 8.6 per cent (3) were neutral and only 20 per cent (7) agreed with it.

We attempt to obtain mutually beneficial relationships with our suppliers

The majority of the contractors, 88.5 per cent agreed with the statement that they attempted to obtain mutual beneficial relationships with their suppliers, with both modal and median responses at 'Agree'. Only 11.5 per cent (4) were neutral.

We seek to obtain a unique advantage over our competitors through our relationships with our suppliers

There was agreement with both modal and median responses at 'Agree' to the statement that contractors seek to obtain a unique advantage over their competitors through their relationships with their suppliers. Of the total sample of 35 responding contractors, 88.6 per cent (31) agreed with the statement and 11.4 per cent (4) were neutral, with none disagreeing with the statement.

We do not believe that sharing our strategic plans with our suppliers is in our best interests

There was slight contradiction to the two immediate statements above when respondents registered neutrality with both modal and median responses at 'Neutral' to the statement that contractors do not believe that sharing their strategic plans with their suppliers is in their best interests. While 40 per cent (14) disagreed with this statement, 22.9 per cent (8) agreed with it and 37.1 per cent (13) expressed neutrality.

We give feedback to suppliers on their delivery performance

The majority of the contractors, 65.7 per cent (23) responded that they gave feedback to suppliers on their delivery performance. The modal response to the statement was 'Agree' and the median response was 'Slightly Agree'.

We expect our potential suppliers to deliver exactly what we specify without question

Despite the positive responses so far recorded, there appeared to be hard practices by the majority of contractors. Over 70 per cent of those surveyed registered responses between 'Slightly agree' and 'Strongly agree' to the statement that they expected their potential suppliers to deliver exactly what they specified without question. Both modal and median responses to the statement were 'Agree'.

We check every delivery - it is the only way to ensure consistent quality

Over 70 per cent of respondents also registered responses between 'Slightly agree' and 'Strongly agree' to the statement that they checked every delivery as the only way to ensure consistent quality with both modal and median responses at 'Agree'.

We always seek the commitment of our suppliers to achieve project delivery goals of cost, time and quality

Over 90 per cent of respondents expressed between 'Slight' and 'Strong' agreement to the statement that they always sought the commitment of their suppliers to achieve project delivery goals of cost, time and quality. Both modal and median responses to the statement were 'Agree'.

We always involve our suppliers when tendering for projects

There was agreement by 91.4 per cent of the contractors between 'Slightly Agree' to 'Strongly Agree' to the statement that contractors always involved their suppliers when tendering for projects.

Communication between us and our suppliers is open, honest and based on mutual respect

The majority of contractors, 85.7 per cent, agreed with the statement that communication between them and their suppliers was open, honest and based on mutual respect.

There is trust in the sharing of project information between us and our suppliers

The majority of contractors, 88.6 per cent, agreed with the statement that there was trust in the sharing of project information between them and their suppliers.

We always give ample time to our suppliers to prepare bids for supply of materials

Contractors disagreed with the statement that they always gave ample time to their suppliers for the supply of materials, recording a modal response of 'Slightly disagree' and a median response of 'Neutral'. While 40 per cent (14) disagreed, 22.9 per cent were neutral and only 37.2 per cent (13) agreed.

We pay our suppliers in time for materials already delivered

The majority of contractors, 62.9 per cent agreed with the statement that contractors paid their suppliers in time for materials already delivered. Both modal and median responses to the statements were at 'Agree'.

8.5 Maintenance of supplier lists by contractors

The practice of maintaining supplier lists by respondent contractors is shown by percentage breakdown in Figure 8.4. Of the total, 94 per cent of the contractors maintained supplier lists and 71 per cent did so on computer databases. The remaining 6 per cent did not keep supplier lists. This result suggests that the majority of contractors knew their suppliers and possibly were engaged in long-term working arrangements.

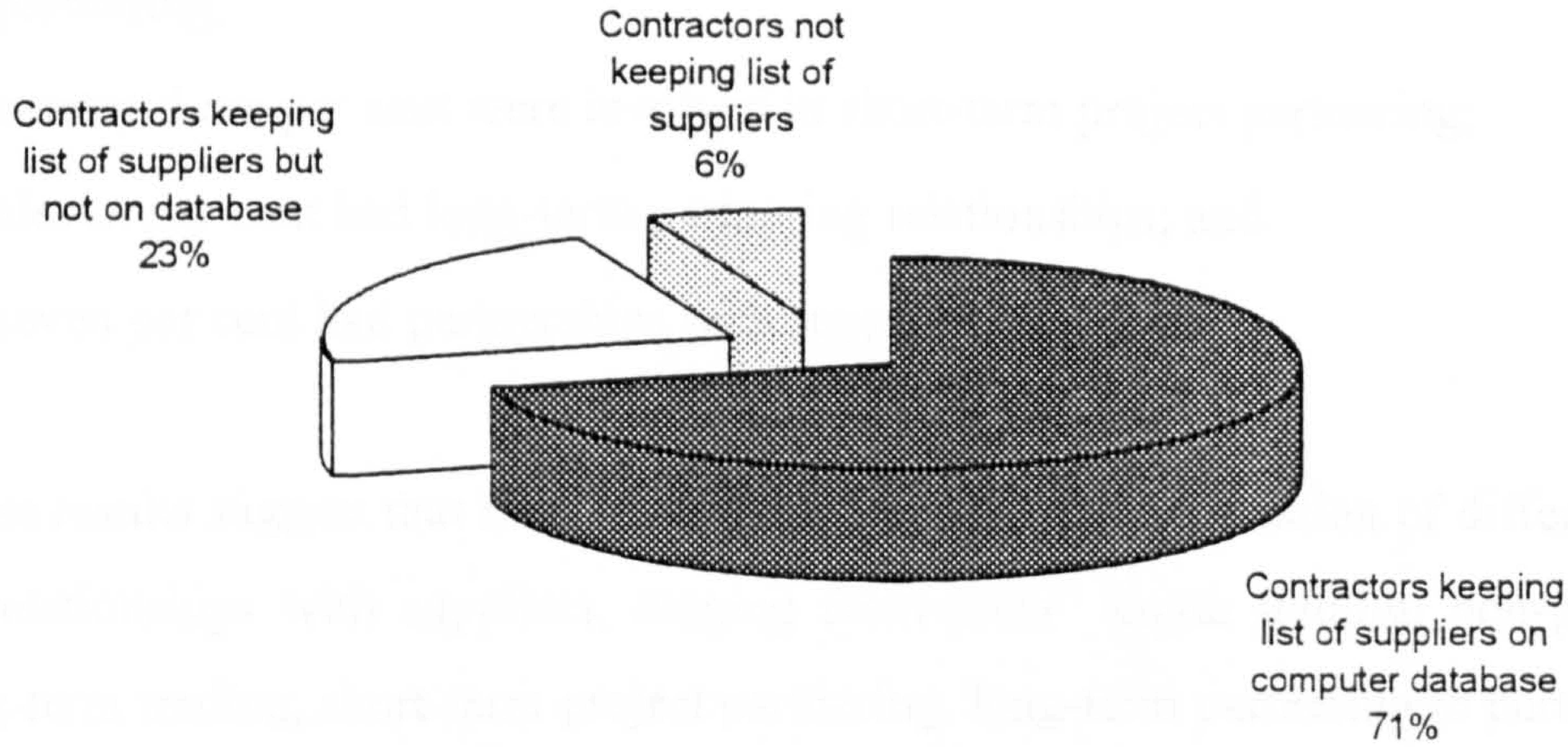


Figure 8.4: Percentage breakdown reflecting the practice of keeping supplier lists by surveyed contractors

This assertion is supported by the contractors' responses in Figure 8.5 which is an analysis of how the contractors described their relationships with suppliers. Only 6 per cent (2) of the contractors maintained arms' length trading relationships with their suppliers. The majority, 94 per cent indicated either a combination of arms' length trading with other types of closer working relationships or responded that they had closer ties with their suppliers.

Figure 8.5 shows that:

- three per cent of the contractors had a combination of arms' length relationships, non-partnering long-term trading and short-term project partnering with suppliers;
- six per cent had a combination of arms' length, non-partnering long-term trading, short-term project partnering, and long-term partnering relationships;
- eleven per cent were involved in a combination of non-partnering long-term trading and short-term project partnering;
- three per cent had both non-partnering long-term trading and long-term partnering relationships;
- twenty per cent had non-partnering long-term trading relationships;

- three per cent were engaged in both short-term project partnering and long-term partnering;
- twenty-three per cent were involved in short-term project partnering;
- eleven per cent had long-term partnering relationships; and
- seven per cent had partnerships with suppliers.

These results suggest that most of the contractors had a combination of different types of relationships with suppliers, ranging from arms' length trading, non-partnering long-term trading, short-term project partnering, long-term partnering to partnerships.

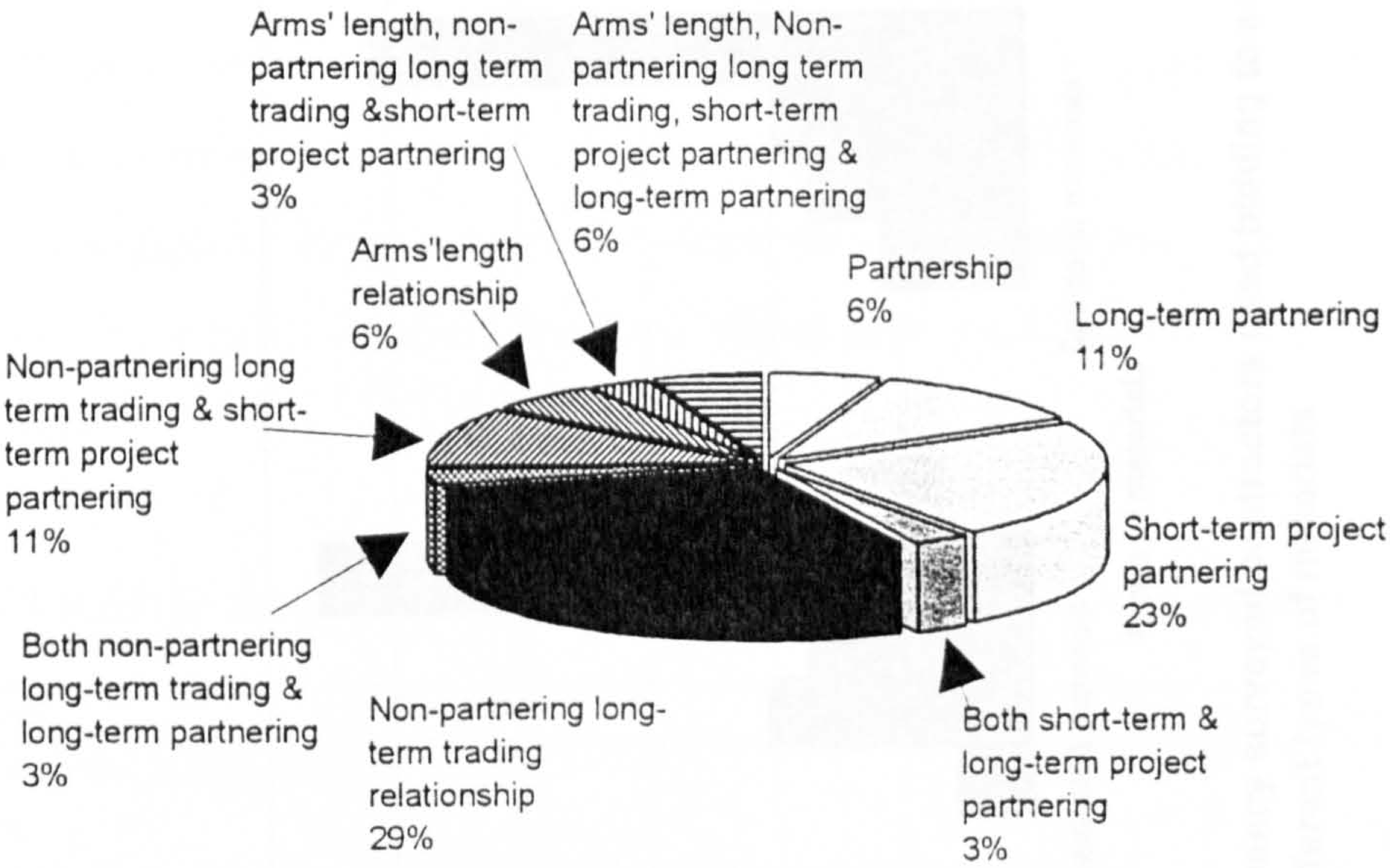


Figure 8.5: Percentage breakdowns describing surveyed contractors' relationships with their materials suppliers

8.6 Supplier evaluation and selection

Even though the majority of the surveyed contractors had close ties with materials suppliers, they still selected materials suppliers using the bidding system. Figure 8.6 is a display of how frequently the surveyed contractors used bidding to select suppliers for the supply of materials. Over 50 per cent of the contractors 'Always' selected suppliers via bidding for bulk, fabricated and specialist materials. About 35 per cent 'Always' and slightly over 25 per cent 'Very often' used bidding to secure

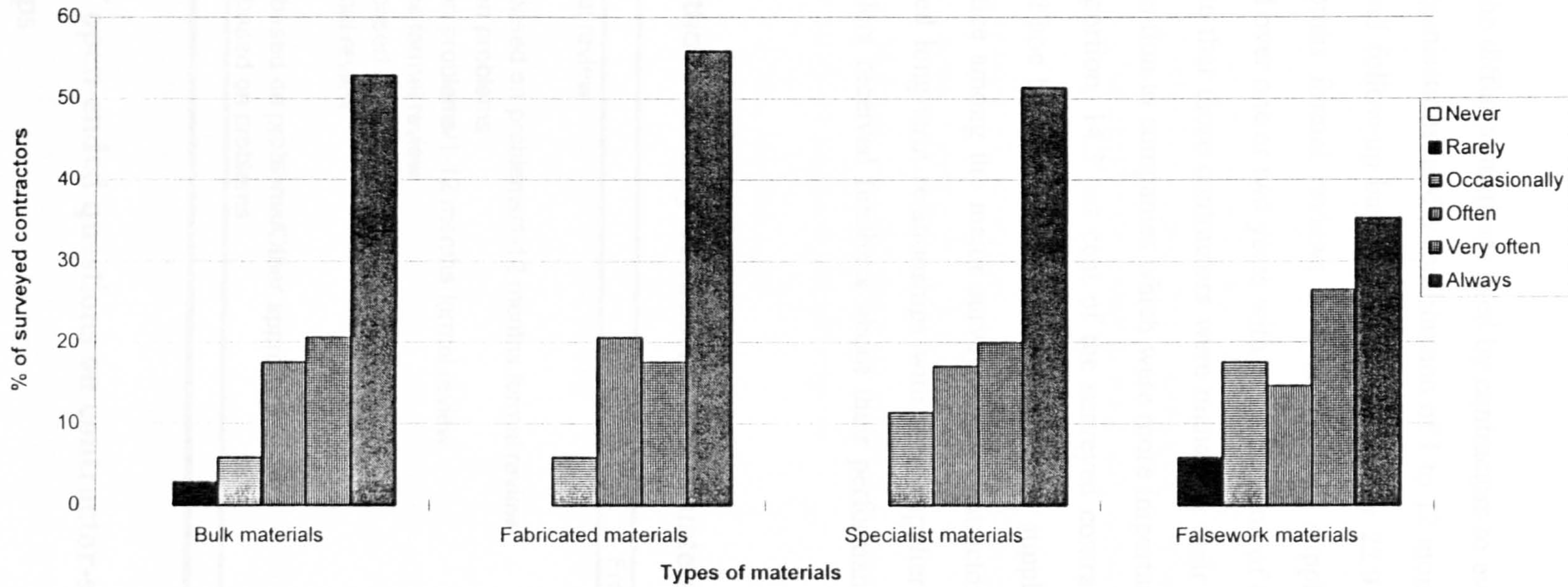


Figure 8.6: Frequency surveyed contractors used bidding to select suppliers for the different types of materials

materials for falsework. The overall picture given by Figure 8.6 is that surveyed contractors mostly used bidding to select suppliers.

Table 8.5 shows the different methods used by contractors to evaluate suppliers. The majority of the organisations used a combination of 1 to 12 months formal review, ad hoc evaluations and follow-up based on problems. Only 22.9 per cent consistently used 1 to 12 months formal reviews to evaluate their suppliers. Where formal reviews were used over one or two years with a combination of other methods, it may have been the case that those contractors were managing their suppliers selectively, paying greater attention to companies which were more important to their businesses. Quite a large proportion, 14.3 per cent of the surveyed contractors, evaluated their suppliers on an ad hoc basis. These results do not show supplier management as a predominant practice among the major surveyed UK contractors, even though their responses suggested long-term relationships with their suppliers. This could create problems if suppliers received feedback about their performance only when things went wrong.

Table 8.5: Methods used by contractors to evaluate suppliers

Method	Frequency	Percentage
1-12 months formal review	8	22.9
Adhoc	5	14.3
Adhoc/Follow-up based on problems/1-12 months formal review	5	14.3
Follow-up based on problems	3	8.6
Follow-up based on problems/1-12 months formal review	3	8.6
Adhoc/1-12 months formal review	3	8.6
Adhoc/Follow-up based on problems	3	8.6
13-24 months formal review	2	5.7
Other approaches	1	2.9
Adhoc/ Follow-up based on problems/Other approaches	1	2.9
Adhoc/ Follow-up based on problems	1	2.9
Total	35	100

8.7 Analysis of open-ended questions on contractor-supplier relationships

To develop further insight into the nature of contractor-supplier relationships, more details were elicited from nine contractors about their relationships with suppliers via interviews involving open-ended questions in the second phase of the research programme. Analysis of their responses is provided in the sections that follow.

8.7.1 Obstacles to formation of long-term contractor- supplier relationships

In order of the most frequently mentioned, the following were the factors identified by contractors to hinder formation of long-term relationships with suppliers:

- 'lack of trust' was mentioned by six of the nine contractors.
- conflict of interest was cited by four of the companies. Whereas contractors want to achieve lowest price, instead of lowest turnout cost, suppliers wanted to achieve the best price;
- two contractors mentioned entrenched traditional arms' length relationships as a hindrance to formation of long-term relationships;
- other hindrances included specifications on traditional contracts which did not consistently use the same materials for all projects;
- lack of continuity of site activities; and
- fluctuating workloads which cannot create consistent repeat business.

One contractor did not believe that "partnering" could work between contracting organisations and its suppliers.

8.7.2 Benefits derived from long-term contractor-supplier relationships

Identified benefits derived from long-term relationships such as partnering with suppliers included:

- long-term commitment to reduce costs and improve efficiency leading to lower total acquisition costs;
- improved lead times, delivery reliability and quality leading to improved customer service;
- external source of specialist knowledge;

- exchange of market information;
- easier working relationships as a result of repeat orders;
- urgent help and assistance when required;
- development of trust;
- improvement in technology and performance; and
- improved reporting and ability to monitor purchases.

8.7.3 Feedback methods on supplier delivery performance

The following were the methods interviewed contractors used to give feedback to suppliers on their delivery performance:

- through a vendor rating system;
- 6-monthly reviews (if applicable);
- through day-to day and personal contact;
- only when their are problems; and
- informally.

8.7.4 General comments about contractor-supplier relationships

In general, contractors identified the following problems as hindering improvements in contractor-supplier relationships:

- workload of individual companies in the industry fluctuates tremendously and this can make strong contractor-supplier relationships awkward;
- construction takes place where the project is, consequently either restricting suppliers from being competitive or being able to offer superior service;
- specifications on traditional contracts reduce scope for repetitively using the same supplier; and
- construction is a hard market with very little long-termism and too cost driven.

Despite the above statements, some contractors observed that the industry is undergoing a cultural change to more co-operative trading such as partnering.

8.8 Importance attached to logistics factors

Tables 8.6 and 8.7 exhibit responses of contractors and how these were ranked to show the relative importance they attached to both logistics performance indicators and enablers in supplier evaluation and selection. Arranging the factors in order of importance respondents attached to each was achieved by calculating the importance index (IN) from which the factor ranking (FR) of each performance indicator and enabler was determined. The importance index was calculated using Equation 7.1 in Chapter 6. The logistics performance indicators and enablers were then ranked separately. These factors were identified from literature and are given in Chapter 7. A logistics performance 'indicator' is defined as a metric by which a supplier can be evaluated in satisfying customer requirements and an 'enabler' is a characteristic which makes it possible for a supplier to meet customer requirements.

8.8.1 Logistics performance indicators

Based on the calculated importance indices, contractors ranked reliability of a supplier as the most important performance indicator. The calculated importance index for this indicator was 0.94 and it received both modal and median responses of "Extreme Importance" as regards supplier evaluation and selection.

Table 8.6: Importance contractors attached to logistics performance indicators in supplier evaluation and selection

Legend of responses: 5=Extreme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance

Combined responses: 3 to 5=Important, 2 to1=Not Important

Factors		Combined responses		Responses					Total	Mode	Median	Importance Index	Factor Ranking
		3 to 5	2 to 1	5	4	3	2	1					
Reliability (ability of supplier to deliver right products, of right quality and quantity on schedule, without damage)	Frequency	35	0	26	8	1	0	0	35	5	5	0.94	1
	% of total	100	0	74.3	22.9	2.9	0	0	100				
Cost-effectiveness: cost of service satisfactory to customer	Frequency	35	0	19	14	2	0	0	35	5	5	0.9	2
	% of total	100	0	54.3	40	5.7	0	0	100				
Flexibility (responsiveness of supplier to changing customer needs)	Frequency	34	1	10	19	5	1	0	35	4	4	0.82	3
	% of total	97.2	2.8	28.6	54.3	14.3	2.8	0	100				
Lead time quoted by supplier	Frequency	35	0	6	24	5	0	0	35	4	4	0.81	4
	% of total	100	0	17.1	68.6	14.3	0	0	100				
Value-added service exceeding basic service requirements	Frequency	32	3	6	9	17	3	0	35	3	3	0.7	5
	% of total	91.4	8.6	17.1	25.7	48.6	8.6	0	100				

Cost-effectiveness of suppliers was ranked second in importance and received an importance index of 0.9 and both modal and median responses were "Extreme Importance".

Flexibility of suppliers was ranked third in importance in supplier evaluation and selection and its calculated importance index was 0.82. It was followed in the fourth rank by lead times of suppliers which had an importance index of 0.81. Flexibility and lead times received both modal and median responses of "Considerable Importance". Value-added service was the least ranked performance indicator, in the fifth position, with an importance index of 0.7 and received both modal and median responses of "Average Importance".

Above 90 per cent of the respondents assessed all the logistics performance indicators to range from "Average Importance" to "Extreme Importance".

8.8.2 Logistics enablers

Among the enablers, contractors ranked quoted prices of materials most important, assigning it an importance index of 0.86 and both modal and median responses of "Considerable Importance".

The second most important enabler was capability of suppliers followed by quality management systems employed by suppliers in third place, health and safety records of suppliers in the fourth rank, and long-term relationships with suppliers in the fifth rank. The importance index for capability was 0.79, 0.78 for quality management systems, 0.76 for health and safety records of suppliers and 0.75 for long term relationships with suppliers. All the four enablers received both modal and median responses of "Considerable Importance" in supplier evaluation and selection.

Management and administrative ability of suppliers was ranked sixth in importance, had an importance index of 0.72, bi-modal responses of "Considerable Importance" and "Average Importance" and a median response "Considerable Importance".

Table 8.7: Importance contractors attached to enablers in supplier evaluation and selection

Legend of response: 5=Exterme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance

Combined responses: 3 to 5=Important, 2 to1=Not Important

Practice		Combined responses		Responses					Total	Mode	Median	Importance index	Factor ranking
		3 to 5	2 to 1	5	4	3	2	1					
Quoted price	Frequency	34	1	15	16	3	1	0	35	4	4	0.86	1
	% of total	97.2	2.8	42.9	45.7	8.6	2.9	0	100				
Capability (financial strength, production technology and efficiency, experience)	Frequency	35	0	8	18	9	0	0	35	4	4	0.79	2
	% of total	100	0	22.9	51.4	25.7	0	0	100				
Quality management systems employed by supplier	Frequency	33	2	6	21	6	2	0	35	4	4	0.78	3
	% of total	94.3	5.7	17.2	60	17.1	5.7	0	100				
Health and Safety records suppliers	Frequency	32	3	9	14	9	2	1	35	4	4	0.76	4
	% of total	91.4	8.6	25.7	40	25.7	5.7	2.9	100				
Long-term relationships with suppliers (such as partnering)	Frequency	33	2	8	13	12	2	0	35	4	4	0.75	5
	% of total	94.3	5.7	22.9	37.1	34.3	5.7	0	100				
Management and administrative capability of suppliers	Frequency	34	1	4	15	15	1	0	35	3,4	4	0.72	6
	% of total	97.1	2.8	11.4	42.9	42.9	2.9	0	100				
Location of supplier in relation to project	Frequency	32	3	4	7	21	2	1	35	3	3	0.66	7
	% of total	91.4	8.6	11.4	20	60	5.7	2 9	100				
Environmental record of supplier	Frequency	31	4	3	9	19	3	1	35	3	3	0.66	7
	% of total	88 6	11.4	8.6	25.7	54.3	8.6	2 9	100				
Information and communication technologies (bar codes, EDI, Database management systems)	Frequency	15	20	0	5	10	14	6	35	2	2	0.48	8
	% of total	42.9	57.1	0	14.3	28.6	40	17.1	100				

Both location of suppliers in relation to projects and environmental records of suppliers were ranked seventh in importance, each with an importance index of 0.66 and both modal and median responses of "Average Importance". Information and communication technologies were ranked the least important, in the eighth position, in supplier evaluation and selection. The importance index for this enabler was 0.48 and received both modal and median responses of "Little Importance". Over 57 per cent of the surveyed contractors considered this enabler to be of 'No' or 'Little Importance' With the exception of information and communication technologies, over 88 per cent of the respondents considered all the other enablers to be of average to extreme importance.

The introduction of quality standards like BS 5750 within the UK which later became ISO 9000 internationally was to encourage quality assessments of suppliers by approved independent bodies. Quality management was considered very important in the early 1990s (Lema, 1996) and the importance of quality management systems of suppliers was ranked quite highly in this research as well. Table 8.8 shows the quality accreditation required of suppliers by contractors. As evidenced from the table most of the contractors required their suppliers to be accredited to ISO 9000 or BS 5750 which are the same standard. Nevertheless, out of the total 35 responding contractors, 9, representing 25.7 per cent, demanded no accreditation to any quality standard of their suppliers. One explanation for this might be that these contractors have become satisfied with the quality performance of their suppliers.

These results point to emphasis on high quality in the supply of construction materials. The high number of contractors not emphasing that suppliers be accredited to any quality system also suggested that quality requirements were generally met.

Table 8.8: Quality standards contractors required their suppliers to adhere to

Quality accreditation required of suppliers by contractors	Frequency of responses	Percentage of contractors
ISO 9000	12	34.3
None	9	25.7
ISO 9000 or BS 5750	5	14.3
BS 5750	4	11.4
BS 5750 or Others	1	2.9
BS 5750 or None	1	2.9
ISO 9000 or Others	1	2.9
ISO 9000 or BS5750 or Others	1	2.9
Others	1	2.9
TOTAL	35	100

8.9 Extent of usage of logistics performance indicators and enablers

While it was essential to examine the importance UK contractors attached to both logistics performance indicators and enablers, it was also necessary to establish the extent to which they actually used or considered these factors in supplier evaluation and selection. Respondents were asked to indicate the extent to which they considered each of the performance indicators and enablers when evaluating suppliers. Using Equation 7.2 in Chapter 7, the frequency index for each of the factors was calculated to facilitate factor ranking.

8.9.1 Logistics performance indicators

Table 8.9 shows results of the extent to which responding contractors considered logistics performance indicators in supplier evaluation and selection.

All of the contractors, 100 per cent, indicated that reliability, cost-effectiveness, lead times and flexibility of suppliers were "Occasionally" to "Always " considered. The highest ranked performance indicators were cost-effectiveness and reliability of suppliers. Both had importance indices of 0.87 and joint factor rankings of 1. Both modal and median responses for cost-effectiveness were "Always" while the modal response for reliability was "Always" and its median response was "Very often".

Table 8.9: Extent contractors used logistics performance indicators in supplier evaluation and selection

Legend of response: 6= Always, 5=Very often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never
Combined responses: 3 to 6=Occaionally - Always, 2 to1=Rarely - Never

Factor		Combined responses		Responses						Total	Mode	Median	Importance index	Factor ranking
		3 to 6	2 to 1	6	5	4	3	2	1					
Cost-effectiveness	Frequency	35	0	18	7	9	1	0	0	35	6	6	0.87	1
	% of total	100	0	51.4	20	25.7	2.9	0	0	100				
Reliability of supplier	Frequency	35	0	17	10	7	1	0	0	35	6	5	0.87	1
	% of total	100	0	48.6	28.6	20	2.9	0	0	100				
Lead time quoted by supplier	Frequency	35	0	11	12	10	1	0	0	35	5	5	0.8	2
	% of total	100	0	32.4	35.3	29.4	2.9	0	0	100				
Flexibility of supplier	Frequency	35	0	7	6	17	5	0	0	35	4	4	0.73	3
	% of total	100	0	20	17.1	48.6	14.3	0	0	100				
Value-added service provided by supplier	Frequency	31	4	4	9	10	8	4	0	35	4	4	0.67	4
	% of total	88.6	11.4	11.4	25.7	28.6	22.9	11.4	0	100				

Lead time, with an importance index of 0.8 was the second most considered performance indicator, followed by flexibility which had an importance index of 0.73, in the third rank. Both modal and median responses for lead time were "Very often" and for flexibility both were "Often".

Value-added service was the lowest ranked performance indicator in fourth position. Its importance index was 0.67. Both modal and median responses for this indicator were "Often". Over 88 per cent of the respondents indicated that value-.added service was "Occasionally" to "Always" considered in supplier evaluation and selection

8.9.2 Logistics enablers

Table 8.10 shows the extent to which UK contractors used enablers in supplier evaluation and selection. Quoted prices of materials and long-term relationships were both ranked first as the most frequently considered enablers in supplier evaluation and selection. Both had frequency indices of 0.71. Both modal and median responses for quoted prices were "Very often" while for long-term relationships, the modal response was 'Very often' and the median response was 'Often'.

Capability and health and safety records of suppliers jointly occupied the second rank, having been assigned the frequency index of 0.68 and both modal and median responses of "Often" considered in supplier evaluation and selection.

Quality management systems of suppliers at a frequency index of 0.67 were ranked third in the level of frequency they were considered in supplier evaluation and selection, followed in the fourth position by location of suppliers in relation to projects which had a frequency index of 0.63, management and administrative ability in the sixth position with a frequency index of 0.56, and information and communication technologies in the seventh rank at a frequency index of 0.5.

Overall, over 62 per cent of respondents considered all identified enablers to be

Table 8.10: Extent contractors used enablers in supplier evaluation and selection

Legend of response modes: 6=always, 5=Very Often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never

Combined responses: 3 to 6= Occasionally to Always, 2 to1=Never to Rarely

Factors		Combined respon		Responses						Total	Mode	Median	Importance index	Factor ranking
		3 to 6	2 to 1	6	5	4	3	2	1					
Quoted price only	Frequency	32	3	6	12	6	8	2	1	35	5	5	0.71	1
	% of total	91.4	8.6	17.1	34.3	17.1	22.9	5.7	2.9	100				
Long-term relationships	Frequency	33	2	3	14	9	7	2	0	35	5	4	0.71	1
	% of total	94.3	5.7	8.6	40	25.7	20	5.7	0	100				
Capability (financial strength, production	Frequency	32	3	4	7	16	5	3	0	35	4	4	0 68	2
technology & efficiency, experience)	% of total	91.4	8.6	11.4	20	45.7	14.3	8.6	0	100				
Health and Safety records of suppliers	Frequency	30	5	7	8	8	7	3	2	35	4	4	0.68	2
	% of total	85.7	14.3	20	22.9	22.9	20	8 6	5.7	100				
Quality management systems	Frequency	31	4	4	8	11	8	4	0	35	4	4	0.67	3
	% of total	88.6	11.4	11.4	22.9	31.4	22.9	11.4	0	100				
Location of suppliers in relation to	Frequency	34	1	2	7	8	17	1	0	35	3	3	0.63	4
projects	% of total	97.2	2.8	5.7	20	22.9	48 6	2 8	0	100				
Management and administrative	Frequency	27	8	3	3	13	8	8	0	35	4	4	0.6	5
capability	% of total	77.1	22.9	8.6	8.6	37.1	22.9	22.9	0	100				
Environmental record s of suppliers	Frequency	27	8	2	8	4	13	6	2	35	3	3	0.56	6
	% of total	77.1	22.9	5.7	22.9	11.4	37.1	17.1	5.7	100				
Information and communication	Frequency	22	13	1	3	9	9	9	4	35	2***	3	0.5	7
technologies (bar codes, EDI, IDBMS, etc.)	% of total	62.9	37.1	2.9	8.6	25.7	25.7	25.7	11.4	100				

"Occasionally " to "Always " considered when evaluating and selecting materials suppliers.

8.10 Satisfaction with supplier evaluation systems

Figure 8.7 shows that 72 per cent of the contractors were satisfied with the supplier evaluation systems they used, 20 per cent were neutral, while 8 per cent were not satisfied. These results are likely biased towards satisfaction because the systems being assessed were those implemented by the contractors themselves.

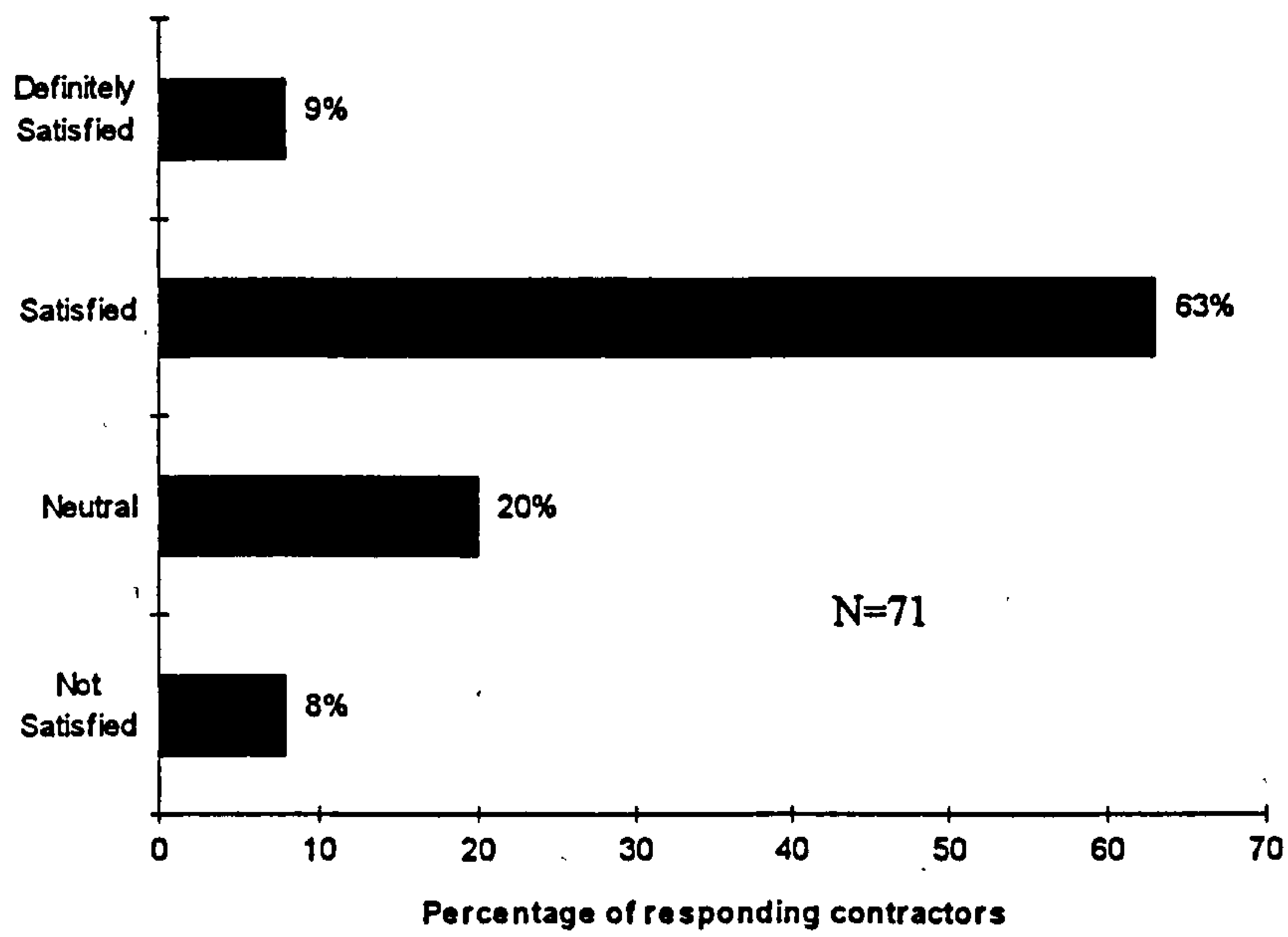


Figure 8.7: Level of satisfaction of contractors with their supplier evaluation systems

8.11 Materials management

The survey also identified and ascertained factors which can help to improve the supply of construction materials to support construction. Initially, respondents were asked to indicate how common problems identified from literature were in the UK construction industry. The analysis of responses of surveyed contractors is discussed in Section 8.11.1.

8.11.1 Problems in the supply of construction materials

In their research into implementation of total quality management in the Engineering and Construction industry in the USA, Oswald and Burati, Jr. (1992) noted a number of historically chronic supplier management problems in the construction industry. In this research, surveyed contractors were asked to indicate how common these problems were in the UK. Table 8.11 outlines the identified problems and summarises the responses of the UK contractors. The Occurrence Indices of the problems were calculated using Equation 7.3 of Chapter 7.

Respondents ranked late submission of drawings by suppliers as the most frequent problem with an occurrence index of 0.65. Both modal and median responses for this problem were "Common". Over 94 per cent of respondents acknowledged the frequency of occurrence of the problem to range between "Sometimes" and "Extremely Common".

Late deliveries, with an occurrence index of 0.61, was ranked second in frequency of occurrence, followed in third rank by incorrect supplier drawings with an occurrence index of 0.56 in fourth rank, poor quality and inadequate supplier control of lower tier suppliers both with an occurrence index of 0.52 in the fifth rank, no supplier quality assurance or quality management programmes with an occurrence index of 0.51 in the sixth rank, and lack of conformance to requirements with an occurrence index of 0.48 in the seventh and last rank. Both modal and median responses for these problems were "Sometimes".

Over 68 per cent of respondents indicated that the occurrence of these problems ranged from "Sometimes" to "Extremely Common". These problems originally identified in the USA construction industry are, thus, also prevalent in the UK construction industry.

Table 8.11: Frequency of occurrence of materials management related problems

Legend of response modes: 6=Extemely common, 5=Very common, 4=Common, 3=Sometimes, 2=Rare, 1=Never

Combined responses: 3 to 6 = Sometimes to Extremely Common, 2 to 1 = Rare to Never

Materials management related problems		Combined responses		Responses						Total	Mode	Media	Frequency ndex	Ranking
		3 to 6	2 to 1	6	5	4	3	2	1					
Late supplier drawings	Frequency	33	2	1	10	12	10	2	0	35	4	4	0.65	1
	% of total	94.3	5.7	2.8	28.6	34.3	28.6	5.7	0	100				
Late deliveries	Frequency	33	2	2	4	11	16	2	0	35	3	3	0.61	2
	% of total	94.3	5.7	5.7	11.4	31.4	45.7	5.7	0	100				
Incorrect supplier drawings	Frequency	32	3	1	5	10	16	3	0	35	3	3	0.6	3
	% of total	91.4	8.6	2.8	14.3	28.6	45.7	8.6	0	100				
Poor communication	Frequency	30	5	0	4	9	17	5	0	35	3	3	0.56	4
	% of total	85.7	14.3	0	11.4	25.7	48.6	14.3	0	100				
Poor quality	Frequency	30	5	0	3	4	23	5	0	35	3	3	0.52	5
	% of total	85.7	14.3	0	8.6	11.4	65.7	14.3	0	100				
Inadequate supplier control of lower-tier suppliers	Frequency	26	9	0	2	9	15	9	0	35	3	3	0.52	5
	% of total	74.3	25.7	0	5.7	25.7	42.9	25.7	0	100				
No supplier quality assurance or quality programmes	Frequency	26	9	0	1	9	16	9	0	35	3	3	0.51	6
	% of total	74.3	25.7	0	2.9	25.7	45.7	25.7	0	100				
Lack of conformance to requirements	Frequency	24	11	0	1	6	17	11	0	35	3	3	0.48	7
	% of total	68.6	31.4	0	2.9	17.1	48.6	31.4	0	100				

8.11.2 Importance attached to materials management practices

Table 8.12 shows summarised responses of the importance responding contractors attached to various materials management practices to support construction. Importance indices were calculated from the responses, using Equation 7.1 of Chapter 7, for purposes of rank ordering the practices in order of perceived importance attached to them by the respondent contractors.

Materials planning by site staff, assigned an importance index of 0.87 was ranked the most important materials management practice to support construction followed by selection of suppliers by contractors with an importance index of 0.84 in the second rank, and management capability of site personnel with an importance index of 0.82 in the third rank.

Customer service levels provided by suppliers, improving contractor-supplier relationships, and improving communication between administrative offices of contractors and suppliers all with importance indices of 0.8 were ranked fourth in importance. Communication between sites and suppliers had an importance index of 0.79 and was ranked fifth in importance.

All the practices so far mentioned received both modal and median responses of "Considerable Importance".

Early payment of suppliers for delivered materials received an importance index of 0.64 and was ranked sixth in importance. The modal response for this practice was "Average Importance" and it received a median response between "Average Importance" and "Considerable Importance".

Stationing a materials manager on site by contractors received an importance index of 0.6, both modal and median responses of "Average Importance" and was ranked seventh in importance.

Table 8.12: Importance contractors attached to materials management practices

Legend of response modes: 5=Exterme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance
Combined responses: 3 to 5 = Average Importance to Extreme Importance, 2 to 1 = Little Importance to No Importance

Practices		Combined responses		Responses					Total	Mode	Median	Importance index	Ranking
		3 to 5	2 to 1	5	4	3	2	1					
Materials planning by site staff	Frequency	34	1	16	17	1	1	0	35	4	4	0.87	1
	% of total	97.2	2.8	45.7	48.6	2.9	2.9	0	100				
Selection of suppliers by	Frequency	35	0	9	24	2	0	0	35	4	4	0.84	2
contractors	% of total	100	0	25.7	68.6	5.7	0	0	100				
Management capability of site	Frequency	35	0	7	26	2	0	0	35	4	4	0.82	3
personnel	% of total	35	0	20	74.3	5.7	0	0	100				
Customer service levels provided	Frequency	35	0	8	19	8	0	0	35	4	4	0.8	4
by suppliers	% of total	100	0	22.9	54.3	22.9	0	0	100				
Improving relationships with suppliers	Frequency	35	0	7	21	7	0	0	35	4	4	0.8	4
	% of total	100	0	20	60	20	0	0	100				
Communication between Head	Frequency	34	1	9	18	7	1	0	35	4	4	0.8	4
Office and suppliers	% of total	97.1	2.9	25.7	51.4	20	2.9	0	100				
Communications between site	Frequency	33	2	9	18	6	1	1	35	4	4	0.79	5
and suppliers	% of total	94.2	5.8	25.7	51.4	17.1	2.9	2.9	100				
Early payment of suppliers for	Frequency	30	5	3	6	21	5	0	35	3	3.5	0.64	6
delivered materials	% of total	85.7	14.3	8.6	17.1	60	14.3	0	100				
Stationing a materials manager	Frequency	24	11	0	11	13	11	0	35	3	3	0.6	7
on site by contractors	% of total	68.6	31.4	0	31.4	37.2	31.4	0	100				
Use of Information and	Frequency	13	22	0	1	11	14	8	34	2	2	0.43	8
communication technologies like	% of total	35.3	64.7	0	2.9	32.4	41.2	23.5	100				
bar codes, EDI, DMBS													

Use of information and communication technologies such as bar codes, EDI and DBMS was considered the least important practice. It received an importance index of 0.43, both modal and median responses of "Little Importance" and was assigned the eighth and last rank. Over 64 per cent of respondents considered use of information and communication technologies in materials management to be of 'Little Importance' to 'No Importance' in contributing to efficiency in the supply of construction materials.

With the exception of the use of information and communication technologies, over 68 per cent of respondents considered the importance of all the other identified practices in improving the supply of materials to support construction to range from "Average Importance" to "Extreme Importance".

8.11.3 Individuals responsible for site control of materials

In Section 8.9.2, respondents suggested that materials planning by site staff and management capability of site personnel were among the most important approaches that could help in improving performance in the supply of construction materials. Respondents were asked to indicate the title of the individual responsible for controlling materials on construction sites run by their companies.

Table 8.13 shows that 60 per cent of the companies exclusively used site managers to control materials on construction sites while a further 17.4 per cent indicated that they also sometimes used site managers though not exclusively.

Table 8.13: Titles of individuals responsible for materials on construction sites

Title	Frequency response	Percentage response
Site manager	21	60.0
General foreman	2	5.7
General foreman/Site manager	1	2.9
Site engineer	1	2.9
Site engineer/ General foreman/Site manager	1	2.9
Site engineer/ Foreman	1	2.9
Material manager	1	2.9
Storeperson	1	2.9
Storeperson/ Site manager	1	2.9
Storeperson/Foreman/ General foreman/	1	2.9
Storeperson/Site engineer/ Foreman/Site manager	1	2.9
Storeperson/Material manager/ Other	1	2.9
Storeperson/Material manager/Foreman/General foreman/Site manager	1	2.9
Storeperson/ Materials manager/Site manager	1	2.9

8.12 Summary

Chapter 8 analysed responses of responding contractors to the questionnaire and open-ended interviews on materials supply logistics practices in the UK construction industry.

Evidence from the surveyed UK contractors predominantly pointed to existence of islands of automation, mainly internally integrated by database management systems with little electronic bridging between contractors, suppliers and construction sites. The main media contractors used in communicating with suppliers and their construction sites were the telephone, facsimile and the post.

The majority of contractors described their relationships with suppliers as close and their responses to statements about contractor-supplier relationships also supported this. They, nevertheless, still used bidding to select suppliers. The survey revealed that most of the contractors had a combination of different types of relationships with their suppliers ranging from arms' length trading, non-partnering long-term trading, short-term project partnering, long-term partnering, to partnerships.

The importance of logistics performance indicators and enablers and the extent to which these were considered by contractors in the evaluation and selection of suppliers were rank-ordered. The importance contractors attached to various materials management practices to support construction was also analysed and discussed.

In Chapter 10, results of this chapter are compared with those of suppliers in Chapter 9 to determine group differences in responses of contractors and suppliers. In Chapter 11, the identified logistics performance indicators and enablers will be evaluated by both contractors and suppliers using the analytic hierarchy process to determine the extent to which they contribute to improvements in customer service in the supply of construction materials.

CHAPTER NINE

ANALYSIS OF CONTRACTOR QUESTIONNAIRE AND OPEN-ENDED INTERVIEW QUESTION RESULTS

CHAPTER NINE

ANALYSIS OF SUPPLIER QUESTIONNAIRE AND OPEN-ENDED INTERVIEW QUESTION RESULTS

9.1 Introduction

Results of responses to the questionnaire sent to contractors were analysed in Chapter 8. This chapter presents analysis of responses to the self-administered questionnaires sent to construction materials suppliers. Analysis of responses of five suppliers to the open ended interview questions in the second phase of the research programme has also been presented. The chapter is in five sections. Section 9.2 discusses independent variables - data on types of surveyed supplier organisations and responding individuals. Section 9.2 assesses whether the respondents had the right background to provide the required information. Sections 9.3, 9.4, 9.5, 9.6 and 9.7 and their sub-sections discuss suppliers' responses to dependent variables which include the use of information and communication technologies, contractor-supplier relationships, perceived importance of logistics factors, the extent to which contractors considered the logistics factors in supplier evaluation and selection and the importance suppliers attached to various materials management practices to support construction. Complementary in-depth data on information and communication technologies and contractor-supplier relationships from the interviews phase of data collection has also been analysed in their respective sections in this chapter. In Chapter 10, the responses of suppliers in this chapter are compared with those of contractors in Chapter 8 in order to determine differences in practices in construction materials logistics between the two groups.

9.2 Independent variables

Independent variables comprised data on types of respondents and surveyed supplier organisations. The analysis of surveyed organisations provide the various categories of responding suppliers. Analysis of types of respondents identified company functions of individuals that responded as an assessment of whether they had the right experience to complete the questionnaires on construction materials logistics.

9.2.1 Types of surveyed supplier organisations

Figure 9.1 shows the percentage breakdown of types of organisations which responded to the supplier questionnaire. From the total sample of 30 companies: three per cent were in manufacturing, supplying and subcontracting; three per cent in manufacturing and supplying; seven per cent in supplying and subcontracting; ten per cent in subcontracting; and 77 per cent in supplying. The purpose of this study was to identify elements that can lead to improvements in the supply of construction materials. Thus, responses of the surveyed suppliers had a bias towards experiences of companies involved mainly in the supply of construction materials as opposed to sub-contracting.

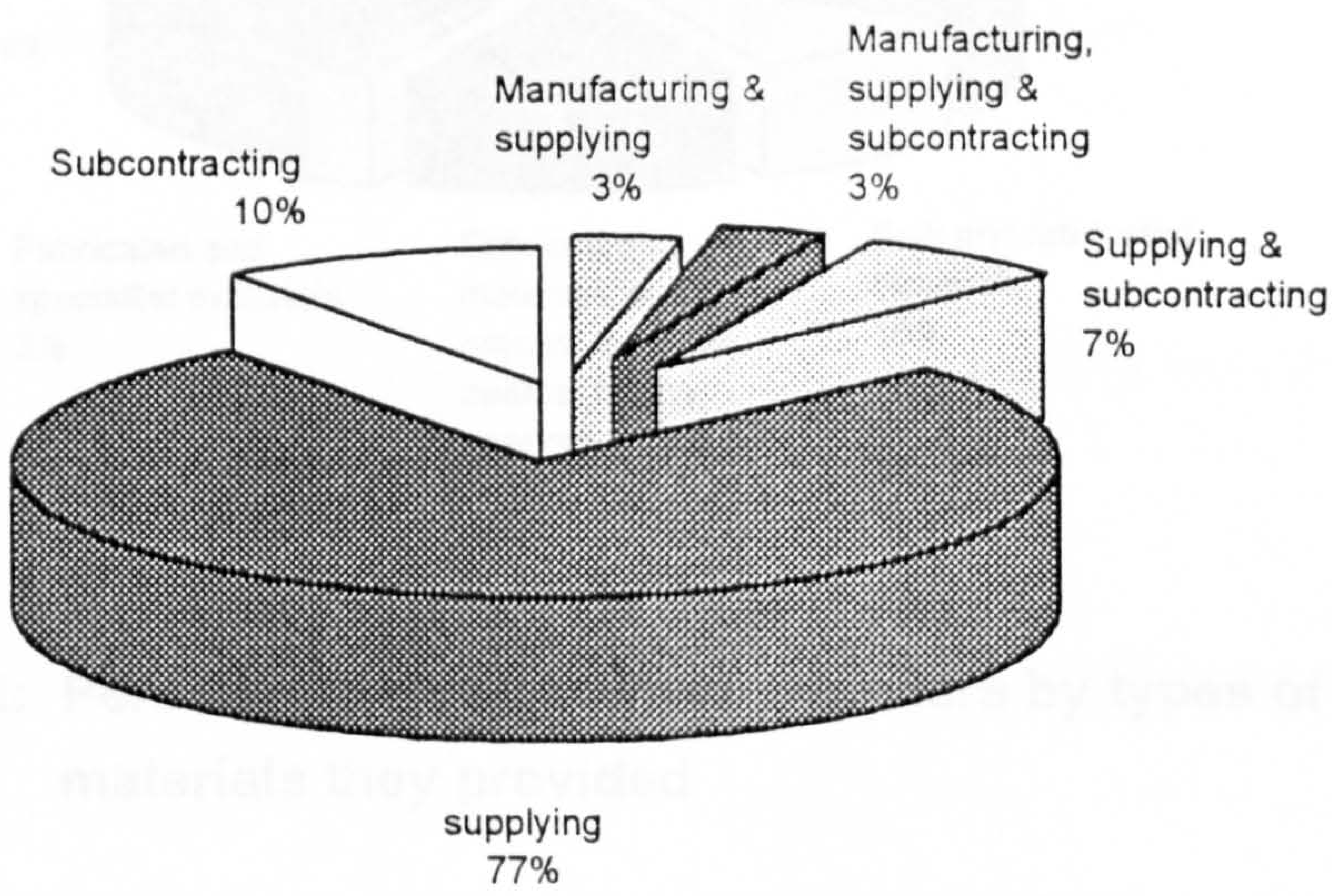


Figure 9.1: Percentage breakdown of suppliers by type of responding supplier organisation

To further describe the types of supplier organisations, various types of materials supplied by the responding companies were identified. The frequency distribution of types of materials dealt in by the companies is shown in Figure 9.2. Companies which supplied bulk materials represented 34 per cent of the total sample; those that supplied specialist materials accounted for 27 per cent; and fabricated materials suppliers accounted for 13 per cent. Companies which supplied both bulk and fabricated materials represented 10 per cent, while those that supplied both specialist and fabricated materials accounted for three per cent of the responses. The remaining companies, categorised under 'Others' accounted for 13 per cent of the respondents. Companies within the 'Others' category did not fit into any of the categories discussed earlier. The percentage breakdown of the various materials supplied by the surveyed organisations represent a wide range of products supplied to the construction industry. Thus, responses of respondent organisations covered practices over a wide spectrum of products supplied to the UK construction industry.

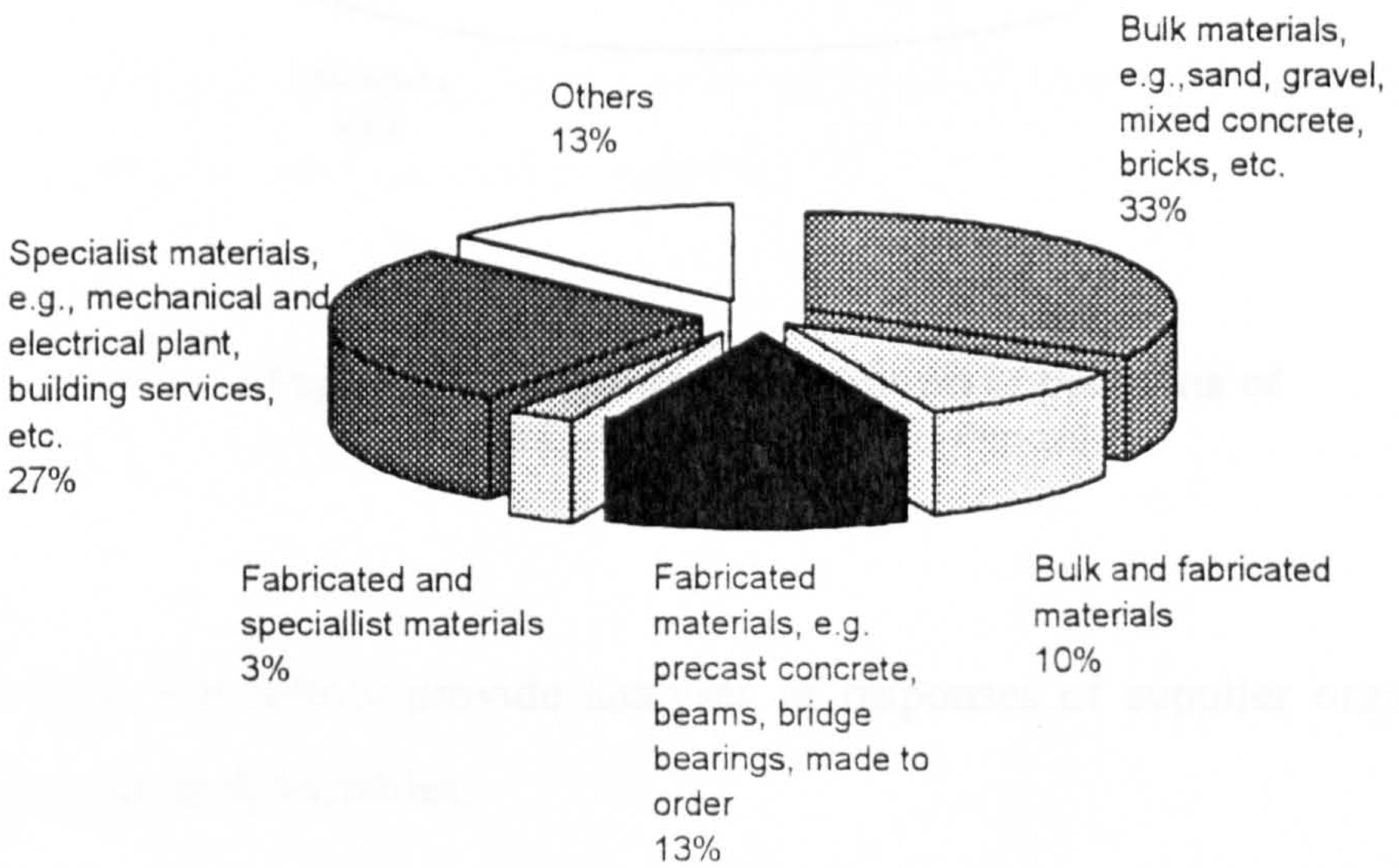


Figure 9.2: Percentage breakdown of suppliers by types of materials they provided

9.2.2 Types of responding individuals

Respondents to the supplier questionnaire were from sales, marketing, customer services and general administration. Appendix C gives specific designations of the respondents from each of the responding surveyed company. Positions of respondents in their companies ranged from general assistant to director. Figure 9.3 gives percentage breakdowns of broad respondent categories by position in companies. Directors completed 36.7 per cent of received usable questionnaires, managers 43.3 per cent and others 20 per cent. The category 'Others' included respondents neither in the 'Manager' nor 'Director' categories. Categories of respondents reflected a bias towards senior management, suggesting responses were from individuals who had broad knowledge of issues asked in the dependent variables section of the questionnaire.

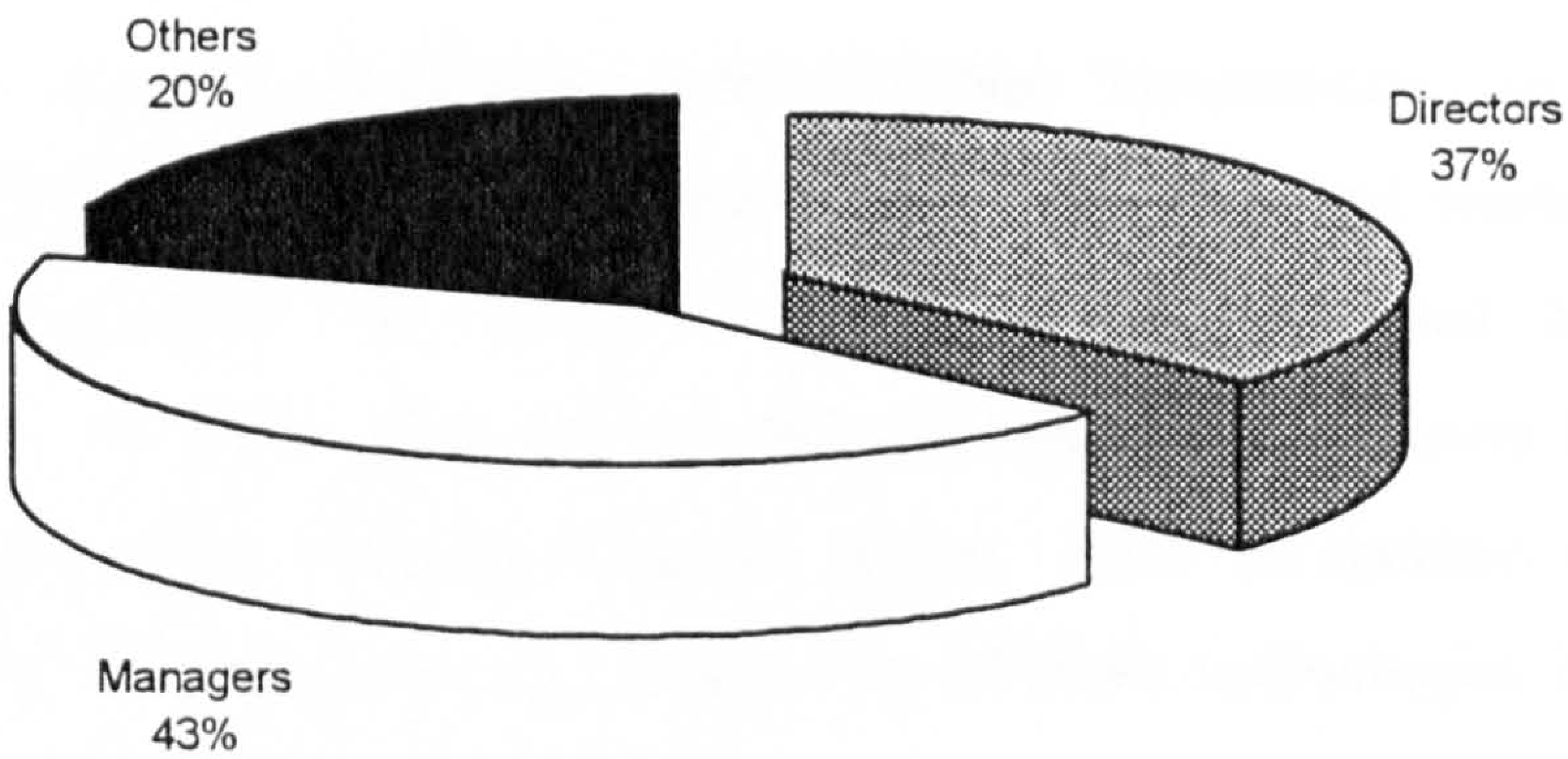


Figure 9.3: Percentage breakdown of positions of respondents in their companies

The sections that follow provide analyses of responses of supplier organisations to dependent research variables.

9.3 Use of ICTs in materials management by construction materials suppliers.

Information and communication technologies were examined in terms of their usage by suppliers in three respects: internal materials management processes; materials management processes between administrative offices of contractors and construction sites; and between contractors and suppliers.

9.3.1 Usage in internal materials management processes

Table 9.1 exhibits the extent to which the surveyed suppliers used information and communication technologies in internal materials management processes.

Integrated database management systems were the most frequently used in internal materials management systems, followed by electronic mail in the second place, electronic data interchange in the third place, bar codes in the fourth place, electronic document imaging in the fifth place, magnetic stripes and voice recognition both in the sixth position, and radio frequency tagging in the seventh and last position.

More than 60 per cent of the suppliers reported that they "Occasionally" to "Always" used IDBMS, whereas 43.4 per cent used both electronic mail and electronic data interchange "Occasionally" to "Always" and 23.3 per cent used bar codes "Occasionally" to "Always". Over 80 per cent of the surveyed suppliers had never used electronic document imaging, magnetic stripes, voice recognition and radio frequency tagging, reflecting very low usage rates of these technologies in internal materials management processes of suppliers.

Table 9.1: Extent suppliers used ICTs in internal materials management processes

Response modes	Information and Communication Technologies															
1=Never 2=Rarely 3=Occasionally 4=Often 5=Very Often 6=Always	Integrated Database Management Systems		Electronic mail		Electronic Data Interchange		Bar codes		Electronic Document Imaging		Magnetic Stripes		Voice Recognition		Radio Frequency Tagging	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
1	11	36.7	13	43.3	16	53.3	21	70.0	24	80.0	28	93.3	28	93.3	29	96.7
2	0	0.0	4	13.3	1	3.3	2	6.7	1	3.3	0	0.0	1	3.3	0	0.0
3	3	10.0	6	20.0	7	23.3	2	6.7	3	10.0	2	6.7	0	0.0	1	3.3
4	2	6.6	3	10.0	2	6.7	1	3.3	0	0.0	0	0.0	0	0.0	0	0.0
5	3	10.0	4	13.3	4	13.3	2	6.7	2	6.7	0	0.0	1	3.3	0	0.0
6	11	36.7	0	0.0	0	0.0	2	6.7	0	0.0	0	0.0	0	0.0	0	0.0
Valid (Totals & %)	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**
2-1(Rarely-Never)	11	36.7	17	56.6	17	56.6	23	76.7	25	83.3	28	93.3	29	96.7	29	96.7
3-6(Occasionally-Always)	19	63.3	13	43.4	13	43.4	7	23.3	5	16.7	2	6.7	1	3.3	1	3.3
Usage Index (UI)	0.6		0.39		0.37		0.32		0.25		0.19		0.19		0.18	
Usage Ranking (UR)	1		2		3		4		5		6		6		7	

9.3.2 Materials logistics between suppliers and sites

Table 9.2 shows that the most commonly used information and communication technologies and methods between surveyed suppliers and construction sites were the telephone, the facsimile and the post in that order. Over 85 per cent of respondents indicated that these were "Occasionally" to "Always" used. Of all the suppliers, 66.7 per cent, 70 per cent and 63.3 per cent of the respondent companies had 'Never' used IDBMS, EDI and electronic mail respectively in materials logistics processes between their organisations and construction sites.

9.3.3 Materials logistics between suppliers and contractors

For materials management processes between suppliers and contractors, the most used information and communication technology was the facsimile, followed by the post and then the telephone in the third place. Over 90 per cent of the suppliers "Occasionally" to "Always" used these technologies in materials management processes. On the other hand, the usage rates of IDBMS, bar codes, electronic mail and EDI in materials supply logistics activities between suppliers and contractors were very low. Over 70 per cent of the respondents indicated that their organisations had used these technologies "Rarely" to "Never".

Table 9.2: Extent of usage of ICTs in materials management between suppliers and construction sites

Response modes	Information and communication technologies and methods											
1=Never 2=Rarely 3=Occasionally 4=Often 5=Very Often 6=Always	Telephone		Facsimile		Post		Integrated Database Management Systems		Electronic mail		Electronic Data Interchange	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
1	1	3.3	2	6.7	3	10.0	20	66.7	19	63.3	21	70.0
2	0	0.0	0	0.0	1	3.3	0	0.0	4	13.3	5	16.7
3	0	0.0	0	0.0	2	6.7	2	6.7	4	13.3	2	6.7
4	1	3.3	3	10.0	3	10.0	3	10.0	2	6.7	1	3.3
5	15	50.0	18	60.0	11	36.7	1	3.3	1	3.3	0	0.0
6	13	43.3	7	23.3	10	33.3	4	13.3	0	0.0	1	3.3
Valid (Totals & %)	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**	**30**	**100.0**
2-1 (Rarely-Never)	1	3.3	2	6.7	4	13.3	20	66.7	23	76.7	26	86.7
3-6 (Occasionally-Always)	29	96.7	28	93.3	26	86.7	10	33.3	7	23.3	4	13.3
Usage Index (UI)	0.89		0.81		0.77		0.37		0.29		0.26	
Usage Ranking (UR)	1		2		3		4		5		6	

Table 9.3: Extent of usage of ICTs in construction materials management between suppliers and contractors

Response modes	Information and communication technologies and methods													
1=Never 2=Rarely 3=Occasionally 4=Often 5=Very Often 6=Always	Facsimile		Post		Telephone		Integrated Database Management Systems		Bar codes		Electronic mail		Electronic Data Interchange	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
1	1	3.3	1	3.3	1	3.3	20	66.7	21	70.0	17	56.7	21	70.0
2	0	0.0	0	0.0	1	3.3	2	6.7	2	6.6	5	16.7	4	13.3
3	0	0.0	4	13.3	1	3.3	0	0.0	2	6.7	5	16.6	4	13.4
4	2	6.7	3	10.0	5	16.7	1	3.3	1	3.3	2	6.7	0	0.0
5	15	50.0	8	26.7	11	36.7	1	3.3	2	6.7	0	0.0	0	0.0
6	12	40.0	14	46.7	11	36.7	6	20.0	2	6.7	1	3.3	1	3.3
Valid total	30	100.0	30	100.0	30	100.0	30	100.0	30	100.0	30	100.0	30	100.0
2-1 (Rarely-Never)	1	3.3	1	3.3	2	6.6	22	73.4	23	76.6	22	73.4	25	73.3
3-6 (Occasionally-Alway	29	96.7	29	96.7	28	93.4	8	26.6	7	23.4	8	26.6	5	16.7
Usage Index (UI)	0.84		0.83		0.82		0.38		0.32		0.31		0.26	
Usage Ranking (UR)	1		2		3		4		5		6		7	

9.3.4 Analysis of suppliers' responses to open-ended interview questions

Open-ended questions during interviews with five suppliers in the second phase of the research developed further insight into the implementation of information and communication technologies by the interviewed companies. Their responses to the questions are analysed below.

9.3.4.1 Benefits from ICTs in materials management processes

In order of the most frequently mentioned, the following were the benefits that the suppliers said they had experienced from implementation of information and communication technologies:

- of the five companies interviewed, four said they had experienced cost reduction;
- three of the five companies had experienced time savings and improved customer service as a result of accurate management information resulting from the use of information and communication technologies; and
- one company stated that information technology had enabled it to tie its customers to its business, giving it an edge in the market place.

9.3.4.2 Obstacles to introduction of ICTs in materials supply logistics

The following were cited as factors which hindered introduction of information and communication technologies in materials management and physical distribution processes in interviewed supplier organisations:

- three companies from the interviewed five stated that required internal re-organisations and the scale of the operation needed to introduce information and communication technologies was a major hindrance to implementation of ICTs; and
- one company cited inability to see any major benefits from the high cost of the technology as a reason it could not justify expenditure on the technology.

9.3.4.3 General comments on implementation of ICTs in materials supply logistics

Nearly all the suppliers, four of the interviewed five, stated that the industry had historically failed to keep up with developments in information and communication technologies in the past, resulting in fewer companies having explored the possibilities of using ICTs and fewer having taken advantage of the technology. The interviewees were, however, aware that the industry was changing very fast in its implementation and usage of information technology.

9.4 Contractor-supplier relationships

Table 9.4 displays summarised results of suppliers' responses to questionnaire statements about their relationships with contractors. Each of the statements is analysed separately.

Contractors know which of their suppliers are vital to their business

Of the total surveyed suppliers, 83.4 per cent (25) "Slightly" to "Strongly" agreed that contractors knew which of their suppliers were vital to their businesses. Both modal and median responses to this statement were "Agree".

Contractors buy on the basis of lowest price alone

Suppliers were equally divided in their opinions to the statement that contractors buy on the basis of lowest price alone. While 46.7 per cent (14) of the respondents agreed with the statement, another 46.7 per cent (14) expressed disagreement, and 6.6 per cent (2) were "Neutral". The modal response for the statement was "Slightly Agree" and the median response was "Neutral".

Table 9.4: Contractor - Supplier relationships

Legend of response modes: Agree (5 to 7), Neutral (4), Disagree (3 to 1)
where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree

Practice		Combined responses			Responses							Total	Mode	Median
		Agree	Neutral	Disagree	7	6	5	4	3	2	1			
Knowledge: Contractors know which of their suppliers are vital to their businesses	Frequency	25	4	1	6	10	9	4	0	1	0	30	6	6
	% of total	83.4	13.3	3.3	20	33.4	30	13.3	0	3.3	0	100		
Purchasing policy: Contractors buy on the basis of lowest price alone	Frequency	14	2	14	2	2	10	2	6	8	0	30	5	4
	% of total	46.7	6.6	46.7	6.7	6.7	33.3	6.6	20	26.7	0	100		
Contractors try to reduce the number of suppliers to a minimum	Frequency	16	6	8	0	6	10	6	5	3	0	30	5	5
	% of total	53.3	20	26.7	0	20	33.3	20	16.7	10	0	100		
Relationships: To obtain the best deal, contractors change their suppliers frequently	Frequency	13	4	13	0	9	4	4	8	5	0	30	6	4
	% of total	43.3	13.3	43.4	0	30	13.3	13.3	26.7	16.7	0	100		
Contractors attempt to obtain mutual beneficial relationships with their suppliers	Frequency	19	3	8	1	11	7	3	3	4	1	30	6	5
	% of total	63.3	10	26.7	3.3	36.7	23.3	10	10	13.4	3.3	100		
Contractors seek to obtain a unique advantage over their competitors though their relationships with their suppliers	Frequency	23	4	3	1	10	12	4	3	0	0	30	5	5
	% of total	76.6	13.3	10	3.3	33.4	40	13.3	10	0	0	100		
Contractors do not believe that sharing their strategic plans with their suppliers is in their best interests	Frequency	11	15	4	0	7	4	15	3	1	0	30	4	4
	% of total	36.7	50	13.3	0	23.4	13.3	50	10	3.3	0	100		
Contractors give feedback to suppliers on delivery performance	Frequency	15	1	14	0	5	10	1	6	6	2	30	5	4.5
	% of total	50	3.3	46.7	0	16.7	33.3	3.3	20	20	6.7	100		

Table 9.4: Contractor - supplier relationships....*continued*

Legend of response modes: Agree (5 to 7), Neutral (4), Disagree (3 to 1)
where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree

Practice		Combined responses			Responses							Total	Mode	Median
		Agree	Neutral	Disagree	7	6	5	4	3	2	1			
Contractors expect their potential	Frequency	22	2	6	4	14	4	2	2	4	0	30	6	6
suppliers to deliver exactly what	% of total	73.3	6.7	20	13.3	46.7	13.3	6.7	6.7	13.3	0	100		
they specify without question														
Contractors check every delivery - it is the	Frequency	8	7	15	1	4	3	7	6	7	2	30	2	3.5
only way to ensure consistent quality	% of total	26.7	23.3	50	3.3	13.4	10	23.3	20	23.3	6.7	100		
Our commitment is always	Frequency	25	5	0	4	16	5	5	0	0	0	30	6	6
sought to achieve project	% of total	83.3	16.7	0	13.3	53.3	16.7	16.7	0	0	0	100		
delivery goals of cost, time														
and quality														
We always get involved during	Frequency	13	9	8	2	9	2	9	1	6	1	30	4	4
development of project goals	% of total	43.4	30	26.6	6.7	30	6.7	30	3.3	20	3.3	100		
at the tendering stage														
Communication between us and	Frequency	20	5	5	2	7	11	5	3	2	0	30	5	5
contractors is open, honest and based on	% of total	66.6	16.7	16.7	6.6	23.3	36.7	16.7	10	6.7	0	100		
based on mutual respect														
There is trust in the sharing of	Frequency	19	6	5	2	8	9	6	3	2	0	30	5	5
project information between us	% of total	63.4	20	16.6	6.7	26.7	30	20	10	6.6	0	100		
and contractors														
We are always given ample time to	Frequency	5	5	20	1	0	4	5	5	11	4	30	2	2.5
to prepare quotations where we	% of total	16.6	16.7	66.7	3.3	0	13.3	16.7	16.7	36.7	13.3	100		
bid to supply materials														
We get paid in time for	Frequency	6	7	17	0	1	5	7	1	8	8	30	1	2
materials already delivered	% of total	20	23.3	56.7	0	3.3	16.7	23.3	3.3	26.7	26.7	100		

Contractors try to reduce the number of their suppliers to a minimum

A slight majority, 53.3 per cent (16) agreed with the statement that contractors try to reduce the number of suppliers to a minimum, as opposed to 26.7 per cent (8) who disagreed and 20 per cent (6) who were "Neutral". Both modal and median responses to the statement were "Neutral".

To obtain the best deal, contractors change their suppliers frequently

Suppliers were divided in their opinions over the statement that to obtain the best deal, contractors change their suppliers frequently, with 43.3 per cent (13) agreeing, 13.3 per cent (4) neutral and 43.3 per cent (13) disagreeing with the statement. While the modal response to the statement was "Agree", the median response was "Neutral".

Contractors attempt to obtain mutual beneficial relationships with their suppliers

The statement that contractors attempt to obtain mutual beneficial relationships with their suppliers received a modal response of "Agree" and a median response of "Slightly Agree", with 63.3 per cent of the suppliers expressing agreement between "Slightly Agree" and "Strongly Agree".

Contractors seek to obtain a unique advantage over their competitors through their relationships with their suppliers

The majority of the suppliers agreed with the statement that contractors seek a unique advantage over their competitors through their relationships with their suppliers. Twenty three, 76.6 per cent, of the respondents "Slightly" to "Strongly" agreed with the statement. Three, representing 10 per cent, slightly disagreed with the statement, while 13.3 per cent (4) were neutral. Both modal and median responses to this statement were "Slightly Agree".

Contractors do not believe that sharing their strategic plans with their suppliers is in their best interests

The majority of the suppliers, 50 per cent (15), were neutral to the statement that contractors do not believe that sharing their strategic plans with their suppliers is in their best interests. Only 36.7 per cent (11) of the companies agreed with the statement. Four, representing 13.3 per cent, disagreed. Both modal and median responses to the statement were "Neutral".

Contractors give feedback to suppliers on delivery performance

Fifty per cent (15) of the respondents expressed agreement between "Slightly Agree" to "Agree" to the statement that contractors give feedback to suppliers on their delivery performance. About the same number, 14 representing 46.7 per cent of the respondents "Slightly" to "Strongly" disagreed with the statement. Only 3.3 per cent (1) were "Neutral".

Contractors expect their potential suppliers to deliver exactly what they specify without question

Twenty-two, representing 73.3 per cent of respondents "Slightly" to "Strongly" agreed with the statement that contractors expect their potential suppliers to deliver exactly what they specify without question. Only 6.7 per cent (2) were "Neutral" and 20 per cent (6) expressed disagreement with the statement. Both modal and median responses to the statement were "Agree".

Contractors check every delivery - it is the only way to ensure consistent quality

Among suppliers, 50 per cent (15) of the respondents "Slightly" to "Strongly" disagreed with the statement that contractors checked every delivery as the only way of ensuring consistent quality. The statement received a modal response of "Disagree" and a median response between "Neutral" and "Slightly Disagree". Only 26.7 per cent (8) were in agreement with the statement, while 23.3 per cent (7) were "Neutral".

The commitment of suppliers is always sought to achieve project delivery goals of cost, time and quality

The majority of the suppliers, 83.3 per cent (25) agreed with the statement that their commitment is always sought to achieve project delivery goals of cost, time and quality. None of the companies disagreed with the statement. Only 16.7 per cent (5) were "Neutral". Both modal and median responses to the statement were "Agree".

Suppliers always get involved during project development goals at the tendering stage

Both modal and median responses to the statement that suppliers always get involved during development of project goals at the tendering stage were "Neutral". Thirty per cent (9) of the respondents expressed neutrality to the statement, 43.4 per cent (13) agreed and 26.6 per cent (8) disagreed with the statement.

Communication between suppliers and contractors is open, honest and based on mutual respect

There was general agreement to the statement that communication between suppliers and contractors is open, honest and based on mutual respect with 66.6 per cent (20) of surveyed suppliers registering agreement in the range 'Slightly Agree' and 'Strongly Agree'. Both modal and median responses were at 'Slightly Agree'.

There is trust in the sharing of project information between suppliers and contractors

Both modal and median responses were at 'Slightly Agree' to the statement that there is trust in the sharing of project information between suppliers and contractors, with 63.4 per cent (19) of the respondents registering agreement to the statement in the range 'Slightly Agree' to 'Strongly Agree'.

Suppliers are always given ample time to prepare quotations when bidding to supply materials

The majority of suppliers disagreed with the statement that they are always given ample time to prepare quotations where they bid to supply materials, with 66.7 per cent of the respondents expressing disagreement with the statement in the range 'Slightly Disagree' to 'Strongly Disagree'. Both modal and median responses were at 'Disagree'.

Suppliers get paid in time for materials already delivered

Among the suppliers, 56.7 per cent of respondents expressed disagreement with the statement that suppliers get paid in time for materials already delivered. Modal response to the statement was at 'Strongly Disagree' and the median response was 'Disagree'. Only 20 per cent (6) agreed with the statement while the remaining 23.3 per cent (7) were neutral.

9.5 Supplier shortlists and types of contractor-supplier relationships

Responses from suppliers revealed that 90 per cent (27) of them had their names on contractors' lists of preferred suppliers and the remaining 10 per cent (3) were not on contractors' lists of preferred suppliers. These results are supported by the analysis in Figure 9.4 which shows a breakdown of suppliers' descriptions of their relationships

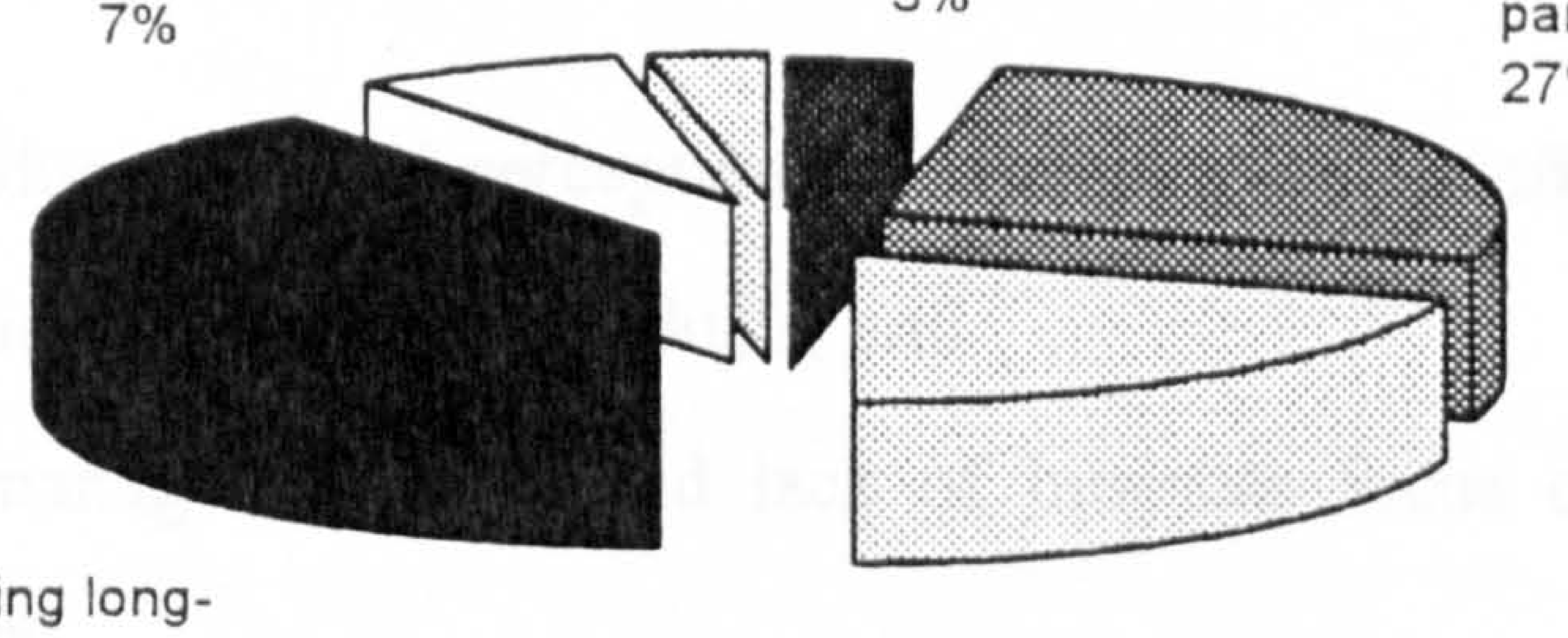


Figure 9.4: Descriptions of suppliers' relationships with contractors

with contractors. Of the total number responding, 10 per cent described their relationships with contractors as arms-length (7 per cent arms-length relationships, three per cent arms-length and non-partnering long-term relationships). All the other suppliers (90 per cent) described their relationships with contractors as close. The suppliers with close relationships with contractors were categorised into: 40 per cent non- partnering long-term trading relationship, 20 per cent short-term project partnering, 27 per cent long-term partnering and 3 per cent partnerships.

9.6 Analysis of open-ended questions on contractor-supplier relationships

To develop further insight into the nature of contractor-supplier relationships, more details were elicited from five suppliers about their relationships with contractors via interviews involving open-ended questions in the second phase of the research programme. Analysis of their responses is provided in the sections that follow.

9.6.1 Obstacles to formation of long-term contractor-supplier relationships

The five interviewed suppliers identified the following factors to hinder formation of long-term relationships with contractors:

- lack of trust resulting from fear that long-term partnering leads to higher prices, thus competition pricing or tendering is seen by contractors as a way of keeping prices down;
- lack of willingness due to limited perception by contractors of benefits to them;
- availability or location of suppliers' products; and
- non-allocation of management time and lack of business focus on the part of suppliers themselves.

Despite these obstacles, the interviewed individuals acknowledged that the tradition of adversarial relationships between contractors and suppliers had begun to change for the better.

9.6.2 Benefits derived from long-term relationships with contractors

Interviewed suppliers acknowledged experiencing the following benefits from long-term relationships with contractors, such as partnering:

- more secure turn-over and profits resulting from continued business as preferred suppliers;

- improved ability to negotiate business deals with contractors;
- better demand prediction;
- greater knowledge and understanding;
- improved payment periods; and
- reduced costs for contractors.

9.6.3 Ways suppliers received feedback on their delivery performance

Interviewed suppliers responded that they received feedback on delivery performance through the following ways:

- customer satisfaction surveys;
- contractors' supplier appraisal systems;
- self-monitoring of delivery performance;
- verbal complaints;
- telemarketing;
- through day-to-day personal contact; and
- continuous appraisal.

9.6.4 General comments about contractor-supplier-relationships

The interviewed suppliers gave varied responses about contractor-supplier relationships. While two of the companies saw their relationships with contractors as generally good, the remaining three did not. One company said contractor-supplier relationships were rarely based on trust, while another viewed contractors as more interested in relationships with their clients than with suppliers. The remaining suppliers were optimistic that in years to come, contractor-supplier relationships would improve as the principles of partnering became more widely understood and accepted.

9.7 Importance attached to logistics factors in supplier evaluation and selection

Tables 9.5 and 9.6 display suppliers' responses indicating the importance they attached to logistics performance indicators and enablers respectively. The factors in each table were arranged in order of importance the respondents attached to them by calculating the importance index (IN) and factor ranking for each factor using Equation 7.1 in Section 7.3.4 of Chapter 7. These factors were identified from literature and are outlined in Chapter 7. A logistics performance 'indicator' is defined as a metric by which a supplier can be evaluated in satisfying customer requirements and an 'enabler' is a characteristic which makes it possible for a supplier to meet customer requirements.

9.7.1 Logistics performance indicators

Surveyed suppliers ranked reliability of a supplier as the most important logistics performance indicator. It received an importance index of 0.85. Cost-effectiveness received an importance index of 0.81 and was ranked the second most important performance indicator, followed in the third rank by flexibility which received an importance index of 0.8.

All the three indicators: reliability, cost-effectiveness and flexibility received both modal and median responses of "Considerable Importance" and were considered to be of "Average" to "Extreme" importance by all the 30 respondents.

Lead time received an importance index of 0.71 and was ranked fourth in importance. The modal response for this indicator was "Average Importance" and the median response was between "Average Importance" and "Considerable Importance". Over 90 per cent (28) of the respondents considered the importance of the indicator to range from "Average" to "Considerable Importance".

Value-added service received an importance index of 0.69, both modal and median responses of "Average Importance" and was assigned the fifth and last rank. Over 80

Table 9.5: Importance suppliers attach to logistics performance indicators and enablers

Legend of response modes: 5=Exterme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance
Combined responses: 3 to 5=Important, 2 to1=Not important

Practice		Combined responses		Responses					Total	Mode	Median	Importance Index	Factor Ranking
		3+4+5	2+1	5	4	3	2	1					
Reliability (ability of supplier to deliver right products, of right quality and quantity on schedule, without damage)	Frequency	30	0	11	16	3	0	0	30	4	4	0.85	1
	% of total	100	0	36.7	53.3	10	0	0	100				
Cost-effectiveness	Frequency	30	0	8	16	6	0	0	30	4	4	0.81	2
	% of total	100	0	26.7	53.3	20	0	0	100				
Flexibility (responsiveness of supplier to changing customer needs)	Frequency	30	0	7	16	7	0	0	30	4	4	0.8	3
	% of total	100	0	23.3	53.3	23.3	0	0	100				
Lead time quoted by supplier	Frequency	28	2	3	12	13	2	0	30	3	3.5	0.71	4
	% of total	93.3	6.7	10	40	43.3	6.7	0	100				
Value-added service exceeding basic service requirements suppliers frequently	Frequency	25	5	5	9	11	5	0	30	3	3	0.69	5
	% of total	83.4	16.6	16.7	30	36.7	16.5	0	100				

per cent (25) of the respondents considered the indicator to be of importance ranging from "Average" to "Considerable".

9.7.2 Logistics enablers

Table 9.6 summarises analysed responses of suppliers concerning the importance they attached to enablers in the evaluation and selection of materials suppliers by contractors.

Quoted price received an importance index of 0.86 and was ranked the most important enabler by all the 30 respondents who indicated that its importance ranged from "Average" to "Extreme". Quality management systems received an importance index of 0.7 and was ranked the second most important enabler after quoted price. Quoted price and quality management systems received both modal and median responses of "Considerable Importance".

Long-term relationships and management and administrative ability of suppliers were both ranked third in importance having received importance indices of 0.66. They both received modal and median responses of "Average Importance". Capability of suppliers was considered less important than the already discussed enablers. It received an importance index of 0.65 and was ranked fourth in importance with both modal and median responses of "Average Importance".

Surveyed suppliers ranked location of suppliers in relation to projects fifth in importance in supplier evaluation and selection with an importance index of 0.6, followed by health and safety records of suppliers which received an importance index of 0.55 in the sixth rank, environmental records of suppliers which received an importance index of 0.48 in the seventh rank, and use of information and communication technologies in materials logistics processes which received an importance index of 0.38 in the eighth and last rank.

Table 9.6: Importance suppliers attached to logistics enablers which can be considered in supplier evaluation

Legend of response modes: 5=Exterme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance
Combined responses: 3 to 5=Important, 2 to 1=Not important

Factors		Combined respons		Responses					Total	Mode	Median	Importance index	Factor ranking
		3+4+5	2+1	5	4	3	2	1					
Quoted price	Frequency	29	0	11	17	1	0	0	29	4	4	0.86	1
	% of total	100	0	37.9	58.6	3.4	0	0	100				
Quality management systems	Frequency	25	5	4	12	9	5	0	30	4	4	0.7	2
employed by supplier	% of total	83.3	16.7	13.3	40	30	16.7	0	100				
Long-term relationships with	Frequency	23	5	2	10	11	5	0	28	3	3	0.66	3
suppliers (such as partnering)	% of total	82.1	17.9	7.1	35.7	39.3	17.9	0	100				
Management and administrative	Frequency	25	5	3	9	13	4	1	30	3	3	0.66	3
capability of suppliers	% of total	83.3	16.7	10	30	43.3	13.4	3.3	100				
Information and													
Capability (financial strength,	Frequency	26	4	1	11	14	3	1	30	3	3	0.65	4
production technology and	% of total	86.7	13.3	3.3	36.7	46.7	10	3.3	100				
efficiency, experience)													
Location of supplier in relation	Frequency	17	12	3	7	7	11	1	29	2	3	0.6	5
to project	% of total	58.6	41.4	10.4	24.1	24.1	37.9	3.5	100				
Health and Safety records	Frequency	19	11	2	4	13	7	4	30	3	3	0.55	6
suppliers	% of total	63.3	36.7	6.7	13.3	43.3	23.4	13.3	100				
Environmental record of	Frequency	14	16	1	2	11	10	6	30	3	2	0.48	7
supplier	% of total	46.7	53.3	3.3	6.7	36.7	33.3	20	100				
communication technologies	Frequency	4	26	1	2	1	15	11	30	2	2	0.38	8
(bar codes, EDI, Database	% of total	13.3	86.7	3.3	6.7	3.3	50	36.7	100				
management systems)													

With the exception of environmental records of suppliers and the use of information and communication technologies, all the identified enablers were considered to be of "Average Importance" to "Extreme Importance" by over 58 per cent of the respondents. However, 53.3 per cent (16) of the suppliers considered environmental records of suppliers to be of "Little" to "No" importance in supplier evaluation and selection while 86.7 per cent (26) of the respondents held the view that use of information and communication technologies was of "Little" to "No" importance in evaluation and selection of construction materials suppliers. Both environmental and information and commutation technologies received median responses of "Little Importance".

9.8 Extent contractors used logistics performance indicators and enablers in supplier evaluation and selection

While it was important to know the importance materials suppliers attached to logistics factors, it was also necessary to establish the extent to which they said contractors took them into account when evaluating suppliers. Tables 9.7 and 9.8 summarise the responses of suppliers.

9.8.1 Logistics performance indicators

Table 9.7 shows results of the extent to which surveyed suppliers said contractors considered logistics performance indicators when evaluating and selecting materials suppliers. Reliability received a calculated importance index of 0.79 and was ranked by suppliers as the most considered performance indicator by contractors when evaluating and selecting materials suppliers. The modal response for this factor was "Often" and the median response was "Very Often" used. All the 30 respondents indicated that this enabler was "Occasionally" to "Always" considered. Cost-effectiveness, with an importance index of 0.77 and both modal and median response of "Very Often" used was the second most considered enabler, followed by flexibility of suppliers which had an importance index of 0.72.

Table 9.7: Extent to which contractors used various factors in supplier evaluation and selection according to suppliers

Legend of response modes: 6= Always, 5=Very often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never
Combined responses: 3 to 6 = Occasionally to Always, 2 to 1 = Rarely to Never

Factors		Combined responses		Responses						Total	Mode	Median	Importance Index	Factor Ranking
		3+4+5+6	2+1	6	5	4	3	2	1					
Reliability of supplier	Frequency	30	0	8	9	11	2	0	0	30	4	5	0.79	1
	% of total	100	0	26.7	30	36.7	6.7	0	0	100				
Cost-effectiveness	Frequency	29	1	7	13	5	4	0	1	30	5	5	0.77	2
	% of total	96.7	3.3	23.3	43.3	16.7	13.3	0	3.3	100				
Flexibility of supplier	Frequency	30	0	3	10	10	7	0	0	30	4	4	0.72	3
	% of total	100	0	10	33.3	33.3	23.3	0	0	100				
Lead time quoted by supplier	Frequency	28	2	2	10	12	4	2	0	30	4	4	0.7	4
	% of total	93.3	6.7	6.7	33.3	40	13.3	6.7	0	100				
Value-added service provided by supplier	Frequency	25	5	1	7	5	12	5	0	30	3	3	0.59	5
	% of total	83.3	16.7	3.3	23.3	16.7	40	16.7	0	100				

Lead time with an importance index of 0.7 was ranked fourth, followed by value-added service which had an importance index 0.59 in the fifth and last rank. Modal and median responses for flexibility and lead time were both "Always", while for value added service these values were "Occasionally" used.

9.8.2 Logistics enablers

Surveyed suppliers ranked quoted price as the most considered enabler by contractors when evaluating and selecting construction materials suppliers. This enabler received an importance index of 0.71 and both modal and median responses of "Often" considered, with 96.7 per cent (29) of the respondents reporting that the enabler was considered "Occasionally" to "Always".

After quoted prices, long-term relationships with a frequency index of 0.6 and both modal and median responses of "Often" were the second most considered enabler, with 83.3 per cent of the respondents indicating that the enabler was considered by contractors "Occasionally" to "Always" when evaluating and selecting suppliers.

Location of suppliers in relation to projects with a frequency index of 0.57 and both modal and median responses of "Occasionally" was ranked third, followed by capability of suppliers with a frequency index of 0.53 and both modal and median responses of "Occasionally" considered in the fourth rank.

Quality management systems of suppliers with a frequency index of 0.48 and modal and median responses of "Often" and "Occasionally" considered respectively was ranked sixth, followed by environmental records of suppliers which had an importance index of 0.46 and modal and median responses of "Rarely" and "Occasionally" considered respectively in the seventh rank.

Table 9.8: Extent to which contractors used various factors in supplier evaluation and selection according to suppliers

Legend of response modes: 5=Always, 6=Very often, 4=Often, 3=Occasionally, 2 Rarely, 1 =Never
Combined responses: 3 to 5 = Occasionally to Always, 2 to 1 = Rarely to Never

Factor		Combined responses		Responses						Total	Mode	Median	Importance Index	Factor Ranking
		3+4+5+6	2+1	6	5	4	3	2	1					
Quoted price only	Frequency	29	1	4	5	17	3	1	0	30	4	4	0.71	1
	% of total	96.7	3.3	13.3	16.7	56.7	10	3.3	0	100				
Long-term relationships	Frequency	25	5	0	7	10	8	5	0	30	4	4	0.6	2
	% of total	83.3	16.7	0	23.3	33.3	26.7	16.7	0	100				
Location of supplier in relation to	Frequency	23	7	2	5	4	12	7	0	30	3	3	0.57	3
project	% of total	76.7	23.3	6.7	16.7	13.3	40	23.3	0	100				
Capability (financial strength, production	Frequency	20	9	0	6	4	10	7	2	29	3	3	0.53	4
technology & efficiency, experience)	% of total	69	31	0	20.7	13.8	34.5	24.1	6.9	100				
Quality management systems	Frequency	19	11	0	3	9	7	10	1	30	2	3	0.52	5
employed by suppliers	% of total	63.3	36.7	0	10	30	23.3	33.4	3.3	100				
Management and administrative	Frequency	17	12	2	0	10	5	8	4	30	4	3	0.48	6
ability of suppliers	% of total	58.6	41.4	6.9	0	34.5	17.2	27.6	13.8	100				
Environmental records of	Frequency	16	14	0	1	8	7	10	4	30	2	3	0.46	7
suppliers	% of total	53.3	46.7	0	3.3	26.7	23.3	33.3	13.4	100				
Information and	Frequency	17	12	0	0	4	13	7	5	29	3	3	0.42	8
communication	% of total	58 6	41.4	0	0	13.8	44.8	24.1	17.3	100				
technologies														
Health and Safety records of	Frequency	14	16	0	2	3	9	10	6	30	2	2	0.42	8
suppliers	% of total	46.7	53.3	0	6.7	10	30	33.3	20	100				

Both information and communication technologies, and health and safety records of suppliers received frequency indices of 0.42 and were both ranked eighth and the least considered enablers by contractors when evaluating and selecting construction materials suppliers. With the exception of health and safety records of suppliers, all the identified enablers were said to be "Occasionally" to "Always" considered by contractors by over 50 per cent of the surveyed suppliers. Health and safety records of suppliers was said to be "Rarely" to "Never" considered by 53.3 per cent (16) of the surveyed suppliers. This enabler received both modal and median responses of "Rarely" considered.

9.9 Quality standards surveyed suppliers were accredited to

Figure 9.5 shows quality systems surveyed suppliers said they were accredited to. The breakdown shows that 46 per cent of the organisations were accredited to ISO 9000 series, 7 per cent adhered to BS 5750, while 20 per cent were accredited to both ISO 9000 series and BS 5750. There rest, 27 per cent, did not adhere to any quality systems.

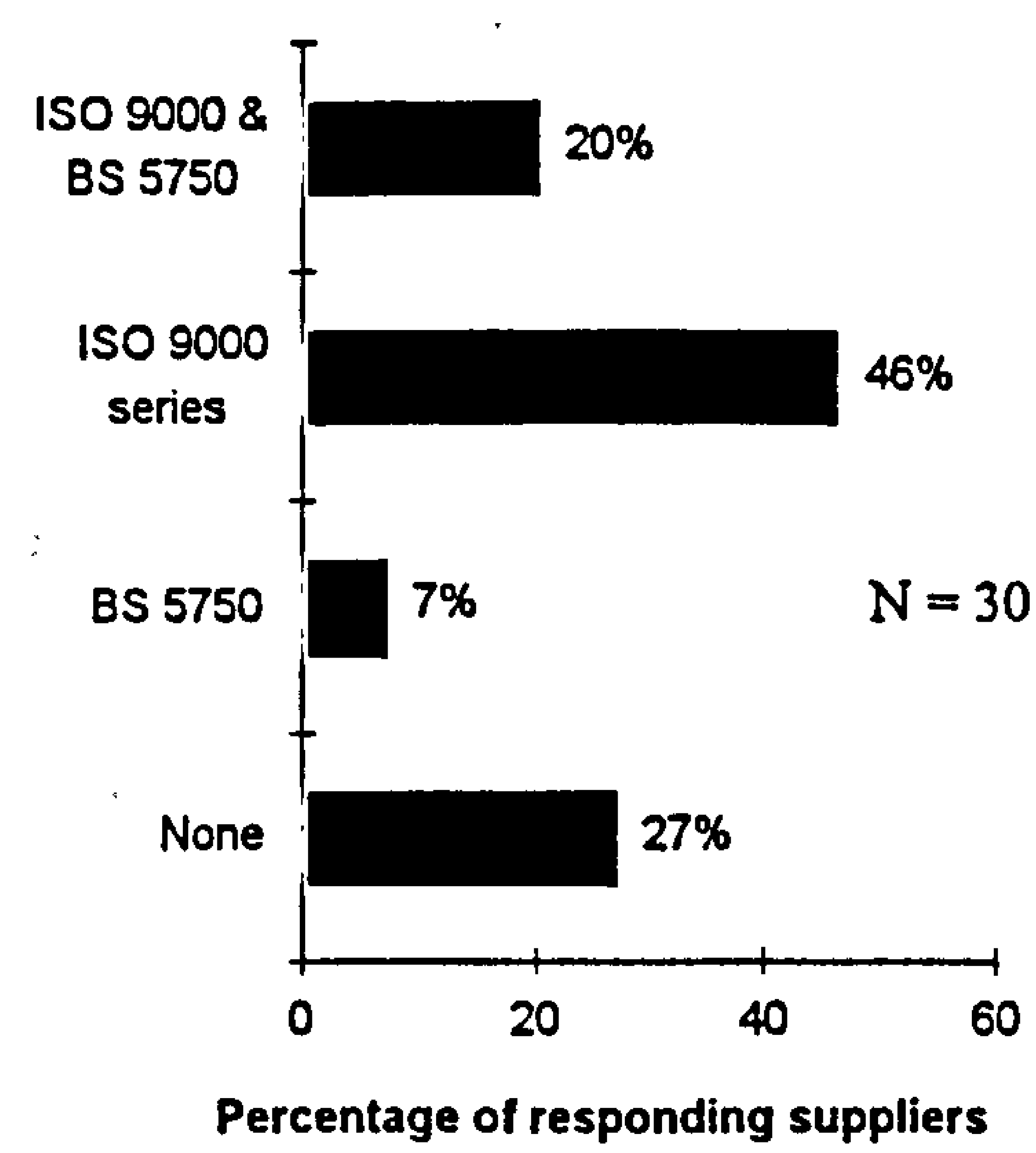


Figure 9.5: Percentage breakdown of responding suppliers by the type of standards they adhered to

9.10 Supplier evaluation and selection methods used by contractors

The majority of suppliers were of the view that supplier evaluation methods used by contractors were mainly on ad hoc basis. Table 9.9 is a summary of responses to item

4.5 of the supplier questionnaire. Overall, 66.8 per cent responded that contractors evaluated suppliers on ad hoc basis at buyers' discretion while 13.4 per cent indicated that contractors evaluated suppliers on ad hoc basis as well as follow-up approach based on problems or complaints.

The rest of the suppliers responded that contractors evaluated suppliers on a combination of approaches ranging from ad hoc to formal review every year or more frequently. Overall, the predominant supplier evaluation approach used by contractors according to the viewpoint of the majority of suppliers was ad hoc basis.

Table 9.9: Methods commonly used by contractors to evaluate suppliers according to suppliers

Method	Response frequency	Response %
Ad hoc evaluation at buyers' discretion	20	66.8
Ad hoc & follow-up evaluation based on problems	4	13.4
Ad hoc evaluation & formal review every one year or more frequentl	1	3.3
Ad hoc evaluation & formal review every one year or less frequently	1	3.3
Ad hoc evaluation & other approaches	1	3.3
Formal review of performance every one year or more frequently	1	3.3
Formal review of performance every 13 to 24 months	1	3.3
Follow-up and evaluate based on problems	1	3.3

9.11 Suppliers' satisfaction with evaluation systems used by contractors

Figure 9.6 shows that the majority of the suppliers, 56 per cent, were "Neutral" to supplier evaluation methods used by contractors. Of the remainder, 17 per cent registered satisfaction with supplier evaluation systems of contractors while 27 per cent were not satisfied.

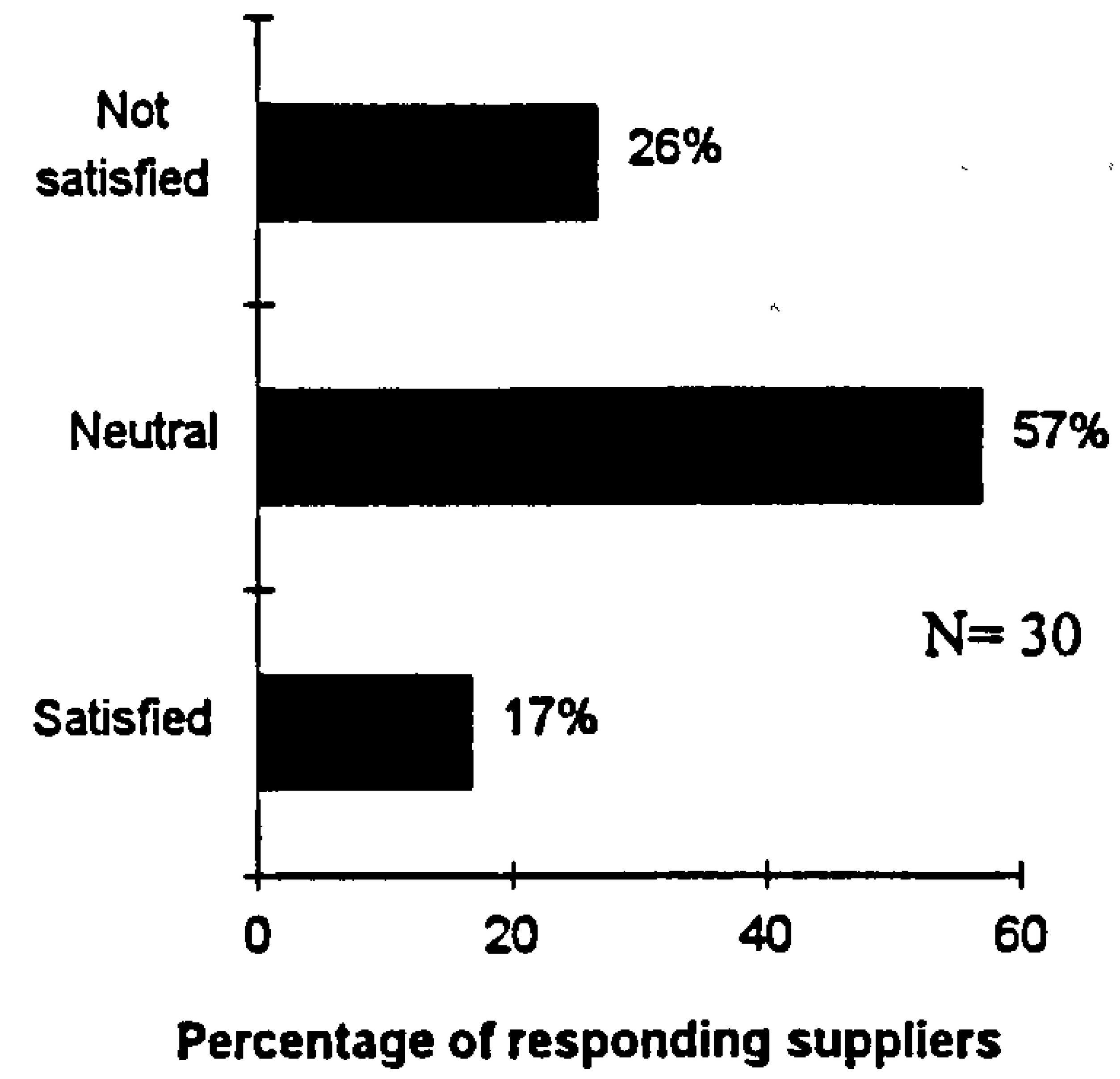


Figure 9.6: Surveyed suppliers' satisfaction with supplier evaluattion syatems used by contractors

9.12 Importance attached to materials management practices

Suppliers were also asked how important they considered various materials management processes in improving the supply of construction materials to support construction. Table 9.9 is a summary of opinions of what respondents thought of various approaches for improving the supply of materials to support construction. The various approaches were ranked using calculated importance indices obtained using Equation 7.1 in Section 7.3.4 of Chapter 7.

Improving communication between construction sites and suppliers received an importance index of 0.83 and was ranked first in importance for improving the supply of construction materials. Of all surveyed suppliers, 96.7 per cent (29) responded that the importance of this element ranged between "Average" to "Extreme". Materials planning by site staff received an importance index of 0.82 and was ranked second in importance with 100 per cent (30) of the respondents indicating that the importance of this practice ranged between "Average" to "Extreme". Closely following materials planning by site staff, management capability of site personnel received an importance index of 0.81 and was ranked third in importance with 96.7 per cent (29) of the respondents rating the importance of this as ranging from "Average" to "Extreme".

Both customer service levels provided by suppliers and improved contractor-supplier relationships received importance indices of 0.77 and were ranked fourth in importance with over 90 per cent (27) of suppliers rating the importance of these two practices to range between "Average" to "Extreme".

Selection of suppliers by contractors received an importance index of 0.74 and was ranked fifth in importance, followed by communication between administrative offices of contractors and suppliers which received an importance index of 0.72 in the sixth rank.

All the above discussed practices received both modal and median responses of "Considerable Importance".

Early payment of suppliers for materials already delivered had an importance index of 0.68, modal response of "Considerable Importance", median response between "Considerable Importance" and "Average Importance" and was ranked seventh in importance, followed in the eighth rank by stationing a materials manager on construction site which had an importance index of 0.58 and both modal and median responses of "Average Importance".

Use of information and communication technologies like bar codes, EDI and DBMS received the least importance index of 0.45 and was ranked ninth in importance. It received "Average Importance" as a modal response and "Little Importance" as a median response. While over 60 per cent of all the respondents considered the other practices to have importance ranging from "Average" to " Extreme", 56.6 per cent (17) of the respondents considered use of information and communication technologies to be of "Little" to "No" importance in improving the supply of construction materials to support construction.

Table 9.10: Importance suppliers attributed to various materials management to support construction

Legend of response modes: 5=Exterme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance
Combined responses: 3 to 5 =Important, 2 to1=Not Important

Practices		Combined responses		Responses					Total	Mode	Median	Importance Index	Factor Ranking
		3 to 5	2 to 1	5	4	3	2	1					
Communications between site	Frequency	29	1	11	14	4	1	0	30	4	4	0.83	1
and suppliers	% of total	96.7	3.3	36.7	46.7	13.3	3.3	0	100				
Materials planning by site staff	Frequency	30	0	8	17	5	0	0	30	4	4	0.82	2
	% of total	100	0	26.7	56.7	16.7	0	0	100				
Management capability of site	Frequency	29	1	7	18	4	1	0	30	4	4	0.81	3
personnel	% of total	96.7	3.3	23.4	60	13.3	3.3	0	100				
Customer service levels provided	Frequency	28	2	5	19	4	1	1	30	4	4	0.77	4
by suppliers	% of total	93.4	6.6	16.7	63.4	13.3	3.3	3.3	100				
Improving relationships with contractors	Frequency	27	3	6	17	4	3	0	30	4	4	0.77	4
	% of total	90	10	20	56.7	13.3	10	0					
Selection of suppliers by	Frequency	28	1	3	16	9	1	0	29	4	4	0.74	5
contractors	% of total	96.5	3.5	10.3	55.2	31	3.5	0	100				
Communication between Head	Frequency	26	4	4	14	8	4	0	30	4	4	0.72	6
Office and suppliers	% of total	86.7	13.3	13.3	46.7	26.7	13.3	0	100				
Early payment of suppliers for	Frequency	25	5	3	12	10	4	1	30	4	3.5	0.68	7
delivered materials	% of total	83.3	16.7	10	40	33.4	13.3	3.3	100				
Stationing a materials manager	Frequency	20	10	1	8	11	8	2	30	3	3	0.58	8
on site by contractors	% of total	66.7	33.4	3.3	26.7	36.7	26.7	6.7	100				
Use of Information and	Frequency	13	17	1	1	11	9	8	30	3	2	0.45	9
communication technologies like	% of total	43.3	56.7	3.3	3.3	36.7	30	26.7	100				
bar codes, EDI, DMBS													

9.13 Summary

Responses of surveyed UK suppliers to the questionnaire on materials supply logistics practices in the construction industry have been analysed in this chapter.

Evidence from the supplier survey suggested existence of islands of automation internally integrated by database management systems but with little electronic bridging with external partners. The main media suppliers used in communicating with contractors were the word of mouth telephone technology and paper-based facsimile and the post. Even though the majority of suppliers described their relationships with contractors as close, their responses to statements on contractor-supplier relationships reflected both good and poor supply chain practices on the part of contractors.

The surveyed suppliers rank-ordered the importance of logistics performance indicators and enablers and the extent to which these were considered by contractors in the evaluation and selection of suppliers. The chapter also recorded the importance suppliers attached to various materials management practices to support construction.

Responses of suppliers in this chapter are compared in Chapter 10 with those of contractors in Chapter 8 to determine group differences for purposes of establishing actual materials logistics practices in the industry. In Chapter 11, the identified logistics performance indicators and enablers will be evaluated using the Analytic Hierarchy Process to determine the extent to which they contribute to improvements in customer service in the supply of construction materials.

CHAPTER TEN

COMPARISON OF CONTRACTOR AND SUPPLIER QUESTIONNAIRE RESULTS

CHAPTER TEN

COMPARISON OF CONTRACTOR AND SUPPLIER QUESTIONNAIRE RESULTS

10.1 Introduction

Results of contractor and supplier questionnaires were independently analysed in Chapters 8 and 9 respectively. Group differences in responses of contractors and suppliers to Sections 2.1, 2.2, 2.3, 3.1, 4.2, 4.4 and 5.2 in both questionnaires have been tested in this chapter. The intention was to identify differences in practices and attitudes that could explain problems in materials logistics and point to ways of effecting supply chain alignment between the two groups. As discussed in Chapter 7, group differences in this chapter were analysed using the Wilcoxon-Mann-Whitney two-tailed probability test. The probabilities were calculated using Statistical Package for the Social Sciences (SPSS).

Levels of significance for all the tests when the null hypothesis, Ho, was true was set at $\alpha = 0.05$ for reasonable evidence of differences in responses of the two groups which can lead to rejection of the null hypothesis. This level of significance is considered sufficiently sensitive for detecting differences in opinions in management research (Hine and Wetherill, 1975).

The actual scales were used in recording opinions of surveyed companies. In applying the Wilcoxon-Mann-Whitneytest, group differences were tested on the basis of these scales. For purposes of assessing which direction opinions of the majority of the respondents fell, however, response categories were combined. For example, for scale of measurement ranging from 7="Strongly Agree", through 4="Neutral" to 1="Strongly Disagree" response categories "Slightly Agree" to "Strongly Agree" were broadly categorised as "Agree", "Neutral" was left as "Neutral" and responses from "Slightly Disagree" to "Strongly Disagree" were broadly grouped as "Disagree

10.2 Differences in the usage of ICTs between suppliers and contractors

Present day information and communication technologies have been acknowledged to enable intra and inter-organisational integration of materials logistics activities (Back and Bell, 1994; Carter et al, 1996). Identification of common practices or differences in the use of information and communication technologies in the management of materials by contractors and suppliers can help to understand industry and organisational behaviour as regards logistics integration in the supply of construction materials. This is because to achieve integration, co-operation is needed between trading partners.

The use of information and communication technologies was investigated in three respects: the use of the technologies in internal materials management processes of both suppliers and contractors; the use of the technologies between suppliers and construction sites on one hand - and between contractors and their construction sites on the other; and inter-organisational use of the technologies between contractors and suppliers.

The null hypothesis, Ho, that was tested for each of the aspects was that there were no differences in the levels of usage for each of the information and communication technologies by contractors and suppliers. The alternative hypothesis, H_1, was that levels of usage of each of the technologies by contractors and suppliers were different.

10.2.1 Differences in internal usage by contractors and suppliers

Table 10.1 shows results of the two-tailed Wilcoxon-Mann-Whitney test for group differences in the usage of information and communication technologies in intra-organisational materials management processes by suppliers and contractors.

The results show that, with the exception of bar codes, there were no significant differences between contractors and suppliers in their intra-organisational usage in materials management processes of integrated database management systems,

Table 10.1: Comparison of IT usage by contractors and suppliers in internal materials management processes

Legend of response modes: 3 to 6 = Occasionally to Always, 2 to 1= Rarely to Never
where 6=Always, 5=Very Often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never

Information and communication technologies	Suppliers				Contractors				Probability
	Number of cases	Occasionally to Always (%)	Rarely to Never (%)	Total (%)	Number of cases	Occasionally to Always (%)	Rarely to Never (%)	Total (%)	Wilcoxon-Mann-Whitney 2-Tailed p
Integrated Database Management Systems	30	63.3	36.7	100	35	65.7	34.3	100	0.3393
Electronic data interchange	30	43.4	56.6	100	35	22.9	77.1	100	0.0905
Electronic mail	30	43.4	56.6	100	35	42.9	57.2	100	0.8845
Bar codes	30	23.3	76.7	100	35	0.0	100.0	100	0.0067*
Radio Frequency Tagging	30	3.3	96.7	100	35	0.0	100.0	100	0.2801
Magnetic Stripes	30	6.7	93.3	100	35	0.0	100.0	100	0.1237
Voice recognition	30	3.3	96.7	100	35	8.6	91.5	100	0.5124
Electronic document imaging	30	16.7	83.3	100	35	22.9	77.1	100	0.4587

*Result statistically significant at 5% significance level electronic data interchange, electronic mail, radio frequency tagging, magnetic stripes, voice recognition and electronic document imaging.

Only bar code technology showed a significant difference in its usage by contractors and suppliers. Table 10.1 shows that more suppliers, 23.3 per cent compared to zero per cent of contractors used bar codes 'Occasionally' to 'Always'. An earlier survey by Alkaabi (1994) had also shown that suppliers used bar codes more than contractors.

Analyses in Chapters 8 and 9 showed that IDBMS were the most used in internal management processes of contractors and suppliers. Over 60 per cent of both surveyed contractors and suppliers used IDBMS 'Occasionally' to 'Always', indicating that there was integration in internal materials management processes of a fairly high proportion of the surveyed companies. However, data entry into computers of surveyed companies was still predominantly manual. This was also acknowledged by Construct IT (1998) who observed much evidence of manual data entry. Manual systems of data entry have associated errors with their likely contribution to inefficiencies in the supply of construction materials.

10.2.2 Differences in usage between contractors and construction sites and between suppliers and construction sites

Table 10.2 shows no significant differences in the usage of these technologies between suppliers and sites, and contractors and their sites.

Over 85 per cent of both contractor and supplier groups used the telephone, facsimile and the post (word of mouth and paper-based methods) 'Occasionally' to 'Always' in their materials management processes with sites. Both groups exhibited very low usage rates of IDBMS, EDI and e-mail (electronic data based technologies) with each group indicating that over 60 per cent used these technologies in materials management processes with construction sites 'Rarely' to 'Never'.

Table 10.2: Comparison of usage of ICTs in materials management between contractors and construction sites and, suppliers and construction sites

Legend of response modes: 3 to 5 = Occasionally to Always, 2 to 1 = Rarely to Never
where 6=Always, 5=Very Often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never

Information and communication and methods	Suppliers				Contractors				Probability
	Number of cases	Occasionally to Always	Rarely to Never (%)	Total (%)	Number of cases	Occasionally to Always (%)	Rarely to Never (%)	Total (%)	Wilcoxon-Mann-Whitney 2-Tailed p
Integrated Database Management Systems	30	33.3	66.7	100	35	28.6	71.5	100	0.9938
Electronic data interchange	30	13.3	86.7	100	34	11.8	88.2	100	0.1862
Electronic mail	30	23.3	76.7	100	34	38.2	61.8	100	0.1684
Telephone	30	96.7	3.3	100	35	97.1	2.9	100	0.682
Facsimile	30	93.3	6.7	100	35	97.1	2.9	100	0.7529
Post	30	86.7	13.3	100	35	91.3	8.6	100	0.3377

10.2.3 Differences in usage between contractors and suppliers

The two-tailed probability test results in Table 10.3 show no significance differences in the extent to which respondents said the identified information and communication technologies were used in materials logistics between contractors and suppliers.

Both groups exhibited very low usage rates of IDBMS, EDI and e-mail, with around 73 per cent of suppliers and 80 per cent of contractors indicating that they used these electronic data management technologies 'Rarely' to 'Never'. The more widely used methods in materials supply logistics activities between contractors and suppliers were: the post, facsimile, and the telephone - word of mouth and paper based methods.

Overall, the results of these surveys point to existence of islands of automation among the surveyed companies which require bridging using electronic data entry technologies, EDI and IDBMS in order to reduce or eliminate errors and non value-added activities and achieve efficient communication between construction sites, suppliers and administrative offices of contractors.

Table 10.3: Comparison of inter-organisational usage of ICTs in materials management processes between contractors and suppliers

Legend of response modes: 3 to 6= Occasionally to Always, 2 to 1 = Rarely to Never
where 6=Always, 5=Very Often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never

Information and communication technologies and methods	Suppliers				Contractors				Probability
	Number of cases	Occasionally to Always (%)	Rarely to Never (%)	Total (%)	Number of cases	Occasionally to Always (%)	Rarely to Never (%)	Total (%)	Wilcoxon-Mann-Whitney 2-Tailed p
Integrated Database Management Systems	30	26.6	73.4	100	35	5.8	94.2	100	0.2371
Electronic data interchange	30	26.7	73.3	100	34	5.8	94.2	100	0.5796
Electronic mail	30	26.6	73.4	100	34	17.6	82.4	100	0.498
Telephone	30	93.4	6.6	100	35	100	0	100	0.1244
Facsimile	30	96.7	3.3	100	35	100	0	100	0.7795
Post	30	96.7	3.3	100	35	100	0	100	0.8822

10.3 Responses to statements about contractor-supplier relationships

Improved customer-supplier relationships have been identified as essntial for improving business performance. Items being presented in this section were designed to assess the nature of relationships between contractors and suppliers and were modelled on the line of those designed by National Economic Development Office (1990). To assess levels of agreement or disagreement, responses of the two groups were tested for group differences and the results are displayed in Table 10.4. What follows is a comparison of responses of contractors and suppliers to each of the statements.

Contractors know which of their suppliers are vital to their business

Of the responding contractors, 97.1 per cent agreed with the statement and among the suppliers, 83.4 per cent also agreed. Even though responses of the two groups were significantly different, the majority of respondents in both groups were generally in agreement with the statement. The need for contractors to know which of their suppliers are vital to their business is based on the requirement for proven performance record established in past relationships with an agenda for co-operative behaviour.

Contractors buy on the basis of lowest price alone

The majority of the contractors, 60 per cent, disagreed with the statement that they purchased materials on the basis of lowest price alone. Suppliers were equally divided over the statement. While 46.7 per cent agreed with the statement, an equal proportion disagreed. Despite differences in response modes, there were no significant differences in responses between contractors and suppliers. Viewing suppliers as a control group, it can be concluded from the responses that price is of primary consideration in the selection of suppliers even though contractors did not necessarily purchase materials based on price alone.

Table 10.4: Contractor - supplier relationships

Legend of response modes: Agree (5 to 7), Neutral (4), Disagree (3 to 1)
where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree

Practice		Contractors				Suppliers				Probability
		Combined responses				Combined responses				Wilcoxon-Mann-Whitney
		Agree	Neutral	Disagree	Total	Agree	Neutral	Disagree	Total	2-Tailed p
Contractors know which of their suppliers are vital to their businesses	Frequency	34.0	1.0	0.0	35	25.0	4.0	1.0	30	
	% of Total	97.1	2.9	0.0	100	83.4	3.3	3.3	100	0.0099*
Contractors buy on the basis of lowest price alone	Frequency	9.0	5.0	21.0	35	14.0	2.0	14.0	30	
	% of Total	25.7	14.3	60.0	100	46.7	6.6	46.7	100	0.1337
Contractors try to reduce the number of suppliers to a minimum	Frequency	20.0	4.0	11.0	35	16.0	6.0	8.0	30	
	% of Total	57.2	11.4	31.4	100	53.3	20.0	26.7	100	0.8979
To obtain the best deal, contractors change their suppliers frequently	Frequency	7.0	3.0	25.0	35	13.0	4.0	13.0	30	
	% of Total	20.0	8.6	71.4	100	43.3	13.3	43.4	100	0.0009*
Contractors attempt to obtain mutual beneficial relationships with their suppliers	Frequency	31.0	4.0	0.0	35	19.0	3.0	8.0	30	
	% of Total	88.6	11.4	0.0	100	63.3	10.0	26.7	100	0.0011*
Contractors seek to obtain unique advantage over their competitors through their relationships with their suppliers	Frequency	31.0	4.0	0.0	35	23.0	4.0	3.0	30	
	% of Total	88.6	11.4	0.0	100	76.6	13.3	10.0	100	0.0080*
Contractors do not believe that sharing their strategic plans with their suppliers is in their best interests	Frequency	8.0	13.0	14.0	35	11.0	15.0	4.0	30	
	% of Total	22.9	37.1	40.0	100	36.7	50.0	13.3	100	0.0165*
Contractors give feedback to suppliers on delivery performance	Frequency	23.0	7.0	5.0	35	15.0	1.0	14.0	30	
	% of Total	65.7	20.0	14.3	100	50.0	3.3	46.7	100	0.0044*

*Result statistically significant at the 5% confidence level

Table 10.4: Contractor-supplier relationships.....*continued*

Legend of response modes: Agree (5 to 7), Neutral (4), Disagree (3 to 1)
where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree

Practice		Contractors				Suppliers				Probability Wilcoxon-Mann-Whitney 2-Tailed p
		Combined responses				Combined responses				
		Agree	Neutral	Disagree	Total	Agree	Neutral	Disagree	Total	
Contractors expect their potential suppliers to deliver exactly what they specify without question	Frequency	25.0	4.0	6.0	35	22.0	2.0	6.0	30	
	% of Total	71.4	11.4	17.1	100	73.3	6.7	20.0	100	0.6866
Contractors check every delivery - it is the only way to ensure consistent quality	Frequency	26.0	5.0	4.0	35	8.0	7.0	15.0	30	
	% of Total	74.3	14.3	11.4	100	26.7	23.3	50.0	100	0.0001*
The commitment of suppliers is always sought to achieve project delivery goals of cost, time and quality	Frequency	33.0	1.0	1.0	35	25.0	5.0	0.0	30	
	% of Total	94.2	2.9	2.9	100	83.3	16.7	0.0	100	0.0454*
Suppliers always get involved during development of project goals at the tendering stage	Frequency	32.0	2.0	1.0	35	13.0	9.0	8.0	30	
	% of Total	91.4	5.7	1.9	100	43.3	30.0	26.6	100	0.0005*
Communication between contractors and is open, honest and based on mutual respect	Frequency	30.0	3.0	2.0	35	20.0	5.0	5.0	30	
	% of Total	85.7	8.6	5.7	100	66.6	16.7	16.7	100	0.0020*
There is trust in the sharing of project information between us and contractors	Frequency	31.0	4.0	0.0	35	19.0	6.0	5.0	30	
	% of Total	88.6	11.4	0.0	100	63.4	20.0	16.6	100	0.0124*
Suppliers are always given ample time to prepare quotations where they bid to supply materials	Frequency	13.0	8.0	14.0	35	5.0	5.0	20.0	30	
	% of Total	37.2	22.9	40.0	100	16.6	16.7	66.7	100	0.0013*
Suppliers get paid in time for materials already delivered	Frequency	22.0	7.0	6.0	35	6.0	7.0	17.0	30	
	% of Total	62.9	20.0	17.1	100	20.0	23.3	56.7	100	0.0000*

*Result statistically significant at the 5% confidence level

Contractors try to reduce the number of suppliers to a minimum

There were no significant differences between the responses of contractors and suppliers for this statement. Among responding contractors, 57.2 per cent agreed with the statement while among suppliers 53.3 per cent agreed. A reduced supplier base is easier to manage. Concentrating efforts on a small number of suppliers can also build up mutual beneficial relationships (National Economic Development Office, 1990).

To obtain the best deal contractors change their suppliers frequently

The majority of contractors, 71.4 per cent, disagreed with this statement. Suppliers were equally split with 43.3 per cent in agreement with the statement, and the same percentage also in disagreement. The responses of the two groups were significantly different. The fact that suppliers did not emerge with a clear position over the statement indicated existence of the practice, even though most contractors denied changing their suppliers frequently.

Contractors attempt to obtain mutual beneficial relationships with their suppliers

There were significant differences in the responses of the two groups to this statement. The differences, however, were mainly in the levels of agreement as the majority in both groups, 88.5 per cent for contractors and 63.3 per cent for suppliers, agreed with the statement.

Contractors seek to obtain a unique advantage over their competitors through their relationships with their suppliers

The majority of contractors, 88.6 per cent, and suppliers, 76.6 per cent, agreed with this statement. Even though the majority in both groups agreed with the statement, the two-tailed probability test revealed significant differences in their responses at the five per cent confidence level.

Contractors do not believe that sharing strategic plans with their suppliers is in their best interests

There were significant differences in response modes of the two groups to this statement. The tendency of contractors was marginally towards disagreement and that of suppliers was towards neutrality. While some contractors might have been involved in the sharing of strategic plans with their suppliers, the practice appears not to have been predominant from the viewpoint of suppliers.

Contractors give feedback to suppliers on delivery performance

Responses of contractors and suppliers regarding this statement were significantly different. A higher percentage of contractors, 66 per cent agreed with the statement than that of suppliers which was 50 per cent. From the viewpoint of suppliers, the practice of giving feedback to suppliers by contractors may not have been as prevalent as the responses of the majority of the contractors indicated.

Contractors expect their potential suppliers to deliver exactly what they specify without question

The majority of both contractors, 71.3 per cent, and suppliers, 73.3 per cent, agreed with this statement. No significant difference in response modes of contractors and suppliers were observed. These responses reflected poor supply chain management practices. This being because contractors could be losing out on opportunities to use suppliers as important sources of new ideas and new business.

Contractors check every delivery - it is the only way to ensure consistent quality

Responses of contractors and suppliers regarding this statement were significantly different. With 50 per cent in disagreement, suppliers held a more optimistic view of the trust contractors had in them than actual claims of the contractors of whom 74.3 per cent agreed with the statement. The practice of checking every delivery, to which most of the contractors alluded, though human and is expected, introduces non-value-added activities leading to poor supply chain management practices.

The commitment of suppliers is always sought to achieve project delivery goals of cost, time and quality

There were significant differences in responses of contractors and suppliers to this statement even though the majority of respondents, 94.2 per cent for contractors and 83.3 per cent for suppliers agreed with the statement.

Suppliers always get involved during development of project goals at the tendering stage

Differences in responses of contractors and suppliers to this statement were significant. While the majority of contractors, 91.4 per cent agreed with the statement, less than 50 per cent of suppliers agreed with it. Thus, while most of the contractors felt that they involved suppliers during project development goals at the tendering stage, a very high number of suppliers felt they were not involved. This points to the possibility that contractors maybe be missing opportunities for using suppliers as new sources of ideas.

Communication between contractors and suppliers is open, honest and based on mutual respect.

The two-tailed probability test revealed significantly different responses for this statement. However, the majority of both contractors, 85.7 per cent, and suppliers 66.6 per cent, agreed with the statement.

There is trust in the sharing of project information between contractors and suppliers

The majority of contractors, 88.6 per cent and suppliers, 63.4 per cent, agreed with this statement even though the two-tailed probability test revealed significant differences in responses of the two groups.

Suppliers are always given ample time to prepare quotations where they bid to supply materials

While the majority of suppliers, 66.7 per cent, disagreed with this statement, only 40 per cent of contractors disagreed. The percentage of suppliers who disagreed was higher than that of contractors. Differences in the responses of the two groups were significant. These results predominantly suggest that contractors did not always give suppliers ample time to prepare quotations for supply of materials.

Suppliers get paid in time for materials already delivered

While over 60 per cent of contractors agreed with this statement, over 55 per cent of suppliers disagreed with it. The responses of the two groups were significantly different. The differences in responses between contractors and suppliers suggested existence of a conflict of interest in which the interests of suppliers appear not to be served. Thus late payment for delivered materials could be one of the factors causing dysfunctional relationships between suppliers and contractors, leading to poor performance in the delivery of materials by suppliers.

The major findings of the survey concerning improved construction materials supply chain management over which the majority of both surveyed contractors and suppliers agreed to, were that UK contractors:

- did not buy construction materials on the basis of lowest price alone;
- knew which suppliers were of most importance to them;
- tried to reduce the total number of their suppliers;
- attempted to obtain mutual beneficial relationships with their suppliers;
- sought to obtain unique advantage over their competitors through their relationships with their suppliers;
- sought the commitment of suppliers to achieve project delivery goals of cost, time and quality;
- maintained open and honest communication based on mutual respect; and
- ensured trust in the sharing of project information with their suppliers.

Statements over which the survey revealed poor supply chain management practices were that:

- contractors changed their suppliers frequently;
- the practice of contractors sharing their strategic plans with their suppliers was not common practice in the industry;
- contractors did not give as much feedback to suppliers as the suppliers would have liked;
- contractors expected suppliers to deliver exactly what was specified without question;
- contractors checked every delivery to ensure consistent quality;
- suppliers did not get quite involved during project development goals at the tendering stage;
- while contractors indicated that they paid suppliers in time for materials already delivered, suppliers disagreed with this; and
- contractors did not always give enough time to suppliers to prepare quotations when bidding to supply materials.

Ellram (1995) established that primary reasons customer companies entered into closer working relationships with suppliers were to obtain a better price or low total cost of purchased items and to secure a reliable source capable of living up to its commitments and dependability. On the other hand, the major reason suppliers entered such relationships were to secure reliable markets for their products.

Trust has been identified as central to development of good customer-supplier relationships (Fojt, 1996a). Both contractors, in Section 8.6.1 of Chapter 8, and suppliers, in Section 9.8.1 of Chapter 9, identified lack of trust as a major impediment to development of good contractor-supplier relationships.

The results of these tests show that there were many disparities in levels of satisfaction of contractors and suppliers in their trading relationships. The proportion of contractors who agreed with statements alluding to good contractor-supplier relationships were generally higher than that of suppliers. Greater benefits to customers accrue when suppliers feel they are in win/win relationships (Fojt, 1996b). This implied that much was still needed to be done by UK contractors before they fully realised the benefits of closer working relationships with suppliers.

10.4 Comparison of importance attached to logistics factors

The logistics factors discussed in this section were identified, defined and discussed in Chapter 11 and were ranked in importance in Chapters 8 and 9. The factors have been classified into two groups, logistics performance indicators and enablers, and have been displayed in two separate tables. Performance indicators are in Table 10.5 and enablers are in Table 10.6. A logistics performance 'indicator' is defined as a metric by which a supplier can be evaluated in satisfying customer requirements and an 'enabler' is a characteristic which makes it possible for a supplier to meet customer requirements.

10.4.1 Logistics performance indicators

Based on importance indices, Table 10.5 shows that both contractors and suppliers ranked performance indicators in the same order of importance. Reliability of suppliers was considered the most important performance indicator followed by cost-effectiveness of products or services supplied. Flexibility of suppliers was the third most important performance indicator followed by lead times. Both groups saw value-added service as the least important indicator of performance in the delivery of construction materials.

Over 80 per cent of all the contractors and suppliers assessed all the performance indicators (from reliability to value-added service) to be of 'Average Importance' to 'Extreme Importance'.

Two-tailed probabilities showed that at the five per cent significance level, there were no significant differences in the importance contractors and suppliers attached to reliability, flexibility and value-added service. Meanwhile significant differences

Table 10.5: Comparison of importance attached to logistics performance indicators in supplier evaluation and selection

Legend of responses: 3 to 5 = Important, 2 to 1 = Not Important
where 5=Extreme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance

Factors		Contractors					Suppliers					Probability Wilcoxon-Mann-Whitney 2-Tailed p
		Combined responses		Total	Importance	Factor	Combined responses		Total	Importance	Factor	
		3 to 5	2 to 1		Index	Ranking	3 to 5	2 to 1		Index	Ranking	
Reliability (ability of supplier to	Frequency	35	0	35			30	0	30			
deliver right products, of right quality and quantity on schedule, without damage)	% of total	100	0	100	0.94	1	100	0	100	0.85	1	0.1845
Cost-effectiveness: cost of	Frequency	35	0	35			30	0	30			
service satisfactory to customer	% of total	100	0	100	0.9	2	100	0	100	0.81	2	0.0134
Flexibility (responsiveness of	Frequency	34	1	35			30	0	30			
supplier to changing customer needs)	% of total	97.2	2.8	100	0.82	3	100	0	100	0.8	3	0.5368
Lead time quoted by supplier	Frequency	35	0	35			28	2	30			
	% of total	100	0	100	0.81	4	93.3	6.7	100	0.71	4	0.0048
Value-added service exceeding	Frequency	32	3	35			25	5	30			
basic service requirements	% of total	91.4	8.6	100	0.7	5	83.4	16.6	100	0.69	5	0.8837

were observed in the importance attached to cost-effectiveness and lead times by contractors and suppliers. Combined responses showed that more contractors attached greater importance to the performance indicators than suppliers.

The difference in importance attached to cost-effectiveness by contractors and suppliers was not surprising because of conflict of interest between the two groups. From interviews results in Chapter 8, it was indicated that whereas contractors want to achieve lowest price, suppliers want to achieve the best price. Similarly, contractors may prefer such arrangements as just-in-time, whereas suppliers would need time to prepare orders. The conflict of interest again resulting in significant differences in the responses of the two groups to lead time.

10.4.2 Logistics enablers

Contractors and suppliers did not show as much agreement in rank ordering enablers as they did performance indicators. Only price quoted by suppliers and environmental records of suppliers were similarly ranked by both contractors and suppliers in the first and seventh position respectively.

Table 10.6 summarises all the details.

Despite differences in ranks, contractors and suppliers did not exhibit significant differences in the importance they attached to prices quoted by suppliers, quality management systems of suppliers, long-term relationships with suppliers, management and administrative ability of suppliers, and location of suppliers in relation to projects.

Quoted prices was ranked first in importance in supplier evaluation and selection by both contractors and suppliers. Whereas contractors ranked capability of suppliers second in importance, suppliers ranked this enabler fourth in importance. Quality management systems employed by suppliers were ranked third in importance by contractors and second by suppliers. Health and safety records of suppliers were also considered highly important by contractors who ranked the enabler fourth in

Table 10.6: Comparison of importance attached to enablers in supplier evaluation and selection

Legend of responses: 3 to 5 = Important, 2 to 1 = Not Important
where 5=Extreme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1= No Importance

Practice		Contractors: Combined responses 3 to 5	Contractors: Combined responses 2 to 1	Contractors: Total	Contractors: Importance index	Contractors: Factor ranking	Suppliers: Combined responses 3 to 5	Suppliers: Combined responses 2 to 1	Suppliers: Total	Suppliers: Importance index	Suppliers: Factor ranking	Wilcoxon-Mann-Whitney 2 Tailed P
Quoted price	Frequency	34	1	35			29	0	29			
	% of total	97.2	2.8	100	0.86	1	100	0	100	0.86	1	0.9819
Capability (financial strength,	Frequency	35		35			26	4				
production technology and	% of total	100	0		0.79	2	86.7	13.3	100	0.65	4	0.001*
efficiency, experience)												
Quality management systems	Frequency	33	2	35			25	5	100			
employed by supplier	% of total	94.3	5.7	100	0.78	3	83.3	16.7	30	0.7	2	0.748
Health and Safety records	Frequency	32	3	35			19	11	30			
suppliers	% of total	91.4	8.6	100	0.76	4	63.3	36.7	100	0.55	6	0.0002*
Long-term relationships with	Frequency	33	2	35			23	5	28			
suppliers (such as partnering)	% of total	94.3	5.7	100	0.75	5	82.1	17.9	100	0.66	3	0.0577
Management and administrative	Frequency	34	1	35			25	5	30			
capability of suppliers	% of total	97.1	2.8	100	0.72	6	83.3	16.7	100	0.66	3	0.1497
Location of supplier in relation	Frequency	32	3	35		7	17	12	29			
to project	% of total	91.4	8.6	100	0.66		58.6	14.4	100	0.6	5	0.0003*
Environmental record of	Frequency	31	4	35			14	16	100			
supplier	% of total	88.6	11.4	100	0.66	7	46.7	53.3	30	0.48	7	0.1585
Information and communication technologies	Frequency	15	20	35			4	26	30			
(bar codes, EDI, Database management systems)	% of total	42.9	57.1	100	0.48	8	13.3	86.7	100	0.38	8	0.0163*

* Statistically significant at 5 % significance level

importance. This enabler was ranked sixth in importance for evaluation and selection of suppliers by suppliers. Long-term relationships were ranked fifth by contractors and third by suppliers, management and administrative ability of a supplier was ranked sixth in importance by contractors and third by suppliers. Evaluation of suppliers on the basis of their location in relation to projects and their environmental records both received the seventh rank from contractors. Suppliers considered location of suppliers to be fifth in importance and environmental records to be seventh in importance. Information and communication technologies were considered the least important in supplier evaluation and selection by both contractors and suppliers and were ranked eighth in importance.

Statistically significant differences in responses between contractors and suppliers were exhibited in importance they attached to capability of suppliers, health and safety records of suppliers, environmental records of suppliers, and the use of information and communication technologies in supplier evaluation and selection. This is reflected in the two-tailed probability values for tests of significance for these enablers shown in Table 10.6, which were lower than the five per cent level of significance. The highest ranking of quoted prices of materials in importance for supplier evaluation and selection by both suppliers and contractors is a reflection of how price-oriented the UK construction industry was.

One notable observation was that, in general terms, contractors ranked health and safety records as more important in supplier evaluation and selection than long-term relationships, suppliers' management and administrative ability, and locations of suppliers in relation to projects. Suppliers and contractors also rank-ordered both health and safety records, and environmental records of suppliers more important than use of information and communication technologies in materials supply logistics.

Overall, results of the rank ordering of enablers reflected entrenched traditional practices in the construction industry in which the fostering of long-term trading relationships and the use of information and communication technologies had not yet taken centre-stage in improving performance in the supply of construction materials to support construction.

10.5 Usage of logistics performance indicators and enablers in supplier evaluation and selection

To further explore actual practices in materials supply logistics, comparisons were made of the extent to which contractors and suppliers said logistics performance indicators and enablers were considered in the evaluation and selection of suppliers. The indicators and enablers were examined separately and are displayed in Tables 10.7 and 10.8 respectively.

10.5.1 Logistics performance indicators

Table 10.7 shows no significant differences between levels to which both contractors and suppliers said cost-effectiveness, flexibility and value-added service provided by suppliers were considered in supplier evaluation and selection. However, two tailed probabilities for reliability and lead times of suppliers indicated significant differences in responses of the two groups.

Despite significant differences, both contractors and suppliers ranked reliability of suppliers as the most considered factor in supplier evaluation and selection. Contractors also rank-ordered cost-effectiveness as highly considered as reliability in the first position whereas suppliers assigned it the second position to reliability. There were no significant differences in response modes of the two groups for this performance indicator.

Lead time was seen by contractors as the second most considered indicator after reliability and cost-effectiveness, whereas suppliers ranked this indicator fourth. The two-tailed probability value of p=0.0032 shows that at the five per cent level of significance, the responses of the two groups were significantly different for this factor.

Both contractors and suppliers ranked flexibility in the third position. They also

Table 10.7: Comparison of extent various logistics performance indicators and enablers were used in supplier evaluation and selection

Legend of responses: 3 to 6= Occasionally to Always, 2 to 1=Never to Rarely
where 6=Always, 5=Very often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never

Performance Indicators		Suppliers: Combined responses 3 to 6	Suppliers: Combined responses 2 to 1	Suppliers: Total	Suppliers: Importance Index	Suppliers: Factors Ranking	Contractors: Combined responses 3 to 6	Contractors: Combined responses 2 to 1	Contractors: Total	Contractors: Importance Index	Contractors: Factors Ranking	Probability Wilcoxon-Mann-Whitney 2-Tailed p
Reliability of supplier	Frequency	30	0	30			35	0	35			
	% of total	100	0	100	0.79	1	100	0	100	0.87	1	0.0432
Cost-effectiveness	Frequency	29	1	30			35	0	35			
	% of total	96.7	3.3	100	0.77	2	100	0	100	0.87	1	0.0561
Lead time quoted by supplier	Frequency	30	0	30			35	0	35			
	% of total	100	0	100	0.7	4	100	0	100	0.8	2	0.0032*
Flexibility of supplier	Frequency	28	2	30			35	0	35			
	% of total	93.3	6.7	100	0.72	3	100	0	100	0.73	3	0.6983
Value-added service provided by supplier	Frequency	25	5	30			31	4	35			
	% of total	83.3	16.7	100	0.59	5	88.6	11.4	100	0.67	4	0.1171

* Statistically significant at 5% significance level

indicated that valued-added service was the least considered indicator in supplier evaluation and selection. It was ranked fourth by contractors and fifth by suppliers. There were no significant differences in responses for flexibility and value-added service between both groups.

Comparisons between Tables 10.5 and 10.7 show that suppliers were consistent in rank-ordering the importance of performance indicators and in the extent to which they considered them used in supplier evaluation and selection. Over 80 per cent of both contractors and suppliers responded that all the five performance indicators were considered "Occasionally" to "Always" in the evaluation and selection of suppliers by contractors.

10.5.2 Logistics enablers

Of the nine enablers, Table 10.8 shows that contractors and suppliers did not exhibit significant differences in their response in the extent to which quoted prices, management and administrative ability of suppliers, location of suppliers and information and communication technologies were used in supplier evaluation and selection. They did, however, exhibit significantly different response modes in the extent they said long-term relationships, capability of suppliers, health and safety records of suppliers, quality management systems of suppliers and environmental records of suppliers were used in supplier evaluation and selection.

Table 10.8 shows that contractors ranked quoted prices and long-term relationships as the most frequently considered enablers in supplier evaluation and selection. Suppliers placed quoted prices in the first place but ranked long-term relationships in the second place. There were no significant differences in responses between the two groups over quoted prices. However, responses of contractors and suppliers over long-term relationships were significantly different.

Contractors ranked both capability and health and safety records of suppliers as the second most considered enablers in supplier evaluation and selection while suppliers ranked them in the fourth and eighth positions respectively. Responses of the two groups over these enablers were significantly different at $\alpha=0.05$

At the 5 per cent level of significance, the two-tailed probability of p = 0.0044 concerning the extent quality management systems of suppliers were considered in supplier evaluation and selection indicated significantly different response modes between contractors and suppliers. This enabler was ranked third in frequency of usage by contractors and fifth by suppliers. Responses of contractors and suppliers about the extent to which location of suppliers in relation to projects was considered in supplier evaluation and selection did not show any significant difference with p = 0.1484 at the 5 per cent level of significance. This enabler was ranked fourth in the level of usage by contractors and third by suppliers. There was also no significant difference between responses of the two groups about the extent to which management and administrative ability of suppliers were taken into account in supplier evaluation and selection. Contractors ranked this enabler in the fifth place and suppliers in the sixth.

Environmental records of suppliers were ranked sixth in the extent to which they were considered in supplier evaluation and selection by contractors whereas suppliers ranked this enabler seventh. With the two-tailed probability, p = 0.0041, responses of the two groups were significantly different at the five per cent level of significance. Contractors exhibited higher levels of consideration of the enabler than suppliers.

Both contractors and suppliers ranked information and communication technologies as the least used enabler in supplier evaluation and selection. There were no significant differences in the responses of the two groups over this enabler.

Over 55 per cent of both contractors and suppliers responded that all the identified enablers were considered in supplier evaluation and selection "Occasionally" to "Always".

Table 10.8: Comparison of extent enablers were used in supplier evaluation and selection

Legend of responses: *3 to 6= Occasionally to Always, 2 to 1=Never to Rarely*
where , 6=Always, 5=Very often, 4=Often, 3=Occasionally, 2=Rarely, 1=Never

Enablers	Suppliers					Contractors					Probability
	Combined responses		Total	Importance	Factor	Combined responses		Total	Importance	Factor	Wilcoxon-Mann-Whitney
	3 to 6	2 to 1		Index	Ranking	3 to 6	2 to 1		Index	Ranking	2-Tailed p
	29	1	30			32	3	35			
Quoted price only	96.7	3.3	100	0.71	1	91.4	8.6	100	0.71	1	0.7744
Long-term relationships with	25	5	30			33	2	35			
suppliers (such as partnering)	83.3	16.7	100	0.6	2	94.3	5.7	100	0.71	1	0.0233*
Capability (financial strength,	20	9	29			32	3	35			
production technology & efficiency,	69	31	100	0.53	4	91.4	8.6	100	0.68	2	0.0031*
experience)											
Health and Safety records	14	16	30			30	30	35			
of suppliers	46.7	53.3	100	0.42	8	85.7	14.3	100	0.68	2	0.0002*
Quality management systems	19	11	30			31	4	35			
(TQM, QA, QC, quality of products)	63.3	36.7	100	0.52	5	88.6	11.4	100	0.67	3	0.0044*
	23	7	30			34	1	35			
Location of supplier in relation to project	76.7	23.3	100	0.57	3	97.2	2.8	100	0.63	4	0.1484
Management and administrative	17	12	30			27	8	35			
capability	58.6	41.4	100	0.48	6	77.1	22.9	100	0.6	5	0.484
Environmental record	16	14				27	8	35			
	53.3	46.7	30	0.46	7	77.1	22.9	100	0.56	6	0.0041*
Information and	17	12	29			22	13	35			
communication technologies	58.6	41.4	100	0.42	8	62.9	37.1	100	0.5	7	0.1445
(IDBMS, EDI, bar codes, etc.)											

* Statistically significant at 5 % significance level

10.6 Importance attributed to various factors in materials management

Two tailed probability tests in Table 10.9 show that with the exception of selection of suppliers by contractors, both contractors and suppliers were in agreement about the level of importance of the various materials management processes to support construction. All the probability test values, with the exception of that for selection of contractors, were greater than the five per cent significance level, implying that there were no significant differences in importance attached to the practices by both contractors and suppliers. Meanwhile, responses to the practice of supplier selection by contractors indicated a significant difference in importance attached to it by both contractors and suppliers.

Materials planning by site staff was considered the most important practice by contractors and was ranked second in importance by suppliers. Management capability of site personnel was ranked third in importance by both contractors and suppliers. No significant differences in responses of contractors and suppliers against the two practices were observed. Thus both groups considered the ability of site personnel to be critical to improving the supply of materials to support construction.

While contractors ranked supplier selection second in importance, suppliers ranked this factor fifth. Contractors and suppliers exhibited significant differences in their responses to this practice. With the exception of the 'Use of information and communication technologies', all the practices were considered to range between 'Average Importance' to 'Extreme Importance' by more than 66 per cent of both contractors and suppliers. Use of information and communication technologies was considered to be of 'Little Importance' to 'No Importance' by 56.7 per cent of suppliers and 35.3 per cent of contractors. Thus while capabilities of site personnel were considered more important in improving materials supply to support construction, contractor-supplier interface practices were also considered to have significant impact on the supply process.

Table 10.9: Comparison of importance attributed to various factors in improving materials management

Legend of responses: 3 to 5=Important, 2 to 1=Not Important
where 5=Exterme Importance, 4=Considerable Importance, 3=Average Importance, "2=Little Importance, 1=No Importance

Practices		Suppliers					Contractors					Probability Wilcoxon-Mann-Whitney
		Combined responses		Cases	Importance	Factor	Combined responses		Cases	Importance	Factor	
		3 to 5	2 to 1	m	Index	Ranking	3 to 5	2 to 1	n	Index	Ranking	2-Tailed p
Materials planning by site staff	Frequency	30	0	30			34	1				0.0714
	% of Total	100	0	100	0.82	2	97.2	2.8	35	0.87	1	
Selection of suppliers by	Frequency	28	1	29			35	0				
contractors	% of Total	96.5	3.5	100	0.74	5	100	0	35	0.84	2	0.0042*
Management capability of site	Frequency	29	1	30			35	0				
personnel	% of Total	96.7	3.3	100	0.81	3	35	0	35	0.82	3	0.6263
Customer service levels provided	Frequency	28	2	30			35	0				
by suppliers	% of Total	93.4	6.6	100	0.77	4	100	0	35	0.8	4	0.7496
Improving contractor-supplier	Frequency	27	3	30			35	0				
relationships	% of Total	90	10	100	0.77	4	100	0	35	0.8	4	0.7164
Communication between Head	Frequency	26	4	30			34	1				
Office and suppliers	% of Total	86.7	13.3	100	0.72	6	97.1	2.9	35	0.8	4	0.0716
Communications between site	Frequency	29	1	30			33	2				
and suppliers	% of Total	96.7	3.3	100	0.83	1	94.2	5.8	35	0.79	5	0.3172
Early payment of suppliers for	Frequency	25	5	30			30	5				
delivered materials	% of Total	83.3	16.7	100	0.68	7	85.7	14.3	35	0.64	6	0.2111
Stationing a materials manager	Frequency	20	10	30			24	11				
on site by contractors	% of Total	66.7	33.3	100	0.58	8	68.6	31.4	35	0.6	7	0.8082
Use of Information and	Frequency	13	17	30			13	22				
communication technologies like bar codes, EDI, IDBMS, etc.	% of Total	43.3	56.7	100	0.45	9	35.3	64.7	34	0.43	8	0.7014

* Statistically significant at the 5% significance level

10.7 Summary

This chapter has presented an analysis of group differences in the responses by contractors and suppliers to: usage of information and communication technologies in materials supply logistics processes; contractor-supplier relationships; importance attached to logistics factors; extent of usage of logistics factors in supplier evaluation and selection; and importance attributed to various factors in improving materials supply logistics to support construction.

With the exception of bar codes, there were no significant differences in the usage of information and communication technologies in materials supply logistics processes within and between surveyed suppliers and contractors. A significant difference was noted in the usage of bar codes in internal materials management by contractors and suppliers. Overall, the usage of electronic data management technologies both within and between contractors and suppliers was in comparison lower than that of the telephone, facsimile and post among surveyed contractors' administrative offices, suppliers and construction sites. This implies that the potential to lower costs and reduce cycle times that could result from increased usage of these technologies as reported in the literature was still under-exploited among the surveyed contractors and suppliers.

Generally, responses to statements about contractor-supplier relationships suggested existence of relationships between contractors and suppliers which tended towards mutual benefit even though significant differences in responses were observed in many of the statements. Major dysfunctional supply chain practices by contractors included delayed payment to suppliers for materials already delivered and not giving ample time to suppliers to prepare bids when they were invited to tender for the supply of materials. To improve performance in the supply of construction materials contractors should endeavour to enhance collaboration in these and all those areas which impact adversely on contractor-supplier relationships where significant differences in responses were observed.

Tests of group differences among performance indicators exhibited significant differences in the importance attached to cost-effectiveness and lead times of suppliers. Responses of the two groups were also significantly different in the extent to which they said reliability and lead time were considered in supplier evaluation and selection. Despite these differences, over 80 per cent of both contractors and suppliers perceived all the performance indicators to be of 'Average Importance' to 'Extreme Importance' and to be 'Occasionally' to 'Always' considered in supplier evaluation and selection.

Among enablers, significant differences were observed in the importance attached to capability, health and safety records of suppliers, environmental records of suppliers and the usage of information and communication technologies in materials supply logistics processes. As regards the extent to which the enablers were said to be used in supplier evaluation and selection, significant differences were noted in responses to long-term relationships, capability, health and safety records, quality management systems and environmental records of suppliers. With the exception of health and safety records of suppliers, over 50 per cent of both surveyed suppliers and contractors responded that all the enablers were 'Occasionally' to 'Always' considered in supplier evaluation and selection. Health and safety records of suppliers were said to be 'Rarely' to 'Never' considered in supplier evaluation and selection by 53.3 per cent of the surveyed suppliers.

Thus, all of the identified logistics performance indicators and enablers were generally considered to be important and were said to be taken into account by the majority of the surveyed contractors and suppliers. The identified differences in responses of the two groups to the importance of performance indicators and the extent to which they are considered in supplier evaluation and selection, nevertheless, point to areas where there were still some misunderstandings between contractors and suppliers. Improving understanding of practices and perceived importance of the performance indicators and enablers among suppliers of the way contractors do business could lead to performance improvements in materials logistics.

With the exception of selection of suppliers by contractors, there were no significant differences between contractors and suppliers about the importance of various materials management practices for improving the supply of materials to support construction. Though both groups agreed that supplier selection was of 'Considerable Importance' in improving the supply of construction materials, their responses were significantly different. The use of information and communication technologies was seen as having little importance by both groups in improving performance in the supply of construction materials.

Chapter 11 further prioritises and explores the levels of contribution of logistics performance indicators and enablers to customer service, using the Analytic Hierarchy Process, in order to identify the importance interviewed companies attached to the logistics factors to further help explain industry behaviour.

CHAPTER ELEVEN

REVIEW OF THE ANALYTIC HIERARCHY PROCESS AND ANALYSIS OF AHP INTERVIEW RESULTS

CHAPTER ELEVEN

REVIEW OF THE ANALYTIC HIERARCHY PROCESS (AHP) AND ANALYSIS OF AHP INTERVIEW RESULTS

11.1 Introduction

Results of questionnaire surveys of contractors and suppliers and open ended interview questions in the second phase of the research programme were analysed and presented in Chapters 8, 9 and 10. Nine contractors and five suppliers from the surveyed companies agreed and participated in more detailed interviews where the Analytic Hierarchy Process (AHP) model was applied. This chapter presents a review of the AHP and an analysis of the AHP model evaluations by the nine contractors and five construction materials suppliers. In addition to the

While Chapters 8 and 9 ranked the logistics factors via relative indices, the AHP was used in this chapter to quantify the perceived relative contributions of the factors to improved customer service in the supply of construction materials. The aim of this was to establish how important the factors were with relative to each other. Comparisons have been made of percentage contributions of the factors by contractors and suppliers to establish whether or not there were differences in the perceived importance the two groups attached to the logistics factors. Justification for selecting and using the AHP in the interviews discussed in this chapter has been presented in Chapter 7.

11.2 Decision making with the Analytic Hierarchy Process

The AHP is a problem-solving framework whose structure systematically represents the elements of a problem into a hierarchy. The AHP organises a problem into smaller parts, which when pairwise compared lead to development of priorities in the hierarchy.

Hierarchies are well recognised in the physical, behavioural and systems science as powerful mental constructs for studying complex systems. Even if used only to understand the structure of a system or the interaction of its parts, a hierarchical model of any system is a powerful means for representing the constituent parts of the problem being studied.

There are many kinds of hierarchies (Saaty, 1983). A hierarchy is a particular type of system, which is based on the assumption that the entities, which have been identified, can be grouped into disjoint sets, with the entities of one group influencing the entities of only one other group, and being influenced by the entities of only one other group (Saaty, 1996). The AHP falls in the category of dominance hierarchies. It is based on the theory of influence of elements of lower levels on the main focus or objective of the hierarchy. The three principles for solving problems with the AHP are decomposition; comparative judgements and synthesis of priorities (Saaty, 1983). The method for developing the analytic hierarchy model and analysing the solution to a problem is given in Figure 11.1.

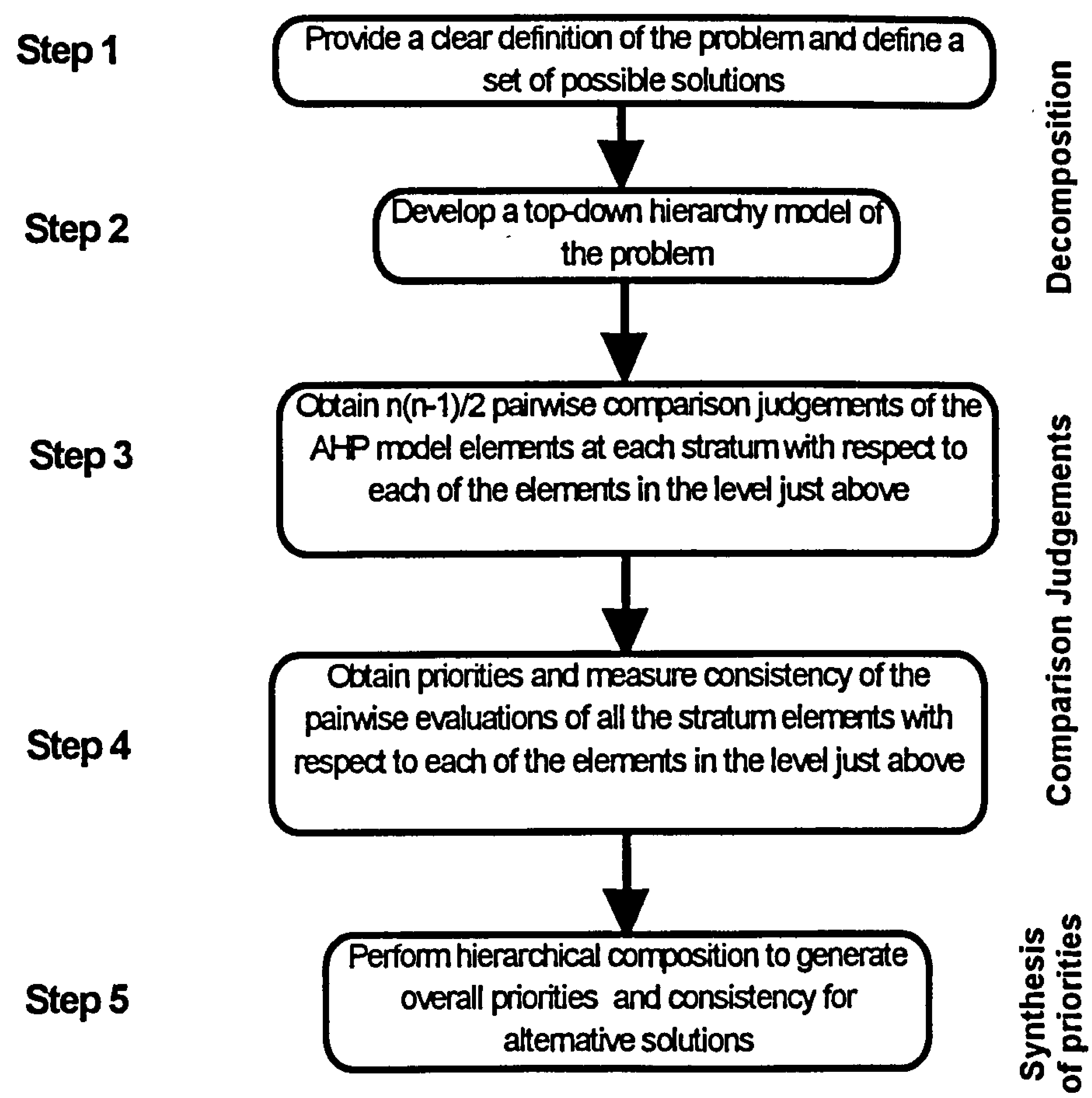


Figure 11.1: Steps for formulating an Analytic Hierarchy Process model

11.2.1 Decomposition

Decomposition involves structuring a problem into its basic elements, working from the focal objective down through various levels; from the more general to particular and more definable elements. Then starting from the definite elements at the bottom, an intermediate set of higher criteria that decomposes into these elements are found which are themselves decompositions of higher level criteria identified in the downward process. Using this approach the focal objective of the hierarchy can be linked to its bottom level in sequential intermediate levels. This constitutes the basic law of hierarchic decomposition, which is that priorities of elements in the last level reflects as best as possible their relative impact on the focal objective of the hierarchy. Generally, the bottom level of the hierarchy contains resources to be allocated or alternatives among which choice is to be made (Saaty, 1983).

There is no single universal AHP hierarchy (Wind and Saaty, 1980). This is an advantage because it offers flexibility to fit unique or specific needs of problem situations. The AHP can suitably be applied to modelling any decision-making or choice situation that can be hierarchically represented on more than one level.

Following Steps 1 and 2 in the AHP methodology in Figure 11.1, a decision model for evaluating contributions of logistics performance indicators and enablers to improved customer service in the supply of construction materials was constructed as shown in Figure 11.2. The defined overall objective in this case was improving customer service, otherwise construed as ensuring efficient, cost-effective construction materials supplies. The logistics performance indicators and enablers were identified from literature in Chapter 7 and confirmed by industry experts through self-administered postal questionnaires, one to contractors and the other to construction materials suppliers, already analysed in Chapters 8 and 9.

A logistics performance 'indicator' is defined as a metric by which a supplier can be evaluated in satisfying customer requirements and an 'enabler' is a characteristic which makes it possible for a supplier to meet customer requirements.

11.2.1.1 Logistics performance indicators

The NEVEM-workgroup (1989) identified lead time, delivery reliability, flexibility and inventory level as factors that directly relate to a suppliers' performance in meeting customers' requirements. The same factors are included in items used by companies in the weighted rating factor system for evaluating suppliers (Dobler et al, 1990; Stukhart, 1995; Korpela and Tuominen, 1996). The performance indicators which include reliability, cost-effectiveness, lead time, flexibility and value added-service are defined in Chapter 7.

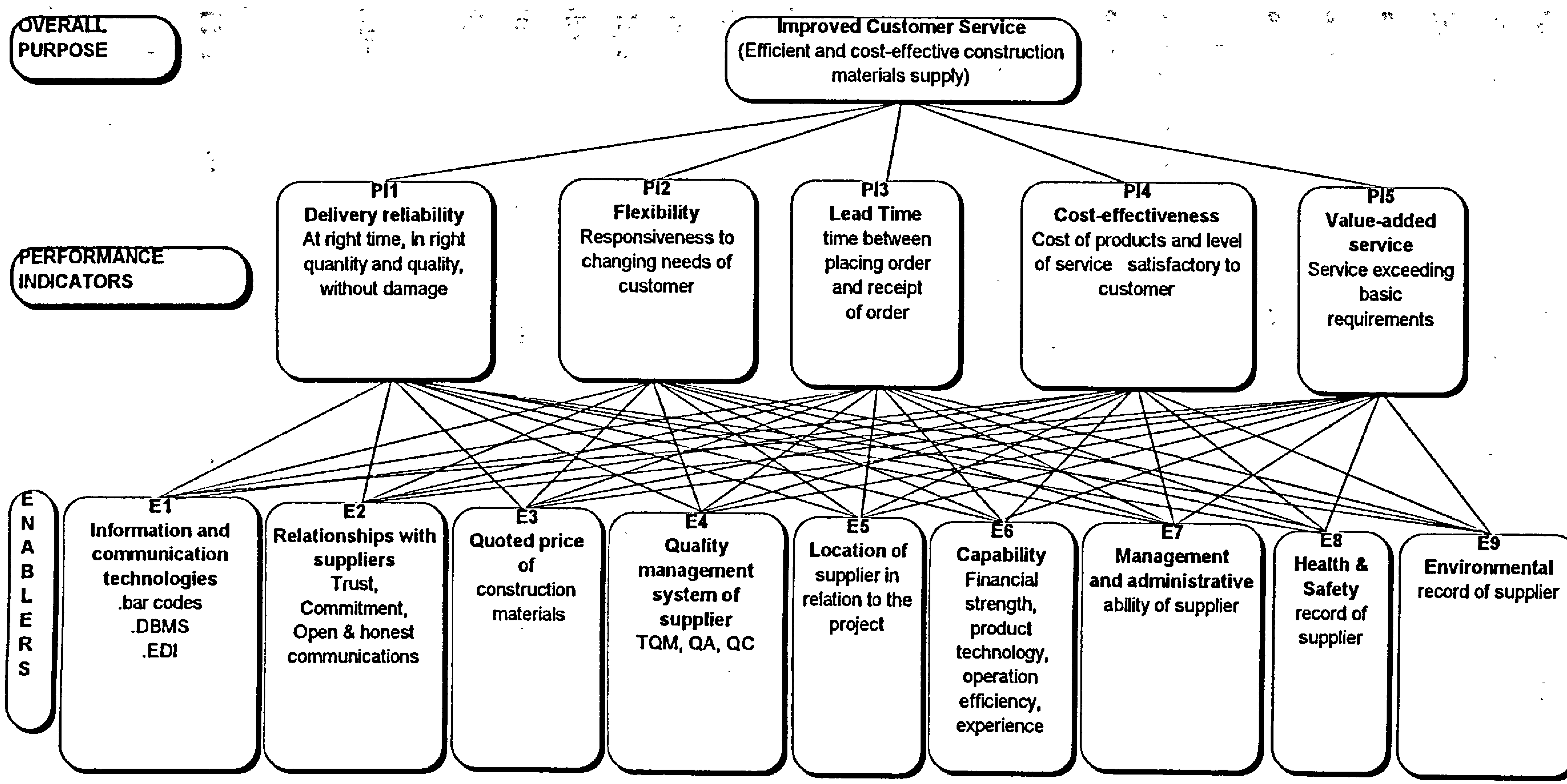


Figure 11.2: Analytic Hierarchy Model for construction materials supply logistics

11.2.1.2 Logistics enablers

Enablers are those characteristics of a supplier which help a company achieve superior performance as measured with respect to logistics performance indicators. The enablers were also identified in literature and are outlined in Chapter 7. They include:

- location of suppliers with respect to projects;
- quality management systems of suppliers;
- capability assessed in terms of financial strength, product technology and operation efficiency, and experience of the supplier;
- management and administrative ability of a supplier;
- quoted price;
- contractor-supplier relationships;
- information and communication technologies;
- environmental records; and
- health and safety records of suppliers.

The rationale of the model in Figure 11.2 is that customer satisfaction in delivery of construction materials is a function of the impact of each of the performance indicators on customer service. However, optimisation of performance indicators is dependent upon an array of factors which have been termed enablers. Thus, through their contribution to performance indicators, enablers can be viewed as the critical success factors which influence improved customer service, and consequently its derivative, customer satisfaction, in the delivery of construction materials.

After decomposing and constructing an AHP model of a problem, comparative judgements (steps 3 to 4) of the elements in the model can then be made.

11.2.2 Comparative judgements

A measurement methodology is used to set priorities among elements of every stratum. This is accomplished by asking the decision maker(s) to evaluate stratum elements pairwise with respect to elements in the next higher stratum. This measurement methodology is the central feature of the AHP and constitutes the framework for data collection and analysis.

The 9-point scale in Table 11.1 is widely used for making numerical judgements in the AHP pairwise comparisons (Anderson et al, 1986; Dyer and Forman, 1992; Korpela and Tuominen; 1996; Thompson, 1994; and Saaty, 1983). The progenitor of the AHP, Thomas L. Saaty strongly recommends the scale and argued that it has been thoroughly validated for effectiveness (Saaty, 1983).

Table11.1: The AHP response scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one activity over another	Experience and judgement slightly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest order of affirmation
2, 4, 6, 8	Intermediate values between the two judgements	When compromise is needed
Reciprocals of judgments	If activity i has one of the above numbers assigned to it when compared to with activity j, then j has the reciprocal value when compared with i.	

Using the given scale, the decision maker or the group of people involved in making a decision exercise judgement about the dominance of each element at a given stratum over the other elements at the same level with respect to each element at the next higher level. This leads to formation of matrices from which relative weights of the elements with respect to each element of the stratum above can be determined. Relative contributions of enablers to performance indicators, and consequently to the overall purpose which is improved customer service, can be evaluated. Such an evaluation can indicate the relative importance of enablers in contributing to efficient and cost effective materials logistics.

11.2.3 Synthesis of priorities

Priorities (step 5 in Figure 11.1) are next calculated. The constructed matrices are used for computing weighted priorities for elements of a given stratum over the other elements of the same stratum with respect to each element of the level just above. In this way the priorities of the enablers can be determined.

The mathematical procedure for arriving at the priorities involves developing matrices constructed using pairwise comparisons (Saaty, 1983). Repeating the comparisons for all elements at each level with respect to criteria at the next higher level, relative weights for all elements in relation to higher objectives are calculated. The computation to arrive at the prioritisation of elements has been made simpler by the use of a software package called Expert Choice.

11.2.4 Consistency test

Any measurement, even when an instrument has been used, is subject to errors from two sources: the experiment itself and the measuring instrument (Oppenheim, 1992; Saaty, 1983). Errors in measurement can lead to inconsistent conclusions. In practice, however, perfect consistence in measurements is unattainable.

Different measurement methods have their own approaches for assessing the amount of error in a measurement. Every response system requires to satisfy some criteria imposed by the algebraic measurement model employed as a test of validity. With the AHP, such a test turns out to be the consistency ratio. Obtaining validity with AHP is not a statistical procedure (Saaty, 1983).

After synthesis of priorities, a consistency test is performed to assess the quality of the judgements made during the pairwise comparisons. From the consistency index, the consistency ratio is calculated. All these calculations are performed automatically via Expert Choice when carrying out the comparison judgements.

An example of the calculation of a consistency ratio follows:

Suppose there are n objects $A_1, \ldots\ldots, A_n$ whose vector of corresponding weights $w = (w_1, \ldots\ldots, w_n)$ is known. The matrix of pairwise comparisons of the n objects therefore is

$$A = \begin{array}{c|ccccc|} & A_1 & . & . & . & A_n \\ A_1 & w_1/w_1 & . & . & . & w_1/w_n \\ . & . & & & & . \\ . & . & & & & . \\ . & . & & & & . \\ A_n & w_n/w_1 & & & & w_n/w_n \end{array}$$

Then $Aw = nw$

where A = pairwise comparison matrix

w = vector of weights

n = largest eigenvalue of A

Matrix A has a unit rank, hence all but one of its eigenvalues $\lambda_1, \ldots, \lambda_n$ are zero.

Since $\sum_{i}^{n} = {}_1\lambda_n$ = trace (A) = n = maximum eigenvalue = λ_{max}

Therefore $Aw = \lambda_{max}\, w$

It has been shown that $\lambda_{max} \geq n$ always (Saaty, 1980) and that $(\lambda_{max}-n)/(n-1)$ serves as the consistency index which gives the departure from consistency in estimating the ratios w_i/w_j with consistency obtaining if and only if $\lambda_{max} = n$

Thus, the consistency index can be calculated.

Since $CI = (\lambda_{max} - n)/(n-1)$

where CI = consistency index

λ_{max} = maximum eigenvalue of the pairwise comparison matrix

n = number of elements

The consistency (CR) ratio may then be determined by taking the ratio of the consistency index with one of the following numbers to see if consistency is 10 per cent or less:

n	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Values of the consistency ratio below 0.1 are preferred. Values of the consistency ratio greater than 0.1 indicate that decisions made during the pairwise comparisons were inconsistent and should be revised. Inconsistency can arise due to any or a combination of: a clerical error; lack of information or experience about the factors being compared; imperfection in the real world; or inadequate model structure (Dyer and Forman, 1992).

The first approach in the revision is to change the manner in which questions are asked in the pairwise comparisons. If this fails, the problem should be more accurately structured by arranging elements under more meaningful criteria. A return to the second step in the restructuring of the process becomes necessary.

From the two questionnaire surveys, nine contractors and five suppliers agreed to take part in the interviews. The sections that follow provide a description of the interviewed companies and analysis of interview results.

11.3 Analytic Hierarchy Process model evaluation interviews

Before soliciting for comparative judgements of experts, the model evaluation process was pre-tested by two 'stand-in experts'. Changes to the model and the evaluation procedure were made following their suggestions.

At the outset, each interviewee was briefly introduced to Expert Choice before they evaluated the AHP model following the steps outlined in Figure 11.3.

INTRODUCTION OF EXPERTCHOICE TO INTERVIEWEE

Brief explanation & demonstration of AHP model evaluation procedure using expertchoice on a lap-top computer

ACTUAL MODEL EVALUATION BY INTERVIEWEE

Phase I

Parirwise comparisons of performance indicators w.r.t. Goal of Improved Customer Service

Pairwise comparison of performance indicator PI1 against performance indicators PI2, PI3, PI4 & PI5 w.r.t. Improved Customer Service; then pairwise comparison of PI2 against, PI3, PI4 & PI5 w.r.t. Improved Customer Service; then pairwise comparison of PI3 against PI4 & PI5 w.r.t. Improved Customer Service ; and finally pairwise comparison of PI4 against PI5 w.r.t. Improved Customer Service, checking consistency each time and revising judgements if necessary

Phase II

Pairwise comparisons of enablers w.r.t. performance indicators

Pairwise comparison of enabler E1 against enablers E2, E3, E4, E5, E6, E7, E8 & E9 w.r.t. PI1; and then pairwise comparison of E2 against E3, E4, E5, E6, E7, E8 & E9 w.r.t. PI1; ....; and then pairwise comparison of E8 against E9 w.r.t. PI1. Then pairwise comparison of E1 against E2, E3, E4, E5, E6, E7, E8 & E9 w.r.t. PI2;....; up to pairwise comparison of E8 against E9 w.r.t. PI2. The evaluation cycles continue until pairwise comparison of E8 against E9 w.r.t. PI5, checking consistency each time and improving it by revising judgements if necessary.

Figure 11.3: Steps followed during AHP model evaluation interviews

11.4 Types of interviewed construction companies and individuals

Background information on types of interviewed construction companies and individuals who represented them is discussed in sub-sections 11.4.1 and 11.4.2.

11.4.1 Interviewed contractors

Table 11.2 gives background information on the interviewed individuals and types of construction companies they worked for. The companies had 1996/97 annual turnover ranging from £80 million to £400 million and workforce ranging from 120 to 3,500 people. All these companies were large contractors listed among the top 100 UK contractors (Construction News, 1996).

11.4.2 Interviewed experts from construction companies

Table 11.2 also shows titles, types and years of experience of interviewed experts who represented the construction companies. All except one buyer held senior positions in their companies. Their years of experience in the construction industry ranged from 8 to 36 and all were either directly involved in procurement/materials management or had detailed knowledge of the function.

Table 11.2: Itinerary for evaluation of AHP model by construction industry experts

Name of contractor and date interviewed	Business area of interviewed	Turnover £m/annum	Workforce	Interviewee		
				Position in company	Type of experience in Industry	Experience in construction industry
C1: Christiani & Nielsen Ltd 18-Nov-97	Building, Civil & Process industries	80	450	Purchasing Manager	Buying	25 years
C2: McNickolas Construction 19-Nov-97	Building, Civil & Process industries	180	3500	Purchasing Manager	Purchasing (Civil)	18 years
C3: Simon Construction 21-Nov-97	Building	100	500	Procurement Manager	Buying	15 years
C4: Jarvis Construction 25-Nov-97	Building & Civil	260	250	Marketing Manager	Marketing & business development for major contractors	11 years
C5: Amec - Civil Division 28-Nov-97	Civil Engineering	400	500	Head of Procurement	Procurement	30 years
C6: Shepherd Construction 04-Dec-97	Building	200	1500	Buyer	Estimating/buying	8 years
C7: Norwest Construction 05-Dec-97	Building & Civil	300	1250	Procurement Director	Procurement	36 years
C9: Kvaerner 10-Dec-97	Civil Engineering	150	600	Head of Procurement	Purchasing (major civil projects)	27 years
HBG Kyle Stewart 16-Dec-97	Building	120	120	Procurement Coordinator	Purchasing	24 years

To illustrate the evaluations by example, pairwise comparisons of performance indicators with respect to the goal of improved customer service by contractor C1 resulted in the direct output from Expert Choice of judgements displayed in Figure 11.4. With reference to the scale in Table 11.1, the entries in Figure 11.4 show pairwise comparison judgements of performance indicators where contractor C1 assessed cost-effectiveness to be 3 times more important than reliability and so on.

Synthesised pairwise comparison judgements by contractor C1 of both performance indicators and enablers with respect to the goal of ensuring efficiency and cost-effectiveness in the supply of construction materials produced direct Expert Choice results shown in Figure 11.5.

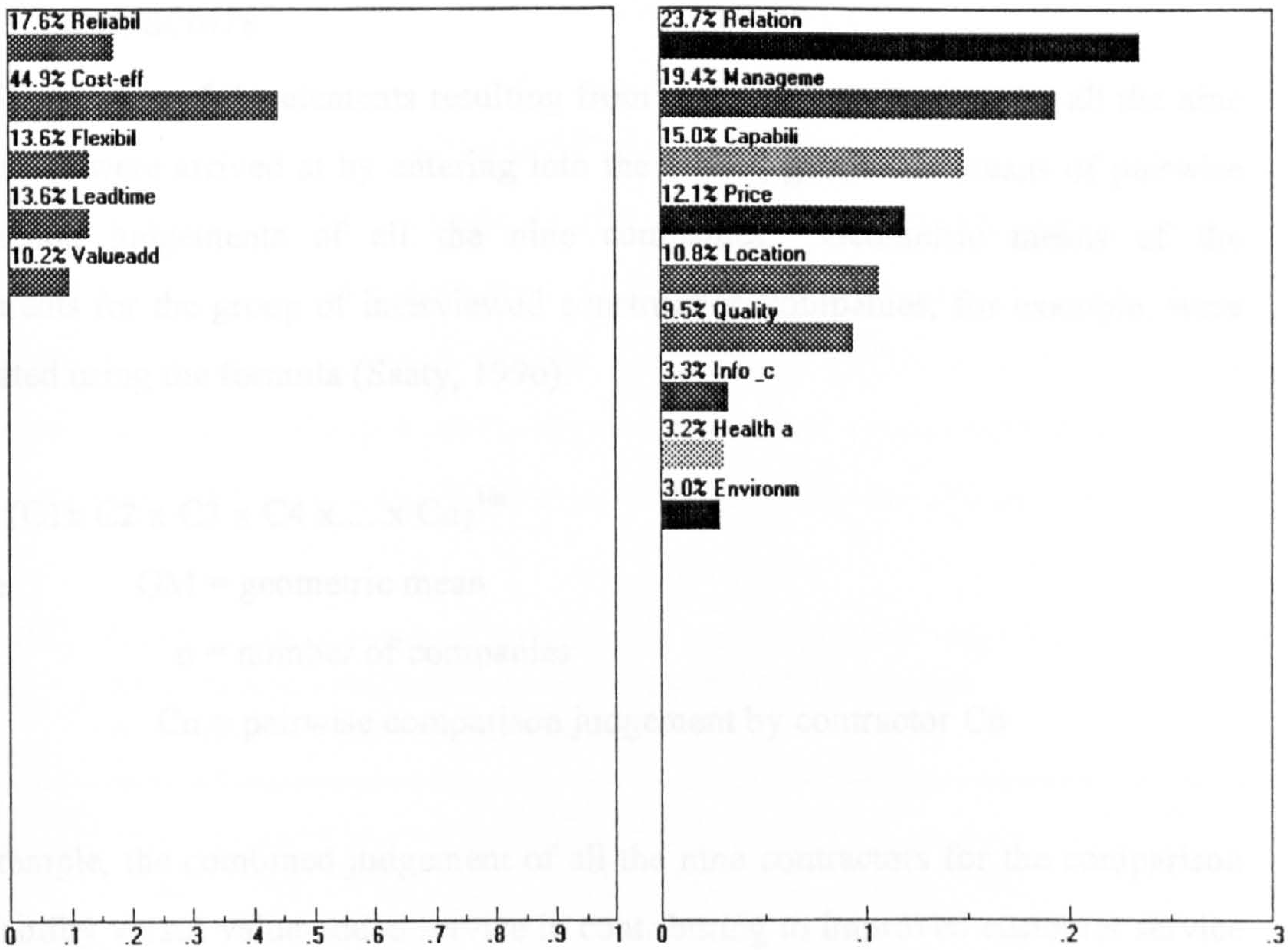
Goal: Achieving efficiency and cost-effectiveness in construction materials supply logistics

	Reliability	Cost-effectiveness	Flexibility	Lead time	Value-added service
Reliability	1.0	1/3	1.0	1.0	3.0
Cost-effectiveness	3.0	1.0	3.0	3.0	5.0
Flexibility	1.0	1/3	1.0	1.0	1.0
Lead time	1.0	1/3	1.0	1.0	1.0
Value-added service	1/3	1/5	1.0	1.0	1.0

Abbreviation	Definition
Goal	Improved Customer Service: Efficient, cost-effective logistics
Reliability	Delivery of products at right time, in right quantity & quality without damage
Cost-effectiveness	Level of service or cost of goods satisfactory to customer
Flexibility	Responsiveness to changing needs of customer
Lead-time	Time between placing order and receipt of order
Value-added service	Service level exceeding basic requirements

Figure 11.4: Pairwise comparison judgements by contractor C1

Goal: Improved customer service (efficient & cost-effective logistics)



Abbreviation		Definition
Reliabil:	Reliability	Delivery of products at right time, in right quantity & quality without damage
Cost-eff:	Cost-effectiveness	Level of service or cost of goods satisfying to customer
Flexibil:	Flexibility	Responsiveness to changing needs of customer
Leadtime:	Lead-time	Time between placing order and receipt of order
Valueadd:	Value-added	Service level exceeding basic requirenments

Relation:	Relationships	Trust, commitment to agreed goals, open & honest communications
Manageme:	Management	Management and administrative ability of supplier
Capabili:	Capability	Financial strength, technology, operation efficiency, experience.
Price:	Price	Quoted price of materials or service
Location:	Location	Location of supplier in relation to project
Quality:	Quality Management	Quality management systems, quality of products
Info-c:	Information & Communication	Infomation and communication tecnologies
Health a:	Health and Safety record	Health and safety of record of supplier
Environm:	Environmental record	Environmental record of supplier

Figure 11.5: Synthesised pairwise comparison judgements by contractor C1

Figure 11.5 shows percentage contributions of both performance indicators and enablers to improved customer service.

11.4.3 Combined evaluation of the AHP model by all nine contractors

Overall priorities of the elements resulting from combined evaluations by all the nine contractors were arrived at by entering into the model, geometric means of pairwise comparison judgements of all the nine companies Geometric means of the judgements for the group of interviewed construction companies, for example, were calculated using the formula (Saaty, 1996):

$GM = (C1 x C2 x C3 x C4 x.....x Cn)^{1/n}$

Where: GM = geometric mean

n = number of companies

Cn = pairwise comparison judgement by contractor Cn

For example, the combined judgement of all the nine contractors for the comparison of reliability versus value-added service in contributing to improved customer service was arrived at by taking the geometric mean of the judgements by all the nine contractors in the calculation shown below:

$GM = (3x6x3x3x5x5x9x7x7)^{1/9} = 4.95 = 5$ (in the pairwise comparison scale),

Where; contractor C1 considered reliability to be 3 times more important than value-added service (see Figure 11.4), C2 considered reliability to be 6 times more important than value added service, and so on.

The resulting geometric means were rounded off to the nearest whole number. Then overall priorities and corresponding inconsistency ratios were derived by entering the geometric means of all the elements as combined group pairwise comparison judgements in the original model.

11.4.4 Discussion of AHP model evaluations by contractors

Evaluations of the AHP model by each of the nine contractors and that resulting from using the geometric means of all the contractors yielded inconsistency ratios equal to or less than 10 per cent for both logistics performance indicators (Table 11.3) and enablers (Table 11.4).

11.4.4.1 Logistics performance indicators

Among performance indicators, reliability of a supplier was ranked highest followed in second place by the cost-effectiveness of the service provided by a supplier in contributing to improved customer service. Overall, reliability of a supplier was considered to contribute 42.6 per cent to improved customer service compared to 25.6 per cent contribution by the cost-effectiveness of the service provided by a supplier.

Table 11.3: Contractors' perceived percentage contribution of logistics performance indicators to efficient and cost-effective construction materials supplies

Performance Indicators	Contractor									Overall Evaluation
	C1 (%)	C2 (%)	C3 (%)	C4 (%)	C5 (%)	C6 (%)	C7 (%)	C8 (%)	C9 (%)	(%)
Reliability	17.6	32.9	43.8	35.2	26.7	36.1	44.8	49.3	61.3	**42.6**
Cost-effectiveness	44.9	17.3	24.8	35.2	41.8	29.4	31.6	20.2	13.8	**25.6**
Lead time	13.6	34.9	13.3	9.6	9.7	8	7.4	11.7	7.9	**13.1**
Flexibility	13.6	11.1	9.9	10.5	17.1	13.4	13.2	14.6	9.8	**11.5**
Value-added service	10.2	3.8	8.2	9.6	4.6	13.1	3.0	4.3	7.1	**7.2**
Overall	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Inconsistency	3.0	8.0	7.0	1.0	9.0	9.0	10.0	10.0	9.0	**1.0**

Lead time was considered the third most important performance indicator, estimated to contribute 13.1 per cent to improved customer service followed by flexibility of a supplier which was assessed to contribute 11.5 per cent. Value-added service was assessed to have the least impact on improved customer service at 7.2 per cent contribution.

11.4.4.2 Logistics enablers

Among characteristics which make it possible for a supplier to improve customer service in the delivery of materials, improved relationships were ranked highest (Table 11.4). It was assessed that improved contractor-supplier relationships

Table 11.4
Contractors' perceived percentage contribution of enablers to efficient and cost-effective construction materials supplies

Enablers	Contractors C1 (%)	C2 (%)	C3 (%)	C4 (%)	C5 (%)	C6 (%)	C7 (%)	C8 (%)	C9 (%)	Overall Evaluation (%)
Relationships	23.7	25.1	24.3	19.8	16.6	18.8	7.1	21	17.1	**19.9**
Capability	15	13.7	26.4	9.6	14.6	18.9	15.2	24	24	**18.6**
Mgt and admin ability	19.4	11	9.9	13.6	8.8	14.8	24.9	14	12.3	**13.9**
Quality Management	9.5	14.4	10.8	18.8	9.7	14.3	4.4	16	16.4	**13.8**
Price	12.1	16.1	16	6.2	19.9	4.5	15.4	4.2	7.2	**10.5**
Location	10.8	5	4.5	5.8	17.4	12	21.6	11	13.3	**10.2**
Info. & Comm. Techn.	3.3	4.6	2.7	6	5.4	10.1	3.7	5.5	4.2	**5.2**
Health & Safety records	3.2	6	3.2	11.2	4.1	3.5	3.8	2.3	3.4	**4.4**
Environmental records	3	4.1	1.8	8.9	3.4	3.1	3.8	2.1	2.1	**3.6**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Inconsistency Ratio	4.0	7.0	9.0	5.0	9.0	8.0	10.0	10.0	10.0	**2.0**

contribute 19.9 per cent to improved customer service in the supply of construction materials. The capability of a supplier viewed in terms of financial strength, operation efficiency, product technology and experience was ranked second in importance and was estimated to contribute 18.6 per cent to improved customer service. Meanwhile, administrative and management capability (people management) of a supplier, and the quality management system employed by a supplier were both considered to have almost the same impact on efficiency and cost-effectiveness. Administrative and management ability of a supplier was ranked third in importance at 13.9 per cent contribution, slightly above quality management systems of suppliers

in the fourth position at 13.8 per cent contribution. The closeness of the assessed percentage contributions of administrative and management ability on one hand and quality management systems used on the other was not surprising. During model evaluation, some interviewees commented that these were almost synonymous. Deployment of quality management systems like TQM was closely linked to an organisations' overall management and administrative effectiveness.

Surprisingly, both quoted prices of materials and location of suppliers in relation to projects were not considered to have much impact in enabling improvements in customer service. Price was ranked fifth and assessed to contribute 10.5 per cent while the location of a supplier was ranked sixth at 10.2 per cent contribution to improved customer service.

In comparison to other enablers, interviewed contractor experts did not regard information, communication and data management technologies to have significant impact over improved customer service in the supply of construction materials. The contribution attributed to this factor was 5.2 per cent almost as little as that by health and safety records of suppliers at 4.4 per cent and suppliers' environmental records at 3.6 per cent.

11.5 Evaluation of the AHP model by construction materials suppliers

11.5.1 Types of interviewed suppliers

Names, types and products dealt in by the interviewed suppliers are displayed in Table 11.4.. Quoted annual turnovers of the companies at the time of the interviews ranged from £203 million to £7.224 billion and their workforces from 776 to 40 400 people. In comparison, these companies were generally larger than interviewed construction companies.

11.5.2 Interviewed experts from supplier companies

Interviewed experts from supplier organisations were all senior managers with years of experience in the construction industry ranging from 4 to 26 (Table 11.5). Their experiences were in the domain of sales, marketing and general management and all were selected in their respective companies as individuals competent to answer questions relating to supply of construction materials and interactions of their companies with contractors.

Table 11.5: Schedule for evaluation of AHP model by construction materials suppliers

Name of supplier and date interviewed	Type of company	Products dealt in	Turnover £m/annum	Workforce	Interviewee		
					Position in company	Experience in construction industry	Type of experience in industry
ARC Central 15-Jan-98	Manufacturer/supplier/ subcontractor	*Coated roadstone, sand & gravel, hardstone*	435	776	Customer Services Manager	22 years	Estimating and sales
Tarmac Heavy Building Materials 20-Jan-98	Supplier/subcontractor	*Aggregates, ready-mixed concrete, concrete blocks, precast concrete products, contracting services*	1500	6000	Business Services Manager	4 years	Management (Systems Strategy)
Sheffield Insulations 22-Jan-98	Distributor	*Insulation and related products*	203	1000	Marketing Executive	9 years	Sales and Marketing
British Steel 27-Jan-98	Manufacturer/supplier	*Beams, columns, sheets & bearing pilings and other steel products used in construction*	7224	50400	General Manager for Marketing and Planning	26 years	General marketing
RMC 02-Feb-98	Manufacturer/supplier	*Ready-mixed concrete and general quarry products such as sand and aggregates*	4500	30000	Marketing and Public Affairs Manager	20 years	Selling, marketing and general management

11.5.3 Analysis of evaluations of the AHP model by construction materials suppliers

Evaluations of the AHP model by suppliers yielded inconsistency ratios equal to or less than 10 per cent (Tables 10.6 and 10.7).

11.5.3.1 Logistics performance indicators

From their experience, the interviewed experts from the five supplier organisations assessed reliability of a supplier to have the greatest impact on improved customer service. This indicator was assessed to contribute 39.4 per cent to improved customer service, followed by cost-effectiveness of the service provided which was assessed to contribute 27.2 per cent to improved customer service. Contribution of flexibility was assessed at 15.3 per cent, improved lead time at 10.8 per cent, and value-added service was assessed to have the least impact on improved customer service with a percentage contribution of 7.3.

Table 11.6: Suppliers' perceived percentage contribution of logistics performance indicators to efficient and cost-effective construction materials supply

Performance Indicators	Supplier S1 (%)	S2 (%)	S3 (%)	S4 (%)	S5 (%)	Overall evaluation (%)
Reliability	21.1	36.3	42.7	38.8	32.2	**39.4**
Cost-effectiveness	57.5	9.7	31.9	33.9	18.1	**27.2**
Flexibility	4.4	38.1	13	16.1	8.8	**15.3**
Lead time	12.5	11.2	5.2	8.4	18.8	**10.8**
Value-added service	4.5	4.7	7.2	2.8	22.1	**7.3**
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Inconsistency ratio	10.0	7.0	10.0	10.0	8.0	**2.0**

11.5.3.2 Logistics enablers

Experience of the interviewed suppliers suggested that through contributing more to reliability, cost-effectiveness, flexibility, improved lead times and value-added service, improved contractor-supplier relationships hold the greatest potential for improving the level of customer service offered by construction materials suppliers. This enabler was estimated to contribute 18.2 per cent to improved customer service, followed by quoted prices of materials with a contribution of 15.3 per cent.

Table 11.7: Suppliers' perceived percentage contribution of enablers to efficient and cost-effective construction materials supply

Enabler	Suppliers					Overall evaluation (%)
	S1 (%)	S2 (%)	S3 (%)	S4 (%)	S5 (%)	
Relationships	16.8	17.3	15.8	14.8	15.5	**18.2**
Quoted prices	23.6	11.5	25.4	23.5	9.6	**15.3**
Mgmt & admin ability	5.7	14.9	10.4	14.1	14.2	**13.3**
Capability	5.3	17.1	11.3	8	14.2	**12.9**
Location	32.2	12.1	18.7	1.8	17.7	**12.9**
Quality	9.2	8.1	7.6	16.9	11.1	**12.7**
Info & Comm. tech	1.9	9.5	6	16.9	8.3	**7.7**
Health & Safety records	2.6	4.3	2.7	2	4.3	**3.5**
Environmental records	2.7	5.2	2.1	2	5.1	**3.5**
Total	**100**	**100**	**100**	**100**	**100**	**100**
Inconsistency ratio	10	6	9	9	6	2

Traditional factors such as management and administrative ability of suppliers, capability of suppliers, location of suppliers in relation to projects and their quality management systems were also assessed to have significant influence on the levels of service offered by suppliers. Management and administrative ability of suppliers was assessed to have 13.3 per cent contribution, both capability and location of suppliers, 12.9 per cent contribution, and quality management systems 12.7 per cent contribution to improved customer service.

Perceptions of the interviewed supplier experts, either from lack of experience or more complex inter-related reasons such as ignorance and cost, were that use of information and communication technologies such as bar codes, EDI and IDBMS did not have much significance in improving customer service, with a contribution of only 7.7 per cent. The experts also did not consider health and safety, and environmental records of suppliers to have much bearing in improving efficiency and cost-effectiveness in the supply of construction materials, both factors having been assessed to have 3.5 per cent contribution to improved customer service.

11.6 Statistical comparisons of contractors' and suppliers' AHP evaluations

To test for levels of agreement between the Analytic Hierarchy Process evaluations of nine contractors and five suppliers, the non-parametric Wilcoxon-Mann-Whitney test was employed. The test was performed on actual evaluations by each of the nine contractors and five suppliers. Even though the scale of measurement was ratio, the t-test was avoided because the assumptions which required that the observations were drawn from normally distributed populations and had the same variance or known ratio of variances could not be verified from such few observations. The 2-tailed probability results of the Wilcoxon-Mann-Whitney test in Table 10.8 show no significant differences between evaluations by contractors and suppliers of percentage contributions of all performance indicators to improved customer service.

Table 11.8: Statistical comparison of contractors' and suppliers' AHP evaluation of contributions of performance indicators to improved customer service

Performance indicators	Arithmetic Means: Contractors (%)	Arithmetic Means: Suppliers (%)	The Wilcoxon-Mann-Whitney 2-tailed test at the 5 % level of significance
Reliability	37.06	34.22	0.549
Cost-effectiveness	29.29	30.22	0.947
Lead time	12.25	11.08	0.947
Flexibility	13.83	16.08	0.898
Value-added service	7.51	8.26	0.841

Similarly, the 2-tailed probability results of the Wilcoxon-Mann-Whitney test in Table 10.9 show no significant differences between the evaluations by contractors and suppliers of percentage contributions of the enablers to improved customer service.

Thus, both contractors and suppliers generally agreed about the level of contributions of performance indicators and enablers to improvements in customer service in the delivery of construction materials.

Table 11.9: t-test statistical comparison of contractors' and suppliers' AHP evaluation of contributions of enablers to improved customer service

Performance indicators	Arithmetic Means: Contractors (%)	Arithmetic Means: Suppliers (%)	The Wilcoxon-Mann-Whitney 2-tailed test at the 5 % level of significance
Relationships	19.32	16.04	0.053
Capability	17.95	11.18	0.053
Mgmt & admin ability	14.26	11.86	0.841
Quality management	12.70	10.58	0.317
Price	11.33	18.72	0.096
Location	11.27	16.50	0.257
Info & comm. tech.	5.06	8.52	0.182
Health and Safety	4.52	3.18	0.385
Environmental records	3.59	3.42	0.947

11.7 Summary

This chapter has presented a review of the Analytic Hierarchy Process as a priority setting methodology. Steps involved in the formulation of an AHP model have been outlined. Evaluations of the developed AHP model with the objective of determining the relative importance of logistics performance indicators and enablers in contributing to improved customer service in the delivery of construction materials, using the Analytic Hierarchy Process, have been presented, analysed, compared and discussed.

Among performance indicators, both interviewed contractors and suppliers ranked reliability of a supplier highest, followed in the second place by the cost-effectiveness of the service provided by a supplier in contributing to improved customer service. Improved lead time was considered the third most important performance indicator by contractors while suppliers ranked it the fourth most important performance indicator. Flexibility was ranked fourth by contractors and third by suppliers in contributing to improved customer service. Value-added service was assessed to have the least impact on improved service by both contractors and suppliers.

Among characteristics which make it possible for a supplier to achieve improved performance in the delivery of materials, improved relationships were ranked highest by both contractors and suppliers. Traditional factors such as capability, management and administrative ability, quality management systems, quoted prices and locations of suppliers in relation to projects were also considered important in contributing to improved customer service in the delivery of construction materials.

Though considered in the evaluation and selection of suppliers, environmental and, health and safety records of suppliers could have other wider impacts on individual project participants and affected public interests but were assessed by both contractors and suppliers to have little direct contribution to providing place and time utility in the supply of construction materials. Both interviewed contractors and suppliers also considered information and communication technologies to have low contribution to improvements in customer service in the delivery of construction materials.

Chapter 12 which follows discusses the supplier management decision-support process model mapped out from the literature review, questionnaire surveys and interviews together with results of the model validation exercise with six UK contractors.

CHAPTER TWELVE

SUPPLIER MANAGEMENT PROCESS MODEL AND ITS VALIDATION

Figure 12.1: Supplier management process map for improving construction materials logistics

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CHAPTER TWELVE

SUPPLIER MANAGEMENT PROCESS MODEL AND ITS VALIDATION

12.1 Introduction

Results of questionnaire surveys and interviews with UK contractors and construction materials suppliers have been presented in Chapters 8 to 11. The aim of this research was to propose a systematic decision-support supplier management model for improved construction materials logistics which contractors can use for both short and long-term management of suppliers. The model was developed from the literature reviewed in Chapters 2 to 6 and 11 and the results presented in Chapters 8 to 11. The model is presented as a flow chart in Figure 12.1. It is in three phases:

- the first phase involves development of the database of preferred suppliers, if the company does not already have one, and subsequent management of the preferred suppliers on the database;
- the second phase involves selection of suppliers from the preferred suppliers on the database for specific projects; and
- the third phase involves performance monitoring of the suppliers selected to supply materials for each project.

The model validation process is also described. The sections that follow describe the various supplier management processes in each of the three phases of the process map. The activities in each phase are described item number by item number as they appear in the model. The validation of the model is described at the end of this chapter.

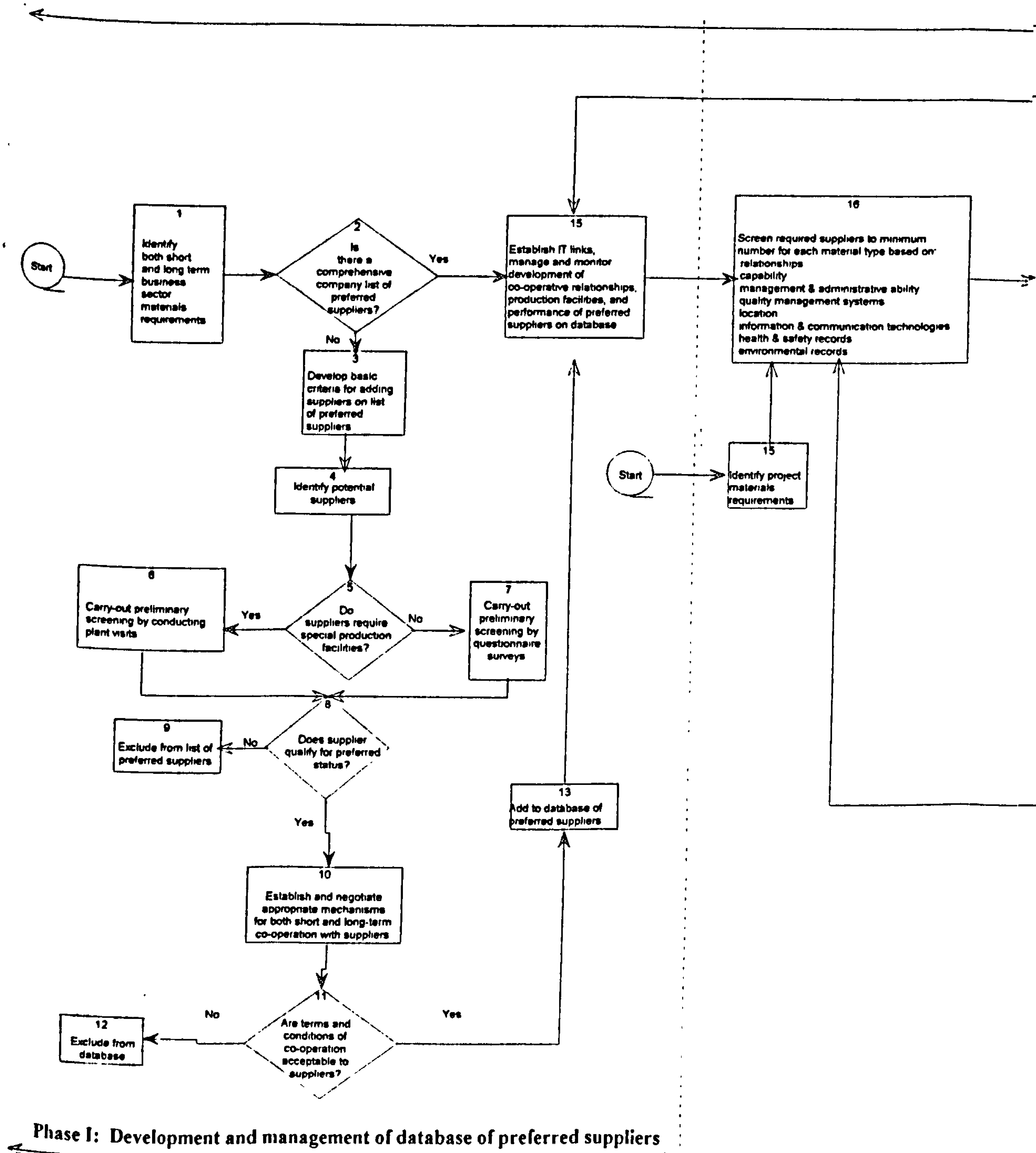

Figure 12.1: Supplier

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12.2 Phase I: Development and management of preferred suppliers database

The first phase of the model involves: development of a preferred suppliers database by the concerned contractor, if one does not exist; or the management of such a database if one is in existence. The activities involved in this phase are described below, beginning from identification of construction sector materials.

1 **Identify major industry sector materials**

Based on the sector of the construction industry in which the contractor is engaged (civil; building; or process), the major materials required should be identified at company level. This should lead to the identification of key materials suppliers in the sector with which the contractor can develop stable relationships.

2 **Is there a comprehensive company database of preferred contractor suppliers?**

If there is no comprehensive company database of contractor preferred suppliers, it is necessary for a contractor to develop one. Such a database prevents time-wasting by avoiding repetitive searches for supplier details each time the contractor requires suppliers to give quotes when new projects are tendered.

3 **Develop own basic criteria for adding suppliers to list of contractor preferred suppliers**

Basic criteria for adding suppliers to the list of preferred suppliers should be identified for companies without a database of preferred suppliers. Such factors will be company specific and thus may not be the same for different companies. The factors may include:

- product quality;
- quality management systems employed by suppliers;
- financial stability of the firm;

- production capacity;
- location of production facilities and warehouses;
- administrative ability of suppliers;
- technology/design capability of suppliers; and
- any other factors deemed important by the contractor.

4 **Identify potential suppliers**

Having identified key sector materials and basic criteria on which to qualify suppliers as preferred, the next stage is to identify potential suppliers before screening them. Sources from where information concerning suppliers may be obtained include:

- records of suppliers in the purchasing department;
- supplier catalogues;
- trade registers and directories;
- trade journals;
- yellow pages;
- trade exhibits;
- company personnel;
- sales personnel; and
- purchasing departments of other companies.

5 **Do suppliers require special production facilities?**

Assurance that the supplier is capable of meeting specific requirements for some materials is required. It may be necessary to determine first whether or not special production facilities are required and to assess the state of such facilities.

6 **Plant visits**

If suppliers require special production facilities, plant visits should be conducted to assess the ability of the supplier in terms of production facilities and capability and whether or not the supplier meets requirements for being conferred preferred status. Items to be checked on plant visits may include:

- research and development capability;
- appropriateness of the equipment;
- effectiveness of the production control, quality control, and cost control systems;
- competence of the technical and managerial staff;
- morale of the personnel in general;
- quality of back orders;
- willingness of the supplier to work co-operatively with the company; and
- quality of key materials management activities.

7 **Preliminary questionnaire surveys**

If plant visits are not required, suppliers should be screened on the basis of information obtained by questionnaires which may include the following:

- bank references;
- credit references;
- annual history of sales and profit for the past five years;
- referral list of customers;
- number of employees;
- expansion plans;
- current production defect rate for similar products;
- number of inspectors used;
- date when statistical process control was adopted; and
- list of equipment and tools used to manufacture, test and inspect the materials.

8 **Does the supplier qualify for preferred status?**

The contractor should determine whether or not the supplier qualifies for preferred status based on the information obtained from plant visits or preliminary questionnaires.

9 **Exclude from list of preferred suppliers**

If, based either on plant visits or questionnaire surveys, the supplier does not qualify for preferred status, then evaluation of that supplier should be discontinued and they should not be included on the list of preferred suppliers.

10 **Establish and negotiate appropriate mechanisms for short and long-term co-operation with preferred suppliers**

If, based either on plant visits and/or questionnaire surveys, the supplier qualifies for preferred status, then appropriate mechanisms for short and long-term co-operation such as partnering, investment in information and communication technologies and development of production facilities of supplier should be established and negotiated.

11 **Are terms and conditions of co-operation acceptable to supplier?**

It is important that terms and conditions of co-operation are spelt out clearly and acceptable to those suppliers that have passed preliminary screening.

12 **Exclude from database of preferred suppliers**

If the terms and conditions of co-operation are not acceptable to the supplier, the contractor may decide to exclude that supplier from the database of preferred suppliers since the ethos of the two companies may not be similar.

13 **Add to database of preferred suppliers**

If the suppliers are agreeable to the terms and conditions of co-operation which may include development of long-term relationships, expansion of production facilities and investment in information technology infrastructure, then the suppliers may be included on database of preferred suppliers.

14 **Establish information and communication links and manage relationships**

with preferred suppliers on database

Implement terms and conditions of co-operation for those suppliers included on database of preferred suppliers such as joint long-term investment in:

- integrative information and communication technologies like EDI, bar codes, IDBMS, extranets;
- production facilities; and
- formation of closer long-term relationships

The management of suppliers on the database then becomes an on-going exercise.

12.3 Phase II: Supplier selection

Phase II of the flow chart proposes systematic selection of suppliers via the following activities:

15 **Identify project materials requirements**

When a project comes up and the contractor decides to bid for it, the required material types and their quantities are identified through materials take-off from bill of quantities or schedules.

16 **Screen required suppliers to a minimum number for each material type**

With the required material types and their quantities known, a minimum number of suppliers, depending on a contractor's practices, for each material type are screened from the database of preferred suppliers. To ensure continuous improvement of co-operation and supplier development, it is recommended that the screening be based on the enablers identified in Chapters 8 and 9 and evaluated in Chapter 11 and these are:

- relationships;

- price of products
- capability;
- management and administrative ability;
- quality management systems;
- location of suppliers in relation to project;
- information and communication technologies;
- health and safety records of suppliers; and
- and environmental records of suppliers.

17 Is early supplier involvement in project required?

It is necessary to determine whether materials specifications or their manufacture require early involvement of suppliers.

18 Are required materials commodity items?

If early supplier involvement is not required, it is important to determine whether the required materials are commodity (easily available) items for which competition may be used or not.

20 Competition based on total cost for commodity items

The minimum number of suppliers identified from the database of preferred suppliers can be invited to submit tenders for commodity items. The competition in this case can be based on the total cost for supplying the materials.

21 Select materials supplier quoting the lowest total cost for commodity items

The supplier quoting the lowest total cost for the supply of commodity items can be selected from the competition of preferred suppliers from the company database.

19 Do materials require competition based on technical specifications or other factors

For materials which are not commodity items, and for which early supplier involvement is required, it should be determined whether the materials require supplier competition based on technical specification and other factors or not.

22 Competition based on technical specifications or other factors for non-commodity items

If competition on specifications or other factors is required, minimum identified preferred suppliers from database are invited to compete on proposals without quoting any price

23 Select bidders of satisfactory proposals and ask them to compete on price

From competition based on technical specifications, ask successful bidders to compete on price.

24 Is negotiation over price necessary?

A purchase contract resulting from competition in Step 23 can be awarded on the basis of either the lowest price from those bidding, or the lowest price from competition can be used as a starting point for negotiations.

25 Select supplier whose proposal has lowest price and negotiate based on target costing

If negotiation over price is necessary, select supplier with lowest price from competition in Step 23 and start negotiations based on target costing.

26 Agreement reached over price negotiations?

If there is a target cost, negotiations over initial bid price may be necessary.

27 Engage a different supplier from competition into negotiation over their own proposal

If agreement over target cost is not reached with the supplier initially selected, engage a different supplier from competition in Step 25 into negotiation towards target cost until the target price is reached. Then move on to Step 32 and place purchase contract when negotiations are successful.

28 Select supplier of proposal with the lowest price

If from Step 23, negotiation over price is not necessary, select supplier of proposal with the lowest price and move on to Step 32 and place the purchase contract with the successful supplier.

29 Select single supplier and negotiate based on target costing

If early supplier involvement is required and the materials do not require competition based on technical specifications or other factors, select a single supplier from the database of preferred suppliers and negotiate based on target costing.

30 Is there agreement over negotiations based on target costing?

The decision to place the purchase contract in Step 28 depends on whether or not agreement is reached in the negotiations.

31 Select different supplier and engage into negotiations based on target costing

If agreement was not reached and the answer to the question in Step 29 was 'No', a different supplier from the database is selected and engaged into negotiations again based on target costing.

32 Place purchase contract and add supplier to purchasing schedule

If the contractor is satisfied with the cost of the materials by the identified supplier, a purchase contract is placed and the name of that supplier added to the purchasing schedule.

12.4 Phase III: Construction site

On site supplier management activities by the contractor involve performance assessments of the suppliers for purposes of developing feedback to the suppliers and the company for benchmarking performance and for future reference.

33 Establish information technology infrastructure between contractor and preferred suppliers

For suppliers selected to supply materials for a given project, establish temporary information and communication technologies between site offices and suppliers that have been evaluated to be necessary for improving performance in the delivery of construction materials. Such technologies may include IDBMS, EDI, telephone, facsimile, bar codes, etc.

34 Monitor customer service level provided by supplier

During project execution, the performance of the selected suppliers should be assessed for purposes of feed back to the suppliers and as a method of monitoring continuous improvement. It is recommended that performance is assessed on the basis of the performance indicators identified in Chapters 8 and 9 and evaluated using the analytic hierarchy process in Chapter 11 and these include:

- reliability;
- cost-effectiveness;
- flexibility;
- lead times; and
- value-added service.

35 Is the customer service level provided satisfactory?

Decisions on whether or not to keep suppliers as preferred will have to be made depending on how satisfactory their levels of customer service is.

38 Feedback on performance and keep as preferred supplier

If the level of customer service is acceptable or it is not consistently poor (i.e. has high likelihood for improvement), suppliers can be retained but should be kept informed of performance assessment so that they know what standards are expected of them.

36 Is performance consistently poor?

If the service of the supplier is not acceptable, further assessment will be necessary to determine whether the supplier should be retained or not. If performance is not consistently poor, then move to Step 38. If it is consistently poor, move to Step 37.

37 Feedback on performance, disengage and remove from list of preferred suppliers and select a different supplier

If the performance of the supplier is consistently poor, with little hope of improvement, the supplier is informed of its performance, disengaged from the current contract and removed from the list of preferred suppliers. A different supplier from the database of preferred suppliers may then be engaged.

Validation of the above model was undertaken after the model was constructed. Rationalisation of the process of validation and results of the validation exercise are presented in Section 12.5 and its sub-sections below.

12.5 Validation

Validation implies that something is assessed to be valid and that the adjudication is conducted by a person or body competent to judge (Church, 1983). The competence of the adjudicator, therefore, has to be specific to that which is being judged. It has been argued, however, that the two bases of the concept of validation, judgement and standards, are neither empirically nor theoretically available (Church, 1983). Empirically, therefore, anyone conducting the process of validation is unlikely to properly account for the basis of their judgement or define the relevant standards they used. Theoretically, there would be no privileged access to presupposed knowledge and values by which a pure and unchallenged judgement might be made.

Although the concept of validation appears to be undermined by the above observations, it is nevertheless an accepted form of critique. The presented arguments recognise philosophical weaknesses which underlie validation but it nevertheless still remains the accepted form of expert seal of approval in cases where subjective judgement might have no other alternative (Church, 1983).

Taking the above views into consideration, the questionnaire for validating the supplier management process map in Figure 12.1 was designed and sent to the nine contractor organisations that had evaluated the AHP models in Chapter 11. The model evaluation questionnaire sample is given in Appendix F and summarised responses of the respondents are displayed in Table 12.1.

12.5.1 Respondents

Designations of sampled experts who represented the construction companies have been presented in Table 12.1. All the experts were either directly involved in procurement/materials management or had detailed knowledge of the function and can thus be considered competent to judge the validity of the model.

12.5.2 Results of the model validation questionnaire survey

Responses of the nine contractors that responded to the validation questionnaire are displayed in Table 12.1. As outlined in the letter that accompanied the validation questionnaire, the purpose of the validation exercise was to assess the supplier management process model in terms of its:

- user-friendliness
- functionality; and

• usefulness.

The one-tailed Binomial Test was used to calculate probabilities for all elements for which all of the possible observations fell into one of two discrete categories. To answer the question "What is the probability of obtaining values as extreme or more extreme than the observed value when we assume the data are generated by a particular process?" the desired one-tailed probability is obtained by the binomial sampling distribution given in Equation 12 (a) (Siegel and Castellan, 1988):

$$P[Y \leq k] = \frac{1}{2} \sum_{i=k}^{N} \binom{N}{i} p^i q^{N-i}$$ ....Equation 12 (a)

Where N = number of observations;

Y = the random variable

p = probability of number of successes or number of 'Yes';

q = probability of number of failures or 'No';

i = $n^{th.}$ observation; and

k = the smaller of the observed frequencies of 'Yes' or 'No'.

In assessing the validity of the supplier management process model, only probabilities for dichotomous elements were determined as shown in Table 12.1. For testing the null and alternative hypotheses below, the level of significance was set at $\alpha = 0.05$:

Null hypothesis H_o: p = q = 0.5

i.e. There is no difference between the probability (p) of 'Yes' responses and the probability (q) of 'No' responses to each of the statements relating to the supplier management process model.

Alternative hypothesis H_1: p > q

i.e. The probability (p) of 'Yes' responses to statements about the supplier management model is greater than the probability (q) of 'No' responses to the statements.

Table 12.1: Validation of supplier management process map

Questionnaire items

1	2	3	4		5		6		7		
Name of company	Position of interviewee in company	What type of work does your company generally undertake?	Have you previously come across a supplier management process map similar to the one described here?		To what extent do you find the procedures involved in the outlined supplier management process map easy to follow?		Does your company have a structured supplier management programme?		If your company has a supplier management system, is it similar to the one outlined in this model?		
			Yes	No	Easy	Not Easy	Yes	No	Yes	No	Not Applicable
AMEC Civil Engineering	Head of Procurement	Civil	x		x			x			x
Norwest Holst Construction Ltd	Procurement Director	Building and Civil		x	x		x Very similar to the supplier management process's map		x		
HBG Kyle Stewart Ltd	Procurement Director	Building	x		x			x Informal and experience only			x
Shepherd Construction Ltd	Chief Buyer	Building	x Department procedures		x		x Supplier assessment programme - supply chain management		x		
Kvaerner Construction	Head of Procurement	Civil		x	x		x We currently have difficult procedures because of a poor computer system. We are currently developing a faster solution			x	
McNicholas Construction Co Ltd	Purchasing Manager	Building & Civil	x		x			x			x
Clugston	Chief Buyer	Building & Civil		x	x		x Preferred suppliers		x		
Stewart Milne Homes	Senior Buyer	Building		x	x		x A database for preferred suppliers			x	
Dean & Dyball	surveyor Quantity	Building & Civil		x	x			x		x	
Total			4	5	9	0	5	4	3	3	3
Binomial Test at 5 per cent level of significance			0 500		0 002		0 500				

Table 12.1: Validation of supplier management process map..... *continued*

Questionnaire items

1	8		9		10						11	
Name of company	If your company were to implement an improved supplier management programme, could you base it on the one proposed here?		If your company were to implement an improved supplier management programme, would you base it on the one proposed here?		Do you think that implementing the proposed supplier management process map would improve performance in the delivery of construction materials via? a more structured selection of suppliers at both company and project level ?		b development of long-term contractor supplier relationships?		c more structured assessment and feedback on performance of suppliers?		To what extent do you accept that implementation of the outlined supplier management process can help your company improve performance in the delivery of construction materials?	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Accepted	Not Accepted
AMEC Civil Engineering	x			x	x			x	x		x	
Norwest Holst Construction Ltd	x		x		x		x		x		x	
HBG Kyle Stewart Ltd	x			x Too detailed for all purchases. Suitable for major items only	x		x		x		x	
Shepherd Construction Ltd	x		x		x		x		x		x	
Kvaerner Construction	x		x		x		x		x		x	
McNicholas Construction Co Ltd	x		x		x		x		x		x	
Clugston	x			x Company still does not use EDI, bar codes	x		x		x		x	
Stewart Milne Homes	x		x		x		x		x		x	
Dean & Dyball	x		x		x		x		x		x	
Total	9	0	6	3	9	0	8	1	9	0	9	0
Binomial Test at 5 per cent level of significance	0.002		0.254		0.002		0.035		0.002		0.002	

Table 12.1: Validation of supplier management process map..... *continued*

Questionnaire items

1	12												13		14
Name of company	If your company were to manage construction materials as proposed in the outlined supplier management process map, which of the following would you expect from the suppliers?												Do you think the effort and cost in terms of time and resources associated with implementing the outlined process map would justify the improvements gained?		Do you have any comments?
	a Improved customer service		b Improved reliability		c Cost-effective materials supplies		d Improved flexibility		e Improved value-added service		f Improved relationships				
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	
AMEC Civil Engineering	x			x	x			x	x			x	x		
Norwest Holst Construction Ltd	x		x			x		x		x	x				
HBG Kyle Stewart Ltd	x		x		x		x		x		x			x Too detailed for all purchases. Suitable for major items only.	
Shepherd Construction Ltd	x		x		x			x		x	x		x		Consideration to be given to value for money rather than lowest cost. Vendor rating to be overlaid to standardize feedback.
Kvaerner Construction	x		x		x		x		x		x		x		
McNickolas Construction Company Ltd	x		x		x		x		x		x		x		No allowance made for either client supplied materials or client nominated suppliers. Where do they fit into the process?
Clugston	x		x		x		x		x		x		x		
Stewart Milne Homes	x		x		x		x		x		x		Unsure at this time as we implement some of these processes		We have a structure in place which is quite similar to the process map as outlined. We have already entered into long term customer/supplier relationships using the same kind of processes
Dean & Dyball		x	x			x	x		x			x	x		
Total	8	1	8	1	7	2	6	3	7	2	7	2	6	1	
Binomial Test at 5 per cent level of significance	0 02		0 02		0 09		0 254		0 09		0 09		0.062		

12.5.2.1 User-friendliness

With reference to the results in Table 12.1, questionnaire items 4, 5, 8 and 9 tested the user-friendliness of the model.

Item 4 of the questionnaire asked the respondents to indicate whether they had previously come across a supplier management process map similar to the proposed model. Four of the nine contractors stated they had and five indicated they had not. For this item $P[Y \leq 4] = 0.5 > \alpha = 0.05$, suggesting that differences in responses between companies that had come across a supplier management process model similar to the one suggested and those that had not were by mere chance and that there were no grounds for rejecting Ho, the null hypothesis. Only one company, among those that had previously come across a supplier management process map described the model they had but indicated that theirs were mere departmental procedures. Even though five of the nine companies had not seen a similar process model before, the four that had, suggest that the map is something contractors can relate to.

In item 5 of the questionnaire, all the nine companies found the procedures outlined in the model 'Easy' to follow. For this item $P[Y \leq k] = P[Y=0] = 0.002 < 0.05$ leading to rejection of the null hypothesis and acceptance of the alternative hypothesis. Therefore, the higher probability of companies finding the procedures involved in the supplier management process model easy to follow was not by mere chance.

In item 8, all the nine companies responded that if they were to implement an improved supplier management process model, they 'could' base it on the proposal. For this statement, $P[Y \leq k] = 0.002 < 0.05$ leading to rejection of the null hypothesis and acceptance of the alternative hypothesis that the probability that contractors could implement the supplier management process model is higher than that of non-implementation.

In item 9, six of the contractors indicated that if they were to implement an improved supplier management process map, they 'would' base it on the proposal while three indicated that they 'would not'. One contractor responded that they would not implement the model because it was too detailed and was only suitable for major purchases. The reason given by another company for saying they would not implement the model was that they did not have EDI and bar codes in place. No reason was given by the third company. For item 9, $P[Y \le k] = P[Y \le 3] = 0.254 > \alpha=0.05$, suggesting no grounds for rejecting Ho, the null hypothesis. Even though the binomial test for item 9 did not show inclination towards implementation of the model, the tests for items 5 and 8 show acceptance of the model as one which is user-friendly.

12.5.2.2 Functionality

The functionality of the model was tested via items 6, 7 and 10 in Table 12.1. Responses to item 6 showed that out of the 9 companies, 4 had no structured supplier management programmes, while 5 indicated that they had. Therefore, $P[Y \le k] = P[Y \le 4] = 0.5 > \alpha=0.05$, giving no grounds for rejecting the null hypothesis, suggesting that differences in responses between those companies which had and those which did not have supplier management process models were by mere chance. One of the companies that had a structured supplier management programme stated that its programme involved supplier assessment as part of its supply chain management practice while another indicated that it currently had supplier management procedures which were difficult to implement because of a poor computer system (but was developing a faster solution). The third company indicated that its supplier management programme was very similar to the proposed process map but did not elaborate. The remaining two companies indicated they employed the system of preferred suppliers, with one stating it had a database of preferred suppliers. One of the companies which had no supplier management programmes stated that it relied on informal procedures and experience only in managing their suppliers.

From item 7, of the five companies that had supplier management programmes (item 6), three indicated that their programmes were similar to the proposed model. Despite their programmes being similar to the proposal, two of the companies still indicated in items 8 and 9 that they 'could' and 'would' implement the proposal if they were to implement an improved supplier management programme. The third company responded that it 'could' but 'would not' implement the proposal because it had no EDI and bar codes in place. The assessment of items 10 (a), (b) and (c) by all the nine companies was that implementing the proposed model would lead to improved performance in the delivery of construction materials via more structured selection of suppliers at both company and project levels; development of long-term contractor- supplier relationships; and more structured assessment and feedback on performance of suppliers. For all three items, $P[Y \leq k] < \alpha=0.05$, leading to the decision for rejecting Ho, the null hypothesis and confirmation of acceptance that implementing the model would improve performance in these areas was not by mere chance. Generally, therefore, opinions of the contractors were that the proposed model was functional, it would produce results, and that if implemented it would lead to more structured supplier management and improvements in the delivery of construction materials.

12.5.2.3 Usefulness

Items 11, 12 and 13 were designed to evaluate the usefulness of the model. As regards item 11, all the nine companies 'Accepted' the declaration that implementation of the model would help them improve performance in the delivery of construction materials.

Responses of the contractors to item 12 indicate that if they were to manage construction materials as proposed in the supplier management process map:

- all the nine contractors expected customer service to improve;
- eight of the nine contractors expected reliability to improve, one did not;
- seven of the contractors expected cost-effective materials supplies, two did not;
- six of the contractors expected improved flexibility from suppliers, three did not;
- seven expected improved value-added service, two did not; and
- seven expected improved relationships, two did not.

For items 12 (a) and 12 (b), $P[Y \leq k] = 0.002 < \alpha = 0.05$, giving grounds for rejecting the null hypothesis, Ho. All the respondents agreed with the statements that managing construction materials as proposed in the supplier management process map would lead to improved customer service and improved reliability. For items 12 (c), (d), (e) and (f) values of $P[Y \leq k]$ were all greater than $\alpha = 0.05$ establishing no grounds for rejecting Ho, the null hypothesis even though the majority of the contractors agreed that managing construction materials as proposed in the supplier management process map would lead to improvements in: reliability, cost-effective materials supplies, flexibility, value-added service and relationships in the delivery of construction materials.

Since items 12 (b) to (f) all contribute to customer service, if looked at in total combination, all the improvements in these elements would lead to improvements in customer service to which responses of sampled contractors were significantly in agreement.

With regards to item 13, seven of the companies were of the opinion that the effort and cost in terms of time and resources associated with implementing the outlined process map would justify the improvements gained. Two companies did not respond to this item. Only one company disagreed, stating that the model was too detailed for all purchases and was only suitable for major items.

Three general comments to item 14 were received. One company suggested that in the evaluation and selection of suppliers consideration should be given to value for money instead of lowest cost and that the process model should incorporate vendor rating in order to standardise feedback. The second comment was that no allowance had been made in the model for either client supplied materials or client nominated suppliers. The contractor simply has to accept client supplied materials and the need for selection of suppliers does not arise. Neither does the need for supplier selection arise in the case of client nominated suppliers unless the contractor has major objections. One contractor responded that it had a structure in place similar to the outlined process map and that the company had already entered into long-term customer-supplier relationships using the same kind of processes.

From the foregoing discussion, responses of the surveyed contractors express acceptance of the proposed supplier management model as a valid tool that would enhance improvements in the delivery of construction materials if implemented and that it is user-friendly, functional and useful.

The potential of incorporating a vendor rating system and the monitoring of performance of client nominated suppliers in the model should be the subject of further investigations as these were not included in the validation survey.

12.6 Summary

This chapter has proposed and presented a systematic decision-support supplier management process model which contractors can implement to improve performance in the supply of construction materials. The various activities in each of the three phases of the model have been outlined.

The model was validated by nine contractors and was found to be user-friendly, useful and functional. Chapter 13 which follows discusses the results of this research in relation to the reviewed literature. The conclusions, recommendations and suggested further work have been presented in Chapter 14.

CHAPTER THIRTEEN

DISCUSSION OF RESULTS

CHAPTER THIRTEEN

DISCUSSION OF RESULTS

13.1 Introduction

This chapter discusses the results of the literature review, two questionnaire surveys (one sent to 71 UK contractors yielding 35 rseponses and the other to 76 UK construction materials suppliers resulting in 30 responses), interviews with nine UK contractors and five UK suppliers, and a supplier management model validation exercise with six UK contractors. An analysis of results has been presented in Chapters 8, 9, 10 and 11. Literature reviewed has been presented in Chapters 2, 3, 4, 5, 6 and 11. The discussion in this chapter is broken down into the following sections:

- the extent of usage of information and communication technologies within and between surveyed contractors and suppliers;
- the nature of contractor-supplier relationships;
- the importance and extent of usage of logistics performance indicators and enablers;
- the importance of different approaches to improving materials management to support construction; and
- the extent of occurrence of supplier-related materials management problems as observed by the surveyed companies.

Customer service has been identified as a major driver for performance improvement in logistics management. Improvements in customer service in the supply of construction materials require logistics management which should lead to harmonisation of relationships between contractors and their suppliers at both corporate and project levels. This calls for supplier management on the part of contractors.

From the literature reviewed in Chapters 2, 3, 4, 5 and 6, 'information management' and 'customer-supplier relationships' emerged as the two key elements which play pivotal roles in optimising efficiency and cost-effectiveness in supply chain management. Improved relationships help to develop the co-operation necessary for harmonising operations between interacting organisations. Information management is essential for integrating logistics activities both internally and externally. Advances in information and communication technology have greatly enabled integration of logistics activities within and outside companies.

13.2 Usage of ICTs in materials logistics

Information and communication technologies encompass a wide spectrum of convergent technologies that include data recognition equipment, computers, communication technologies and other hardware and services which businesses can use to create and process information in the supply of construction materials. These technologies facilitate timeliness, accuracy, multilocational availability and format flexibility of information which are essential elements of improved information quality. The importance of the technologies is their ability to manipulate and provide real-time information on on-going activities, thus improving decision making capabilities in organisations and ensuring that responses to in-puts are fast enough to guide processes.

Areas where information and communication technologies can facilitate improvement in materials logistics include inventory control, shipments and receipts. Various needs for real-time information on materials control systems include cost control, schedule monitoring, safety, productivity enhancement, quality assurance and security (Stukhart, 1995). Previous research has demonstrated that the industry can realise major benefits from the use of such technologies in materials management (Alkaabi, 1994; Back and Bell, 1994; and Carter et al, 1996).

In contrast, manual data collection and handling methods have inherent errors. The lag-time in such systems may be such that no room maybe available for taking corrective action after events have happened.

13.2.1 Usage within contractor and supplier organisations

With the exception of integrated database management systems, the usage of information and communication technologies, especially electronic data input technologies, in the UK construction industry was relatively low. Integrated database management systems were more widely used than any of the other technologies, with about 66 per cent of responding surveyed contractors and 63 per cent of suppliers indicating that they used the technology 'Occasionally' to 'Always' in their internal materials management processes. Electronic mail was the next most frequently used technology, with about 43 per cent of both responding surveyed contractors and suppliers stating that they 'Occasionally' to 'Always' used it in internal materials management processes.

Even though electronic data interchange (EDI) has been defined as a direct computer application to computer application exchange of business data which facilitates external integration of process information across organisational boundaries, 20 per cent of the responding contractors and 43.3 per cent of responding suppliers stated that they used it in intra-organisational materials management processes 'Occasionally' to 'Always'. Possible intra-organisational uses of EDI could be between head offices and regional offices of both contractors and suppliers, and between construction sites and administrative offices of construction companies.

Among electronic data input technologies, 22.9 per cent of contractors and 16.7 per cent of suppliers stated that they used electronic document imaging 'Occasionally' to 'Always'. Of the responding suppliers, 23.3 per cent 'Occasionally' to 'Always' used bar codes. All the contractors that completed the questionnaire responded that they had 'Rarely' to 'Never' used bar codes in internal materials management processes. The usage rates of voice recognition, radio frequency tagging and magnetic stripes were very low, with less than 10 per cent of both surveyed contractors and suppliers responding that they used them 'Occasionally' to 'Always'.

The only significant difference in the usage rates of the technologies by contractors and suppliers was observed in the case of bar codes. More suppliers used bar codes than contractors, suggesting that usage was restricted to a single stage without addressing follow-on uses in operations of contractors.

13.2.2 Usage between contractors and their construction sites, and suppliers and construction sites

Over 95 per cent of the contractors and over 85 per cent of the suppliers responded that they used the telephone, facsimile and post 'Occasionally' to 'Always' in materials logistics activities between them and construction sites. On the other hand, the usage rates of electronic mail, integrated database management systems and electronic data interchange were still relatively low, with less than 35 per cent of the organisations indicating that they used these technologies 'Occasionally' to 'Always' in these processes.

13.2.3 Usage between suppliers and contractors

The most widely used information and communication technologies and methods in construction materials logistics processes between supplier organisations and administrative offices of contractors were the telephone, facsimile and the post. Over 90 per cent of the responding suppliers and all contractors stated that they 'Occasionally' to 'Always' used these technologies and methods in materials logistics activities between administrative offices of contractors and suppliers. Usage rates of integrated database management systems, electronic mail and electronic data interchange were very low. Less than 30 per cent of the responding suppliers and less than 20 per cent of the responding contractors stated that they used these technologies 'Occasionally' to 'Always' in materials logistics processes between contractors and suppliers.

The telephone and paper based facsimile and postal services were the most widely used information and communication technologies in inter-organisational materials logistics activities between construction materials suppliers and contractors; construction materials suppliers and construction sites, and between administrative offices of contractors and their construction sites. The percentages of both contractors and suppliers that used electronic technologies such as integrated database management systems, electronic mail, and electronic data interchange in external materials logistics activities 'Occasionally' to 'Always' were still relatively low. In the case of EDI, findings of the study by Akintoye and McKellar (1997) showed that the industry still had a long way to go before the technology was used regularly for information exchange.

In internal materials management processes, the usage of integrated database management systems by both contractors and suppliers was fairly high compared to the other technologies. Data entry was still predominantly manual. These findings were also observed by Construct IT (1998), whose study noted much evidence of manual data entry and existence of islands of automation which required external bridging to achieve more effective use of information and communication technologies.

13.2.4 Benefits reported by interviewed contractors and suppliers

Benefits cited from implemented information and communication technologies by the nine contractors that were interviewed included:

- fast access to data;
- quicker information flows between sites, administrative offices and among personnel;
- increased work output;
- improved quality and efficiency in communication; and
- less number of errors in data entry.

Most of these benefits as reported, by contractors, related to use of information and communication technologies in intra-organisational materials management processes. This corresponded with the findings of the questionnaire survey which had revealed relatively higher usage of electronic data management, information and communication technologies by contractors in this area. Even though cost reduction was not mentioned by contractors, probably because it was difficult to quantify, the cited benefits can have a significant bearing on reducing cycle times and improving productivity in the procurement of construction materials, and consequently in reducing costs.

Interviewed supplier organisations acknowledged experiencing the following benefits from use of information and communication technologies:

- cost reductions;
- accurate management information leading to time savings and improved customer service; and
- one company stated that information technology had enabled it to tie its customers to its business, giving it an edge in the market place.

In addition to time savings, the interviewed suppliers noted cost reductions as a result of implemented information technology. The inter-organisational integrative nature of information technologies was also acknowledged to give a competitive edge in the market place.

A number of factors that hindered implementation of information and communication technologies in materials logistics processes were identified by interviewed contractors and suppliers.

13.2.5 Obstacles to introduction in materials management processes

Factors identified by contractors to hinder implementation of information and communication technologies in materials management processes included:

- incompatibility of technologies in use. Companies using their stand-alone databases, incompatibility of information between departments, technology format incompatibility between contractors and suppliers, and problems in the design of bespoke systems were the various problems cited;
- high capital cost of the technology leading to lack of expenditure on software and hardware;
- fear of change resulting in lack of confidence in using the technology; and

- non-availability of people with information technology expertise.

Interviewed suppliers cited the following as factors which hindered introduction of information and communication technologies in materials management and physical distribution processes:

- required internal re-organisations and the scale of the operation needed to introduce information and communication technologies. Three companies from the interviewed five mentioned this as a major hindrance; and
- one company cited inability to see any major benefits from the high capital cost of the technology as a reason it could not justify expenditure on the technologies.

Interviewed companies were aware that the industry had historically failed to keep up with developments in information and communication technologies in the past, resulting in few companies having explored the possibilities of using and even fewer having taken advantage of the technologies. The major impediment identified by contractors was that designers, suppliers, contractors and subcontractors were not agreed on standards. The other obstacle pointed out by one contractor was that unlike manufacturing and retailing, each construction project is unique and it is difficult to use similar information and communication solutions or approach each time.

A major obstacle, not mentioned by the interviewed companies, was the attitude of both contractor and supplier organisations towards the importance of information and communication technologies. Both contractor and supplier questionnaire surveys and the structured interviews using the Analytic Hierarchy Process established that the surveyed companies did not regard the use of information and communication technologies to contribute significantly to efficiency and cost-effectiveness in materials logistics. While there were other obstacles to implementation of the technologies, the underlying problem of perceived benefits that can accrue from the usage of the technologies could probably be one of the major impediments to the usage of these technologies.

Despite these obstacles, progress was being made and the interviewees were aware that the industry was changing very fast in its implementation and usage of information technologies.

13.3 Contractor-supplier relationships

A survey by Construction Manager (1998) revealed that the client driven trend towards more co-operative ways of working in the form of partnering in the UK construction industry was gaining momentum. Almost all national contractors surveyed in the report were prepared to enter formal as well as informal partnering arrangements with their clients. Clients were also satisfied that costs were being kept lower and projects completed on time.

The questionnaire surveys among UK contractors and suppliers in this research established existence of closer working relationships among contractors and construction materials suppliers. This was supported by comparisons of contractors' and suppliers' responses to statements relating to closer working relationships between the two groups.

Wilcoxon-Mann-Whitney statistical tests at the five per cent significance level were performed to detect if significant differences existed in responses of contractors and suppliers in their levels of agreement to statements concerning closer working relationships. Even though the tests exhibited significant differences in levels of agreement to a number of statements concerning existence of closer working relationships, closer examination of responses indicated that the majority of both contractors and suppliers agreed with many of the statements.

The major findings of the survey relating to improved supply chain management practices, over which there was consensus between the contractors and suppliers were that UK contractors:

- did not buy construction materials on the basis of lowest price alone;
- knew which suppliers were more important to them and tried to reduce their numbers;

- attempted to obtain mutual beneficial relationships with their suppliers;
- sought to obtain unique advantage over their competitors through their relationships with their suppliers;
- sought the commitment of suppliers to achieve project delivery goals of cost, time and quality;
- maintained open and honest communication with suppliers based on mutual respect; and
- ensured trust in the sharing of project information with their suppliers.

These findings reflected good supply chain management practices on the part of contractors. The total cost of materials is a function of many factors and not of price alone. Choice of suppliers should, therefore, not be based solely on price alone, but consideration should be taken of other factors such as reliability, flexibility, lead times, location and quality of products when evaluating and selecting suppliers.

Real gains should be achieved in mutual beneficial contractor-supplier relationships in which suppliers are allowed to participate actively in the learning process. This is better achieved with a small number of suppliers. Reducing the number of suppliers enables concentration of resources on the development of best suppliers, who should be easier to manage. Increased mutual dependence lowers the risk of losing supply source and creates greater stability through increased supplier loyalty. This may only be possible in an environment where there is trust, open and honest communication based on mutual respect.

Statements over which the survey revealed poor supply chain management practices as deduced from responses of contractors and suppliers were that:

- contractors still changed their suppliers frequently;
- the practice of contractors sharing their strategic plans with their suppliers was not common practice in the industry;
- contractors did not give as much feedback to suppliers as most of the suppliers would have liked;

- contractors expected suppliers to deliver exactly what was specified without question;
- contractors checked every delivery to ensure consistent quality due to lack of trust in the reliability and quality management systems of suppliers;
- suppliers did not get as involved during project development goals at the tendering stage as the majority of surveyed suppliers would have liked;
- while contractors indicated that they paid suppliers in time for materials already delivered, suppliers disagreed with this; and
- contractors did not always give enough time to suppliers to prepare quotations when the latter prepared bids to supply materials.

The practice of changing suppliers frequently does not auger well with development of long-term relationships, even though this practice may be unavoidable in construction where the one-off project nature of the industry is location dependent. The practice can lead to loss of supplier loyalty. While the majority of both contractors and suppliers agreed that there was trust in the sharing of project information, this was not the case at the corporate level and the practice of sharing strategic plans was not common. Many of the surveyed suppliers were also either neutral or disagreed with the statement that contractors involved them during development of project goals at the tendering stage.

By expecting suppliers to deliver exactly what was specified without question, contractors could be losing out on opportunities to use suppliers as sources of new ideas and new business. Without sufficient feedback on their performance, suppliers cannot be expected to be up-to-date with expectations of contractors and would not know in which areas to improve performance.

All these were poor supply chain management practices on the part of contractors. Trust is a pivotal element in the development of relationships between trading organisations. Checking every delivery to ensure consistent quality reflected lack of trust in the reliability and quality management systems of suppliers by contractors.

While responses to some of the statements in the survey pointed to the fact that relationships between contractors and suppliers were towards co-operative behaviour and mutual benefit, responses to a number of the other statements also indicated that entrenched practices and attitudes among UK contractors still impeded full supply chain integration with construction materials suppliers.

In general, higher percentages of contractors expressed agreement to existence of good contractor-supplier relationships than did suppliers. In other words, more of the surveyed suppliers were less satisfied with supply chain management practices employed by contractors. It may be inferred from these findings that full opportunities for performance improvements in materials logistics through closer involvement of suppliers were still not being exploited.

13.3.1 Maintenance of supplier lists

Further indication that contractors knew which of their suppliers were vital to their business was reflected in the practice of keeping supplier lists. Nearly all the surveyed contractors, 94 per cent, responded that they maintained supplier lists. Of the surveyed suppliers, 90 per cent had their names on contractors' lists of preferred suppliers.

The maintenance of supplier lists was also further testimony to existence of closer working relationships between contractors and their suppliers. Ninety-four per cent of the contractors responded that they had either a combination of arms' length trading relationships with other types of closer working relationships or simply that they had closer ties with their suppliers. Among suppliers, 90 per cent described their relationships with contractors as close. Closer working relationships were described in terms of non-partnering long-term trading, short-term project partnering, long-term partnering or partnerships.

These results point to the existence of close working arrangements between most contractors and their suppliers. The results, however, show that the relationships were of different grades, with some suppliers being more preferred than others. Despite existence of closer relationships, most of the contractors still used bidding to select materials suppliers for all the different types of construction materials. Särkilahti (1996) acknowledged that project specific price competition on construction materials cannot be avoided.

13.3.2 Benefits derived from closer contractor-supplier relationships

The benefits that interviewed contractors derived from long-term closer working relationships with suppliers included:

- long-term commitment to reduce costs and improve efficiency leading to lower total acquisition costs;
- improved lead times, delivery reliability and quality leading to improved customer service;
- external source of specialist knowledge;
- exchange of market information;
- easier working relationships as a result of repeat orders;
- urgent help and assistance when required;
- development of trust;
- improvement in technology and performance; and
- improved reporting and ability to monitor purchases.

Benefits from long-term closer working relationships with contractors reported by interviewed suppliers included the following:

- secure turn-over and profits resulting from continued business as preferred suppliers;
- ability to negotiate business deals with contractors;
- better demand prediction;
- greater knowledge and understanding;
- improved payment periods; and

- reduced costs for contractors.

These responses show that both contractors and suppliers benefit from working closely on long-term basis with their trading partners. Such benefits should be incentive for cultural change from adversarial attitudes for which construction has been traditionally well known for to more collaborative working arrangements in materials supply logistics. However, formation of long-term relationships is not without its problems. The nine contractors and five suppliers interviewed were asked via open-ended questions, to enumerate what they considered to be major problems that stood in the way of formation of long-term closer working relationships between contractors and suppliers. The results are discussed below.

13.3.3 Obstacles to formation of long-term relationships

The following were the factors identified by contractors to hinder formation of long-term relationships with suppliers:

- lack of trust between contractors and suppliers;
- conflict of interest. For example, whereas contractors want to achieve lowest price, instead of lowest turnout cost, suppliers want to achieve best price;
- entrenched traditional arms' length relationships;
- specifications on traditional contracts which do not consistently use the same materials for all projects reduce scope for repetitively using the same supplier;
- lack of continuity of site activities;
- workloads of individual companies in the industry fluctuates tremendously and this can make strong contractor-supplier relationships awkward;
- construction takes place where the project is, consequently sometimes restricting suppliers from being competitive or being able to offer superior service; and
- construction is a hard market with very little long-termism and too much cost driven.

One contractor did not believe that "partnering" could work between contracting organisations and its suppliers.

The interviewed suppliers identified the following factors to hinder formation of long-term relationships with contractors:

- lack of trust resulting from fear that long-term partnering leads to higher prices, thus competition pricing or tendering is seen by contractors as a way of keeping prices down;
- lack of willingness due to limited perception by contractors of benefits to them;
- availability or location of suppliers' products; and
- non-allocation of management time and lack of business focus on the part of suppliers themselves.

Despite these obstacles, the interviewed individuals acknowledged that the tradition of adversarial relationships between contractors and suppliers had begun to change for the better.

13.3.4 Ways suppliers received feedback on their delivery performance

One essential element for continuous improvement in any repetitive process such as long-term trading is the need for feedback from which both customers and suppliers can benchmark performance improvements in materials logistics. Both contractors and suppliers were asked how suppliers received feedback on their performance in the delivery of construction materials. The following were the methods that interviewed contractors said they used to give feedback to suppliers on their delivery performance:

- through a vendor rating system;
- 6-monthly reviews (if applicable);
- through day-to day personal contact;
- only when there are problems;
- informal.

Interviewed suppliers said they received feedback on delivery performance through the following ways:

- customer satisfaction surveys;
- contractors' supplier appraisal systems;
- self-monitoring of delivery performance;
- verbal complaints;
- through day-to-day personal contact; and
- continuous appraisal.

According to the above responses of both interviewed contractors and suppliers, different methods were used for giving feedback. Various approaches of evaluating suppliers which could as well be used for giving feedback to suppliers were identified. Frequencies of contractors' responses to these approaches are displayed in Table 8.5 of Chapter 8 while frequencies of suppliers' responses are as shown in Table 9.9 of Chapter 9. While 22.9 per cent of the contractors responded that they used 1 to 12 months formal reviews of performance and the responses of the rest were split among ad hoc and a combination of different approaches, the majority of suppliers, 66.7 per cent responded that evaluation of suppliers was on ad hoc basis. There was no clear agreement between the responses of the two groups as to which methods contractors used most for evaluating suppliers.

13.3.5 General comments about contractor-supplier-relationships

Despite obstacles to collaboration between contractors and suppliers observed earlier, some contractors noted that the industry is undergoing a cultural change to more co-operative trading such as partnering. The interviewed suppliers gave varied responses about contractor supplier relationships. Two of the companies saw their relationships with contractors as generally good. The remaining three did not. One supplier organisation observed that contractor-supplier relationships were rarely based on trust, while another viewed contractors as more interested in relationships with their clients rather than with suppliers. The third supplier was optimistic that in years to come, contractor-supplier relationships would improve as the principles of partnering became more widely understood and accepted.

13.4 Importance attached to logistics factors by UK contractors and suppliers

Logistics factors were reviewed in Chapter 11. They comprise logistics performance indicators and enablers. The importance attached to these factors were determined through analysis of questionnaire responses and by interviews with nine contractors and five construction materials suppliers.

13.4.1 Logistics performance indicators

In Chapters 8 and 9, over 91.4 per cent of the contractors and above 83.4 per cent of the suppliers assessed all logistics performance indicators to be of "Average Importance" to "Extreme Importance" in the evaluation and selection of suppliers. Both groups ranked all the indicators in the same order of importance: reliability first, then cost-effectiveness, flexibility, lead time and finally value-added service.

The two-tailed Wilcoxon-Mann-Whitney test showed no significant differences in the importance both contractors and suppliers attached to reliability, flexibility and value-added service at five per cent level of significance. Significant differences were only noted in the importance attached to cost-effectiveness and lead. The percentage that placed higher importance on both cost-effectiveness and lead time was higher for contractors than for suppliers.

The ranking of the importance of performance indicators in the same order established existence of a common understanding, which is an essential element in supply chains, among both interviewed contractors and suppliers of requirements for meeting customer needs.

Significant differences in importance contractors and suppliers attached to cost-effectiveness most likely reflected opposing interests of customers and suppliers. Cost-effectiveness could imply lower prices for contractors, while to suppliers it may imply better prices for their products. Significance differences in importance attached to lead time likely reflected differences in opinions between the two groups regarding its importance in supplier evaluation and selection. Contractors most likely considered this indicator to be more important in meeting their requirements than suppliers, as reflected in frequencies of combined responses.

The more detailed analysis of the prioritisation of the performance indicators in contributing to improved customer service performed using the Analytic Hierarchy Process in Chapter 11 produced results which showed no significant differences when subjected to the Wilcoxon-Mann-Whitney test even though the results were by relatively smaller sample sizes of both contractors and suppliers.

13.4.2 Logistics enablers

From Chapter 8, over 88 per cent of the contractors considered all the enables, with the exception of information and communication technologies, to be of "Average Importance" to "Extreme Importance" in supplier evaluation and selection. Only 42.9 per cent of the contractors considered information and communication technologies to be of "Average Importance" to "Extreme Importance". The rest of the contractors, 57.1 per cent, assessed information and communication technologies to be of "Little Importance" to "No Importance" in supplier evaluation and selection.

From Chapter 9, over 58.6 per cent of the suppliers assessed all the enables, with the exception of environmental records and information and communication technologies, to be of "Average Importance" to "Extreme Importance" in the evaluation and selection of suppliers. Only 46.7 per cent and 13.3 per cent of suppliers assessed environmental and information and communication technologies respectively to be of "Average Importance" to "Extreme Importance" in the evaluation and selection of suppliers.

The ranking of the importance of enablers by contractors and materials suppliers did not perfectly match. The results are presented in Table 12.2.

No significance differences were observed in the importance attached by both contractors and suppliers to quoted price, quality management systems of suppliers, long-term relationships, management and administrative ability of suppliers and location of suppliers in relation to projects. Significant differences were exhibited in the importance attached to capability of suppliers, health and safety records of suppliers, environmental records and information and communication technologies in supplier evaluation and selection.

Table 13.1: Comparison of importance attached to enablers by UK contractors and suppliers

Legend of responses: 5=Extreme Importance, 4=Considerable Importance, 3=Average Importance, 2=Little Importance, 1=No Importance

	Suppliers			Contractors			Probability
Enablers	Cases m	Importance Index	Factor Ranking	Case n	Importanc Index	Factor Ranking	**Wilcoxon-Mann-Whitney** 2-Tailed p
Quoted **price**	29	0.86	1	35	0.86	1	0.9819
Capability (financial strength, production technology and efficiency, experience)	30	0.65	5	35	0.79	2	0.001
Quality management systems employed by supplier (TQM, QC, QA)and quality of products	30	0.7	2	35	0.78	3	0.0748
Health and Safety records suppliers	30	0.55	7	35	0.76	4	0.0002
Long-term relationships with suppliers (such as partnering)	28	0.66	3	35	0.75	5	0.0577
Management and administrative capability of suppliers	30	0.66	3	35	0.72	6	0.1497
Environmental record of supplier	30	0.48	8	35	0.66	7	0.0003
Location of supplier in relation to project	29	0.6	6	35	0.64	8	0.1585
Information and Communication technologies (bar codes, EDI, Database management systems)	30	0.38	9	35	0.48	9	0.0163

The more detailed analysis of the prioritisation of the enables in contributing to improved customer service performed using the Analytic Hierarchy Process in Chapter 11 produced results which showed no significant differences, except for capability, when subjected to the t-test even though the results were by relatively smaller sample sizes of both contractors and suppliers.

Though location was cited as one of the obstacles to formation of long-term relationships, the surveyed contractors and suppliers did not rank this factor among the most important enables for evaluation and selection of suppliers. Information and communication technologies were considered the least important enablers by both contractors and suppliers in supplier evaluation and selection suppliers. The AHP evaluations also produced results which rated the technologies at the bottom of the list among enablers in contributing to improved customer service.

13.5 Usage of logistics performance indicators and enablers in supplier evaluation and selection

13.5.1 Logistics performance indicators

From the analyses presented in Chapters 8 and 9, over 88 per cent of contractors and 83 per cent of suppliers, respectively, responded that all the five identified performance indicators were "Occasionally" to " Always" considered in the evaluation and selection of suppliers.

The ranking of the extent to which contractors and suppliers said logistics performance indicators were used in supplier evaluation and selection did not quite match. While contractors ranked both reliability and cost-effectiveness of suppliers in the first position, suppliers ranked reliability first and cost-effectiveness second. Lead time was ranked second by contractors and fourth by suppliers, while flexibility was ranked third by both groups. Both groups ranked value-added service the least considered performance indicator in the evaluation and selection of construction materials suppliers.

Statistically, responses of both contractors and suppliers showed no significant difference in the extent to which cost-effectiveness, flexibility and value-added service were considered in supplier evaluation and selection. Significant differences were exhibited in the extent to which reliability and lead times of suppliers were said by both groups to be considered in supplier evaluation and selection. Differences in responses of contractors and suppliers over reliability can be considered negligible because both groups assigned this enabler the first rank. However, differences in responses over lead time were not negligible because while exhibiting significant differences, contractors ranked the enabler second while suppliers ranked it fourth in the extent it was considered in supplier evaluation and selection.

Comparisons between Tables 9.5 and 9.7 show that suppliers were consistent in ranking the importance of the indicators and the extent to which they said the indicators were considered in supplier evaluation and selection. Contractors, however, were less consistent in their ranking of cost-effectiveness, lead time and flexibility. While contractors considered flexibility more important than lead time (Table 8.6), in practice they took lead time more into account than flexibility when evaluating and selecting materials suppliers (Table 8.9).

13.5.2 Logistics enablers

From the analysis of the contractors' questionnaire in Chapter 8, over 62 per cent of contractors responded that all the identified enablers were " Occasionally" to "Always" considered in supplier evaluation and selection. From analysis of the supplier questionnaire in Chapter 9, over 53 per cent of the suppliers responded that all the identified enables, with the exception of health and safety records of suppliers, were "Occasionally" to "Always" considered in supplier evaluation and selection.

Comparisons of responses of contractors and suppliers did not exhibit significant differences for quoted prices, management and administrative ability of suppliers, location of suppliers, and information and communication technologies.

Significant differences were, however, exhibited in the extent to which contractors and suppliers said long-term relationships, capability of suppliers, health and safety records of suppliers, quality management systems of suppliers and environmental records of suppliers were considered in supplier evaluation and selection. These differences in the viewpoints of the two groups revealed misunderstandings in construction materials supply chain practices which require 'ironing-out' in order to reach industry-wide prioritised consensus about developments in construction materials supply chains.

13.6 Evaluation of contributions of performance indicators and enablers to customer service using the Analytic Hierarchy Process

In Chapter 11, assessments of contributions of the identified logistics performance indicators and enablers to improvements in customer service by both contractors and suppliers were made using the Analytic Hierarchy Process via the software package called Expert Choice.

The 2-tailed t-test probability results showed no significant differences between the evaluations by contractors and suppliers of percentage contributions of all performance indicators to improved customer service. Similarly, with the exception of capability, the 2-tailed t-test probability results showed no significant differences in the evaluations by contractors and suppliers of percentage contributions of the rest of the enablers to improved customer service.

The evaluations of percentage contributions of capability to improved customer service by contractors and suppliers were significantly different. While contractors ranked capability of suppliers second with a contribution of 18.6 per cent to customer service, suppliers ranked it fourth at a contribution of 12.9 per cent. Thus, with this single exception, both contractors and suppliers generally agreed about the level of contributions of performance indicators and enablers to improvements in customer service in the delivery of construction materials.

Even though the one-off project nature of construction may constrain the formation of long-term contractor-supplier relationships, experiences of the interviewed experts from both contractor and supplier organisations suggested that greatest contributions to customer service accrue from improved contractor-supplier relationships. Overall, the interviewees determined that improved contractor-supplier relationships contributed more to all the performance indicators: reliability, cost-effectiveness, flexibility, lead time and value-added service and consequently were assessed to be the most important enabler in improving customer service in the supply of construction materials. Price was considered to be the second most important enabler in satisfying customer requirements, especially through cost-effectiveness of the products or services provided by suppliers.

Traditional factors such as capability, management and administrative ability, quality management systems, quoted prices and locations of suppliers in relation to projects continue being considered important by industry experts and have to be taken into account in the evaluation and selection of suppliers. On the other hand, though considered in the evaluation and selection of suppliers, environmental and, health and safety records of suppliers could have other wider impacts on individual project participants and affected public interests but were assessed to have little direct bearing over the provision of time and place utility in the supply of construction materials.

The difference in the many benefits from use of information and communication technologies reported from literature and the low level of contribution interviewed contractors attached to contributions of the technologies to improvements in efficiency and cost-effectiveness in the supply of construction materials suggest very low or non usage of the technologies by the interviewed contractors and suppliers.

13.7 Importance of various elements in improving materials management

The responses of contractors and suppliers to various factors for improving materials management to support construction were discussed in Chapters 8 and 9 and compared in Chapter 10. Table 10.9 in Chapter 10 presented the rankings of these factors and tests of significance in responses of contractors and suppliers in as far as they considered how important these factors were in improving materials management to support construction.

Even though the rankings of the importance of the factors by contractors and suppliers did not uniformly match, comparison results exhibited no significance differences in the importance attached to all the practices with the exception of 'Selection of suppliers by contractors' for which significant differences were noted. With the exception of the use of information and communication technologies, over 50 per cent of both suppliers and contractors considered all the practices important in improving materials management to support construction.

'Materials planning by site staff' was ranked as the most important practice by contractors and the second most important practice by suppliers in improving materials management to support construction. Materials planning is the most important materials function as it guides all subsequent activities and can have great impact on project plans (Stukhart, 1995).

'Selection of suppliers by contractors' was ranked the second most important practice by contractors and fifth by suppliers. The ranking of this practice in relation to materials logistics by contractors runs almost parallel to an earlier assertion by Ndekugri (1988) who had identified selection of sub-contractors as one of the key ways of contributing to successful construction.

'Management capability of site staff' was ranked third, 'Customer service levels provided by suppliers' and 'Improving contractor-supplier relationships' were both ranked fourth in importance by both contractors and suppliers. The view that management capability of site staff was important in improving the management of materials to support construction was further upheld by contractors' responses in sub-section 8.8.2 in which 60 per cent of them indicated that they exclusively used site managers, as opposed to individuals of lower responsibilities, to control materials on construction sites while a further 17.4 per cent used site managers though not exclusively.

While 'Communication between head office and suppliers' was ranked fourth in importance by contractors and sixth by suppliers, 'Communications between sites and suppliers' was ranked first by suppliers and fifth by contractors. Early payment of suppliers for delivered materials was not considered very important by both contractors and suppliers who ranked it seventh and sixth respectively. Both groups also did not see 'Stationing a materials manager on site by contractors' among the most important approaches to improving materials management to support construction. This practice was ranked eighth by suppliers and seventh by contractors.

13.8 Problems in the supply of construction materials

In decreasing order of frequency of occurrence, supplier related problems identified from the contractor questionnaire included:

- late submission of supplier drawings;
- late deliveries;
- incorrect supplier drawings;
- poor communication;
- poor quality, and inadequate supplier control of lower tier suppliers;
- no supplier quality assurance or quality management programmes; and
- lack of conformance to requirements.

Over 68 per cent of respondents indicated that the occurrence of these problems ranged from "Sometimes" to "Extremely Common". These problems originally identified in the USA construction industry were, thus, still prevalent in the UK construction industry. These are supplier related problems whose impact on productivity can be mitigated via interface and supply chain management of suppliers by contractors.

Addressing these and many other problems identified earlier in the review of literature in materials management requires approaching the problem from three directions, as already identified above and proposed in the supplier management process model in Chapter 12:

- the contractor's administrative offices through the selection of suppliers, improving contractor supplier relationships, paying suppliers early for materials already delivered and improving communication with suppliers;

- the construction site through materials planning by site staff, improving management capability of site staff and improving communication between construction sites and suppliers; and
- the suppliers' end by improving customer service levels in the delivery of materials to construction sites, suppliers' technical and administrative ability.

13.9 Summary

This chapter has presented the discussion of results of the research into construction materials logistics in the UK construction industry analysed in Chapters 8, 9, 10 and 11.

The extent to which information and communication technologies were being used within and between the surveyed UK suppliers and contractors has been examined, and benefits of and impediments experienced by interviewed companies to implementation of the technologies have been identified. Integrated database management systems (IDBMS) were more widely used by the surveyed companies in internal materials management processes in comparison to other electronic data management technologies. On the other hand, the telephone, facsimile and postal services were more widely used information exchange mediums in materials logistics activities between construction sites and surveyed UK suppliers and contractors.

The nature of contractor-supplier relationships, and benefits of and obstacles to formation of such relationships experienced by the interviewed companies have also been discussed. The research established existence of both closer working relationships among interviewed suppliers and contractors and also entrenched arms'-length practices on the part of the contractors. Benefits of and obstacles to implementation of closer working relationships between the contractors and the suppliers were identified.

The importance attached to logistics performance indicators and enablers, and the extent to which these factors were considered in supplier selection were assessed and ranked by both contractors and suppliers using Equations 7.1 and 7.2 in Chapter 7. While significant differences were observed in the evaluations, all the performance indicators were considered to be of 'Average Importance' to ' Extreme Importance' by the surveyed companies. Also, over 60 per cent of the surveyed contractors indicated that they 'Occasionally' to 'Always' considered all the enablers in supplier evaluation and selection.

Further evaluations of contributions of the performance indicators and enablers to improvements in customer service using the Analytic Hierarchy Process resulted in relative quantified priority rankings of the factors. Results of the 2 tailed t-test showed that, with the exception of capability, both contractors and suppliers generally agreed on the level of contributions of performance indicators and enablers to improvements in customer service in the delivery of construction materials.

The extent of occurrence of various supplier related materials management problems was assessed and the levels of importance of different approaches for improving materials management to support construction were determined and prioritised.

Chapter 14 which follows presents the conclusions, recommendations and further work.

CHAPTER FOURTEEN

CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK

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CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK

14.1 Introduction

The previous chapter discussed the results of the questionnaire surveys and interviews with contractors and materials suppliers presented in Chapters 8, 9, 10 and 11. This chapter presents the conclusions, recommendations and suggests further work. The main aim of this research was to develop a systematic supplier management decision-support process model that contractors could use for short and long-term management of suppliers in the implementation of construction materials supply logistics. Such a model would benefit construction companies by identifying the most important elements that can lead to efficient supply of construction materials. The research involved an investigation of the implementation of materials logistics in the UK construction industry. The specific objectives of the study were to:

- assess the extent to which information and communication technologies were being used in materials supply logistics in the UK construction industry;
- examine the nature of relationships and attitudes between contractors and suppliers in construction materials supply logistics in the UK;
- assess the importance that UK contractors and suppliers attached to logistics performance indicators and the extent to which they assessed the indicators to contribute to improved customer service in the supply of construction materials; and
- assess the importance that UK contractors attached to logistics enablers and the extent to which they took the enablers into consideration when evaluating and selecting construction materials.

The aim and objectives of the research were achieved through: a literature survey; two 'mirror-image' questionnaires (one sent to 71 UK contractors and the other to 76 UK construction materials suppliers); structured interviews with nine UK contractors and five UK construction materials suppliers; and a supplier management process model validation exercise with nine UK contractors. The conclusions drawn from the research are presented below.

14.2 Conclusions

The questionnaires and interviews used as research instruments were designed on the basis of the conclusions drawn from the literature review. Results of the questionnaires and interviews have been presented in Chapters 8, 9 and 10 while evaluations of the AHP model by the interviewed contractors and suppliers have been presented in Chapter 11. The supplier management decision-support model has been presented in Chapter 12. What follows are conclusions drawn from the findings of both questionnaire surveys and interviews with UK contractors and construction materials suppliers in relation to the objectives of the research.

14.2.1 Use of information and communication technologies in construction materials supply logistics

The information and communication technologies investigated in this research, that could be used for data entry, include electronic document imaging, voice recognition, radio frequency tagging, bar codes and magnetic stripes. Integrated database management systems, electronic mail and electronic data interchange can be used for internal and external integration of materials management processes. The telephone, facsimile and post comprise information and communication technologies that have been traditionally used for relaying information between companies in materials logistics activities. The extent to which all these technologies were used by interviewed contractors and suppliers in materials logistics was investigated.

14.2.1.1 Usage within companies

Results of this research revealed that data entry into computers of the surveyed contractors and suppliers was predominantly performed manually via the keyboard. Usage of electronic data entry technologies was found to be very low. The industry had not yet exploited the advantages of fast and virtually error free data entry offered by these technologies. Keyboard data entry is slow and errors due to miskeying are high with the likely creation of 'bottlenecks' in the flow of information. This inevitably adversely affects the cost, timeliness and accuracy of such systems and requires operatives to spend unnecessary periods of time doing tasks which could otherwise be eliminated.

With integrated database management systems being used by about 66 per cent of surveyed contractors and 63 per cent of suppliers 'Occasionally' to 'Always' in their internal materials management processes, internal integration of materials logistics processes was fairly widespread among the surveyed UK contractors and construction materials suppliers. Electronic mail was also slightly widely used with about 43 per cent of both surveyed contractors and suppliers stating that they 'Occasionally' to 'Always' used it in internal materials management processes.

Even though the integration of materials logistics processes in both contractor and supplier organisations appeared to be on the increase, the full potential has not been reached and much could still be done to enhance efficiency in the delivery of construction materials. Primary benefits from information and communication technologies in internal integration of construction materials management processes can result in reduced errors, elimination of duplicate effort and input, and shorter cycle times. All these can lead to improved quality of information processing and elimination of redundant effort.

14.2.1.2 Usage in materials logistics activities between construction sites, suppliers and contractors

The telephone, facsimile and postal services were the most widely used information and communication technologies in materials logistics activities between construction materials suppliers and contractors; construction materials suppliers and construction sites, and between administrative offices of contractors and their construction sites. The usage rates of electronic technologies such as integrated database management systems, electronic mail, and electronic data interchange in these logistics activities were low.

The contrast between the high usage of integrated database management systems in internal materials management processes and the low usage of integrative electronic technologies in external materials management processes suggested existence of islands of automation. It was clear from these results that companies were widely using information and communication technologies to process information but not for exchanging it across organisational boundaries. Achieving internal integration is desirable, but the performance of islands of automation is generally degraded due to poorly performing suppliers in the supply chain.

14.2.2 Contractor-supplier relationships

Most of the surveyed UK contractors had either long-term trading relationships or a combination of different types of closer working relationships with their suppliers, ranging from non-partnering long-term trading, short-term project partnering, long-term partnering to partnerships.

The contractor questionnaire survey revealed that 94 per cent of all contractors maintained lists of preferred suppliers and 90 per cent of surveyed suppliers responded that their names were on contractors' lists of preferred suppliers. The same proportions of contractors, 94 per cent, and suppliers, 90 per cent responded that they either had closer working relationships or a combination of arms' length trading with other types of closer working relationships with their trading partners. Very small proportions of contractors, six per cent, and suppliers, ten per cent described their relationships with their trading partners as strictly arms' length.

The results of the statistical tests on contractor-supplier relationships showed significant differences in responses of contractors and suppliers to many of the statements concerning their trading relationships. The proportions of contractors who agreed with statements alluding to good contractor-supplier relationships were generally higher than that of suppliers.

The major findings of the survey concerning improved contractor-supplier relationships to which more than 50 per cent of both surveyed contractors and suppliers agreed were that UK contractors:

- knew which suppliers were more important to them;
- tried to reduce the number of their suppliers to a minimum;
- attempted to obtain mutual beneficial relationships with their suppliers;
- sought to obtain unique advantage over their competitors through their relationships with their suppliers;
- sought the commitment of suppliers to achieve project delivery goals of cost, time and quality;
- maintained open and honest communication with their suppliers based on mutual respect; and
- ensured trust in the sharing of project information with their suppliers.

Even though contractors' working relationships with their suppliers were close, responses of both contractors and suppliers to the remaining statements on relationships revealed some poor supply chain management practices. Statements which reflected poor practices were that:

- contractors changed their suppliers frequently;
- the practice of contractors sharing their strategic plans with their suppliers was not common practice in the industry;
- contractors did not give as much feedback to suppliers as the suppliers would have liked;
- contractors expected suppliers to deliver exactly what was specified without question;
- contractors checked every delivery to ensure consistent quality due to lack of trust in the reliability and quality management systems of suppliers;
- suppliers did not get involved during project development goals at the tendering stage;
- contractors often did not pay suppliers in time for materials already delivered; and

- contractors did not always give enough time to suppliers to prepare quotations when bidding to supply materials.

Even though evidence suggested existence of closer working relationships among contractors and suppliers, much was still needed to be done by UK contractors to improve relationships to the point where feelings of win-win relationships were mutual.

14.2.3 Logistics performance indicators

The research identified five indicators over which the performance of suppliers in contributing to customer service can be evaluated. The indicators are:

- reliability;
- cost-effectiveness;
- flexibility;
- lead time; and
- value-added service

Over 80 per cent of all the contractors and suppliers assessed all the performance indicators to be of 'Average Importance' to 'Extreme Importance' in contributing to improved customer service and that the indicators were "Occasionally" to "Always" considered in the evaluation and selection of suppliers.

Contributions of performance indicators to improved customer service were next evaluated using the Analytic Hierarchy Process. Reliability of a supplier was assessed to have the highest contribution to improved customer service followed in the second place by the cost-effectiveness of the service provided by a supplier in the supply of construction materials. Contractors assessed lead time as the third most important performance indicator followed by flexibility in the fourth rank. However, suppliers assessed flexibility to be third and lead time to be fourth. Value-added service was assessed by both contractors and suppliers to have the least impact on customer service.

14.2.4 Logistics enablers

Factors identified in this research to enable suppliers to achieve improved customer service in the delivery of construction materials as measured on the basis of the performance indicators identified above include:

- quoted prices of materials;
- capability of suppliers in terms of financial strength, production technology and efficiency, and experience;
- quality management systems employed by suppliers;
- health and safety records of suppliers;
- contractors' long-term relationships with suppliers (for example, partnering);
- management and administrative ability of suppliers;
- location of suppliers in relation to projects;
- environmental records of suppliers; and
- information and communication technologies (for example, bar codes, EDI, database management systems)

Over 60 per cent of the contractors responded that all the identified enablers were "Occasionally" to "Always" considered when evaluating and selecting construction materials suppliers. With the exception of health and safety records of suppliers, all the identified enablers were also said to be "Occasionally" to "Always" considered by over 50 per cent of the surveyed suppliers.

The perceived importance of the enablers were also established, and with the exception of information and communication technologies, over 88 per cent of the surveyed contractors considered all the other enablers to be of "Average Importance" to "Extreme Importance". With the exception of environmental records of suppliers and the use of information and communication technologies, all the identified enablers were considered to be of "Average Importance" to "Extreme Importance" by over 58 per cent of the surveyed suppliers.

From the AHP evaluations, the general view of the interviewed UK construction industry experts was that improving contractor-supplier relationships would contribute more to improved customer service in the supply of construction materials by ensuring better reliability, cost-effective sources of supply, increased flexibility, improved lead times and greater value-added service. Traditional elements like capability of suppliers, their administrative and management ability, quality management systems, quoted prices and their locations in relation to projects were also considered important.

Interviewed experts assessed the contribution of information and communication technologies to improvements in customer service to be relatively low. This was not surprising. As was seen in Chapters 8, 9, and 10, the usage of these technologies by both groups had not 'matured' sufficiently for them to experience major benefits. Health and safety, and environmental records of suppliers were also considered to have little influence on customer service in the delivery of construction materials.

The t-test exhibited no significant differences in the AHP evaluations by contractors and suppliers of the contribution of logistics performance indicators to improved customer service. Similarly, there were also no significant differences in the AHP evaluations by contractors and suppliers of the contribution of enablers, with the exception of capability, to improved customer service. Interviewed experts from both contractor and supplier organisations were thus, generally agreed about the levels of contribution of both logistics performance indicators and enablers to customer service.

14.3 Recommendations

This research developed a systematic supplier management decision-support process model that contractors could use for short and long-term management of suppliers in the implementation of construction materials logistics. The model has been provided in form of a flow chart shown in Figure 12.1 in Chapter 12. It was validated and found to be functional, user-friendly and useful by nine contractors through a self-completion questionnaire. The views of the interviewed contractors were that implementation of the model could lead to cost-effective materials supplies, improved reliability of suppliers, improved relationships and improved customer service. Suppliers directly affect the price, quality, delivery reliability and availability of products and are an essential part of the supply chain (Oleson, J. D., 1998; Pearson and Ellram, 1995). Thus, management of suppliers through proper maintenance of a database of preferred suppliers; more structured selection of suppliers at both company and project level; and monitoring of their performance by contractors as proposed in the model is recommended.

Within overall supplier management programmes, specific activities are recommended to improve the supply of construction materials.

- To remove 'bottlenecks' in the flow of information resulting from slow keyboard data entry and errors due to miskeying, both contractors and suppliers should identify and implement electronic data entry technologies such as electronic document imaging, voice recognition, radio frequency tagging, bar codes or magnetic stripes appropriate for their operations in construction materials logistics.
- To derive full benefits such as shorter cycle times and elimination of redundant effort, both contractors and suppliers should intensify internal integration of their materials management processes via increased implementation and usage of integrated database management systems.
- To increase efficiency in construction materials supply chains, there is need to invest in and increase usage of electronic database management systems, electronic mail, electronic data interchange and data input technologies to facilitate improved exchange of information between contractors and suppliers.
- To remove incompatibilities in ICT systems, there is need for a combined industry effort to standardise information and communication technology formats and processes.
- To ensure continuous improvement, team efforts to improve collaboration leading to strategic partnering between contractors and suppliers in materials logistics should be pursued.

- Overall, all efforts at supplier management via improved contractor-supplier relationships by contractors should be focused on meeting client requirements of reduced costs, improved delivery lead times and improved quality.
- To minimise inventory related costs such as capital lock-up, forfeited interest, theft and obsolesce the drive to implement Just-In-Time (JIT) practices in construction logistics in order to reduce lead times should be pursued.

14.4 Further work

The research investigated the implementation of materials logistics with emphasis on the management of the contractor-supplier interface. It identified: information and communication technologies; relationships; logistics performance indicators and logistics enablers as essential elements in the efficient supply of construction materials. To improve performance in the supply of construction materials, the following further work is recommended.

14.4.1 Information and communication technologies

Reviewed literature demonstrated that major benefits can accrue from implementation of information and communication technologies despite the fact that industry remains pessimistic. Information and communication technologies are rapidly developing with an acknowledged growing increase in the usage of the technologies. Internet based information and communication technologies like intranets and extranets which were not investigated in this research have come into common usage. Further work is required to periodically determine the extent to which information and communication technologies which hold potential in materials logistics are used, and resulting benefits and obstacles to their implementation examined and compared with previous evaluations. The results from such evaluations should be publicised in order to raise awareness about the benefits so that exploitation of the technologies is encouraged.

This research has identified that usage of information and communication technologies is low. Obstacles to implementation of the technologies have also been identified. These include:

- incompatibility of technologies in use;
- high capital cost of the technology;
- fear of change;
- non-availability of information technology experts;
- required internal re-organisations and the scale of the operation needed to introduce ICTs; and
- inability to see major benefits from investment in the technology.

Further work to identify best practices of how of how these obstacles can be overcome is recommended.

14.4.2 Contractor-supplier relationships

After Latham's (1994) recommendations, the concepts of collaboration such as partnering within the UK construction industry have become increasingly important. As a practice that is on the increase, it is also important to periodically evaluate the extent and nature of partnering relationships between contractors and suppliers; determine accruing benefits; and assess obstacles to partnering in order to develop awareness in the search for continuous improvements in materials logistics. Factors that hinder formation of long-term relationships identified in this research include:

- lack of trust between contractors and suppliers;
- conflict of interest where contractors want to achieve lowest price, instead of lowest turnout cost and suppliers want to achieve best price;
- entrenched traditional arms' length relationships;
- specifications which do not consistently use the same materials for all projects reduce scope for repetitively using the same supplier;
- lack of continuity of site activities;
- workloads of individual companies fluctuates tremendously, making strong contractor-supplier relationships awkward; and

- construction takes place where the project is, consequently sometimes restricting suppliers from being competitive or being able to offer superior service.

Further work to identify best practices which highlight how these obstacles to closer contractor-supplier relationships can be overcome is recommended. Ensuing periodic evaluations of contractor-supplier relationships should be compared with previous studies to assess changes or improvements that have taken place since earlier studies were performed.

14.4.3 Implementation of the supplier management process model

The implementation of the proposed supplier management process model in Chapter 12 should be the subject of further research and the developed system further validated and evaluated in order to refine it to suit implementable industry practices. Further research should also investigate how a vendor rating system and the monitoring of performance of client nominated suppliers can be incorporated in the model.

LIST OF REFERENCES

Abdul-Rahman, H. and Alidrisyi, M. N. (1994). A perspective of materials management practices in a fast developing economy: The case of Malaysia. *Construction Management and Economics*, Vol. 12, No. 5, pp. 413 - 422.

Agapiou, A., Price, A. D. F. and McCaffer, R. (1995). Planning future construction skill requirements: understanding labour resource issues. *Construction Management and Economics*, Vol. 13, No. 2, pp. 149 -161.

Ahmad, M. (1996). Construction Impediments in Bangladesh and Sustainable Developments. *Productivity in Construction - International Experiences. Second International Congress on Construction, pp. 145-150.*

Ahmed, S. M. and Kangari, R., (1995). *Analysis of Client-satisfaction Factors in Construction Industry*. Journal of management in Engineering, Volume 11 (2), pp. 36

Alderson, F. (1999, May 13). A scheme to tax industry's minds. *Construction News*. Construction News, pp. 42.

Alkaabi, J. A. (1994). *Improved materials management using automatic identification techniques*. Unpublished Ph.D. Thesis, Loughborough University.

Alkass, S., Aromian, A. and Moselhi, O. (1993). Computer-Aided Equipment Selection for Transporting and Placing Concrete. *Journal of Construction Engineering and Management*, Vol. 119, No. 3, pp. 445-465.

Allen, S. J. and Gibb, A. G. F. (1996). Effectiveness of short-term planning for interface management of trade contractors. In Langford, D. A. and Retik, A., *The Organisation and Management of Construction*, Vol. 2, E & FN Spon, pp. 162 - 171

Anderson, D. R., Sweeney, D. J. and Williams, (1986). *Quantitative Methods for Business. Third Edition*. St. Paul: West Publishing Company.

Arnold, A. (1992). Introduction to Materials Management. Prentice-Hall International, Inc.

Back, W. E. and Bell, L. C. (1995). Quantifying Process Benefits of Electronic Data

Management Technologies. Journal of Construction Engineering and Management, Vol. 121, No. 4, pp. 415-421.

Back, W. E. and Bell, L. C. (1994). *Quantifying benefits of electronic technology applied to materials management.* Construction Industry Action Group.

Bailey, P. (1991). *Purchasing Systems and Records.* Third Edition. Gower Publishing Company Limited.

Baldry, D. (1996). Client benchmarking of contractor performance. Managing the Construction Project and Managing Risk. International Symposium for the Organisation and Management of Construction, Vol. 2, E & FN Spon, pp. 72 - 81.

Banwell, G. H. (1964). The Banwell Report. H. M. S. O.

Barret, L. T. (1994). Process visualisation. *Information Systems Management,* Vol. 11, Spring, pp. 14-23.

Bartoski, M. (1995). Reengineering to be the best. *APICS: The Performance Advantage*, Vol. 5, No. 7, pp. 38 -41.

Bashein, J., Markus, M. L. and Riley, P. (1994). Business Re-engineering: Pre-conditions for BPR success. *Information Systems Management,* Vol. 11, Spring , pp. 7-13.

Baxter, L. F. and MacFarlane, A. W., (1992). Just-in-Time for the Construction Industry. Construction Papers No. 14. *The Chartered Institute of Building.*

Bell, L. and McCullouch, B. (1988). Bar Code Applications in Construction. Journal of Construction Engineering and Management, Vol. 114, No. 2, pp. 263 - 279.

Berka, J. H. and Conn, W. D. (1994). Materials Management: A Comprehensive System. *AACE Transactions,* SI.2.1 - SI.2.5.

Bingham, T. (1995). Share the Profits of Trust. *Building Magazine*, November 24, pp. 38.

Blanchard, B. S. (1981). Logistics engineering and management. 2nd Edition. London: Prentice-Hall.

Blatherwich, A. (1996). The supply chain balancing act - stock and service at a profit. *Logistics Information Management,* Vol. 9, No. 6, pp. 24-26.

Borcheding, J. D. and Garner, D. F. (1981, September). Work Force Motivation and Productivity on Large Jobs. *Journal of the Construction Division, Proceedings of the American Society of Civil Engineers,* Vol. 107, No. CO3, pp. 443-453.

Borcheding, J. D., Sebastian, S. J. and Samelson, N. M. (1980). Improving Motivation and Productivity on Large Projects. Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 106, No. CO1, pp. 73-89.

Bowersox, D. J. (1978). *Logistical Management.* Second Edition. New York; London: Macmillan Publishing Co., Inc.

Bowersox, D. J. and Closs, D. J. (1996). *Logistical management: The Integrated Supply Chain Process.* London: The McGraw-Hill Companies, Inc.

Bubshait, A. A. and Al-Musaid, A. A. (1992). *Owner Involvement in Construction Projects in Saudi Arabia.* Journal of Management in Engineering, ASCE, Vol. 8, No (2), pp. 176-185.

Building (1995). TEAM TALK at half-time, July 28, *pp. 28-30.*

Carter, C., Baldwin, A. and Thorpe, A. (1996). *Simulating work process changes: simulating the procurement process.* Civil and Building Engineering Department. Loughborough University.

Cassell Concise English Dictionary (1992). London: Cassell.

Central Unit on Procurement (1995). Guidance No. 51: Introduction to the EC Procurement Rules. HM Treasury.

CIPS, (1994, April). *Productivity and Costs: Contribution by the Chartered Institute of Purchasing and Supply to the Review of Construction Contracting.*

Cleary, T. (1998). *Business Information Technology.* London: Financial Times Professional Limited.

Christopher, M. (1992). *Logistics and Supply Chain Management.* London: Pitman

Publishing.

Church, C. H. (1983). *Practice and Perspective in Validation*: Research into Higher Education Proceedings. Guildford: Society of Research into Higher Education.

Compton, H. K., (1985). *Supplies and Materials Management.* Macdonald and Evans Ltd.

Construct IT (1998). *Benchmarking Best Practice Report: Supplier Management Update.*

Construction and Civil Engineering CD-ROM (1997, July-October). Reproduced from *Technical Indexes Ltd and Information Handling Services.*

Construction Computing (1997). EDI Awareness Poor, Issue No. 56, April, pp. 3

Construction Industry Institute (1992). The Integrated Data Environment: Task Force Product. The Construction Industry Institute, Austin, Texas.

Construction Industry Institute (1991). *In Search of Partnering Excellence.* CII Annual Conference.

Construction Industry Institute (1987). *Project Materials Management Handbook.*

Construction Manager (1998). *The essential accessory*, February, pp. 16-17.

Construction News, (1996). Financial review of the top 100 UK construction contractors, No. 6478, 22 August, 1996

Construction Productivity Network (1997, 24 April). *Better Supply Chain Management in Construction*, 24 April. Workshop Summary.

Contract Journal (1997c). Comment: who will benefit as business booms? 2 April, pp. 1.

Cooper, J. (1993). *Strategic Planning in Logistics and Transportation.* London: Kogan Page.

Coulson-Thomas, C. J. (1995). Business process re-engineering: the development requirements and implications. *Executive Development*, Vol. 8, No. 2, pp. 3-6.

Coyle, J. J., Bardi, E. J. and Langley, C. J. (1996). *The Management of Business*

Logistics. Sixth Edition. Minneapolis; St. Paul: Western Publishing Company.

Crowley, L. G. and Karim, M. A. (1995). Conceptual Model of Partnering. *Journal of Management in Engineering,* Vol. 11, No. 5, pp. 33 - 39.

Dand, R. and Farmer, D. (1970). Purchasing in the construction industry. London: Gower Press.

Davenport, T. H. (1993). Process Innovation: Re-engineering Work through Information Technology. Boston: Harvard Business School.

de Vaus, D. A., (1996). Surveys in Social Research. Fourth Edition. University College London Press Limited: London .

Dobler, D. W., Burt, D. N. and Lee, L. (1990). *Purchasing and Materials Management: Text and Cases.* Fifth Edition. New York: McGraw-Hill.

Druker, J., White G. and Hegewisch A. (1996). Between hard and soft HRM: human resource management in the construction industry. *Construction Management and Economics,* Vol. 14, No. 5, pp. 405-416.

Dyer, R. F. and Forman, E. H., (1992). Group Decision Support with the Analytic Hierarchy Process. *Decision Support Systems,* Vol. 8, No. 2, pp. 99-124.

Edum-Fotwe, E. T. (1995). *A Framework for Improving the Strategic Management of Construction Contractors.* Unpublished Ph.D. Thesis. Loughborough University of Technology.

Ellram, L. M. (1995). Partnering Pitfalls and Succes Factors. International Journal of Purchasing and Materials Management, Vol. 31, Spring, pp. 36 - 44.

Ellram, L. M. (1991). A Managerial Guideline for the Development and Implementation of Purchasing Partnerships. International Journal of Purchasing and Materials Management, Vol. 27, Summer, pp. 2 - 8.

Eubanks, F. M. and Bruno, G. A. (1995). Partnering: The Construction Management Method of the Future. American Professional Constructor, Vol. 19, September, pp. 11- 17.

Evans, G. N., Towill, D. R. and Naim, M. M. (1995). Business process re-engineering the supply chain. *Production Planning and Control*, Vol. 6, No. 3, pp. 32-38.

European Construction Institute (1997). *Partnering in the Public Sector: A Toolkit for the Implementation of Post Award, Project Specific Partnering on Construction Projects.*

European Construction Institute (1996). *Implementing TQ in the Construction Industry: A Practical Guide.* Thomas Telford.

Fink, A. (1995). How to analyse survey data. Thousand Oaks; London: Sage Publications.

Fink, A. and Kosecoff, J. (1985). How to conduct surveys: A Step-by Step Guide. Beverly Hills; London: Sage Publications.

Fisk, C. J. (1985). Contractor/Sub-contractor relationships. *The Practice of Site Management, Volume 3. The Chartered Institute of Building.*

Fojt, M. (1996a). Driving future trends. *Logistics Information Management*, Vol. 9, No. 5, pp. 31 - 32.

Fojt, M., (1996b). Briefings. Supplier alliances: Chrysler-MAGNA International. *Logistics Information Management*, Vol. 9, No. 5, pp. 55-56.

Forrester, J. W. (1961). *Industrial Dynamics.* Cambridge: Cambridge: M.I.T. Press,

Franks, J. (1991). Building Contract Administration and Practice. London: BT Batsford Ltd.

Gattorna, J., Day, A. and Hargreaves, C. J. (1991). What is Logistics?. *Logistics Information Management*, Vol. 4, No. 2, pp. 3 -5.

Glen, P. (1981). Project Management and Construction Control. London: Construction Press.

Goucha, H. Y. and O'Connor, J. T. (1997). Redesign of Vendor-Data Processes For Industrial Projects. *Journal of Management in Engineering*, Vol. 12, No. 5, 53-61.

Hakserver, A. M. (1995). Eliminating information overload in Construction Project Management: a critical success factor (CSFM) method. *Information and Dynamism for Future Prosperity. First International on Construction Project Management Proceedings. pp. 189-198.*

Hammant, J., (1995). Information technology trends in logistics. *Logistics Information Management,* Vol. 8, No. 6, pp. 32-37.

Hammer, M. and Champy, J. (1993). Re-engineering the Corporation. London: Nicholas Brealey Publishing.

Hancock, P. A. (1996). *A Study of Logistics Activities and Integrated Logistics within the Construction Industry.* Unpublished M.Sc. Dissertation, Loughborough University.

Harrington, H. J. (1991). Business Process Improvement. New York; London: McGraw-Hill, Inc.

Harrison, A. (1992). Just-in-Time Manufacturing in Perspective. London: Prentice Hall.

Henry, G. T. (1990). *Practical sampling.* Newbury Park; London: Sage Publications Ltd.

Hine, J. and Wetherill, G. B. (1975). A programmed text in statistics: The t-test and χ^2 Goodness of fit. Book Three. Chapman and Hall: London.

Hill, C. (1995). Don't trust too much. *Building Magazine*, November 24, pp. 39.

Holt, G. D., Olomolaiye, P. O., Harris, F. C. (1994). Factors Influencing UK construction Client's Choice of Contractor. Building and Environment, Vol. 29, No. 2, pp. 241 - 248.

Hope, C. (1999, February). BAA axes top fims in cost-cuttingmove. Construction News, pp. 4

Horner, R. M. W., Zakieh, R., Lall, H., Duff, A. R. and Raimsberry (1996). Improving Construction Productivity - A Practical Demonstration of a Process-Based Approach. Productivity in Construction - International Experiences. Second

International Congress on Construction, 5 - 6 November, 1996. Singapore, pp. 97-103.

Illingworth, J. R. (1987). *Temporary works: their role in construction.* London: Thomas Telford.

Illingworth, J. R. (1993). *Construction methods and planning.* London: E & FN Spon.

Institution of Production Engineers (1989). *A Management Guide to Logistics Engineering.* London: Institution of Production Engineers.

Johnston, J. E. (1981). Site Control of Materials. London: Butterworths.

Kapplemann, L. A., Richard, T. C. and Tsai, R. J. (1996). A manager's guide to electronic data interchange: doing business on the information superhighway. *Logistics Information Management*, Vol. 9, No. 1, pp. 12-17.

Kerridge, A. E. (1987). Manage materials effectively. *Hydrocarbon Processing*, May, pp. 63-67.

Kickert, W. J. M. (1978). *Fuzzy theories on decision-making: A critical Review.* London: Kluwer Academic Publishers.

Kirby, D. (1995). Site Materials Management. *In*: Construction Materials Management, by Stukhart, G, pp. 155- 169, New York: Marcel Dekker, Inc .

Korpela, J. and Tuominen, M., (1996). Logistics Performance with an Application of the Analytic Hierarchy Process. *IEEE Transactions on Engineering Management*, Vol. 43, No. 3, pp. 323-333.

LaLonde, B. J. and Zinszer, P. H. (1976). Customer Service: Management and Measurement. National Council of Physical Distribution Management.

Latham, M. (1994). *Constructing the Team.* HMSO, London.

Lambert, D. M. and Stock, J. R. (1993). *Strategic Logistics Management.* Third Edition. Boston: Irwin.

Leitch, J. (1997). Midas turns partnering arrangements into gold, Contract Journal, 21 May, pp. 13.

Lema, N. M. (1996). Construction Labour Productivity Analysis and Benchmarking - The Case of Tanzania. Unpublished Ph.D. Thesis, Loughborough University.

Lim, E. C. (1996). The Analysis of Productivity in Building Construction. Unpublished PhD Thesis, Loughborough University.

Lombardi, P. (1995). Non-Market and Multi Criteria Evaluation Methods for Public Goods and Urban Plans. *Financial Management of Property and Construction.* Proceedings of International Conference. Newcastle, Northern Ireland. Published by University of Ulster.

Lombardi, P. (1997). Decision-making in Urban Regeneration Plans. Engineering, Construction and Architectural Management, Volume 4 (2), pp. 127-142.

Luck, R. A. C. and Newcombe, R. (1996). The case for the integration of the project participants' activities within a construction project environment. The Organisation and Management of Construction, Vol. 2, pp. 458 - 470.

Magad, E. L. and Amos, J. M. (1989). *Total Materials Management.* Van Nostrand Reinhod: New York

Majid, M. Z. A. and McCaffer, R. (1996). *Critical factors that influence schedule performance. Productivity in Construction - International Experiences.* Second International Congress on Construction, May, pp. 73 - 79.

Marquardt, T. R. (1994). Total Cost Management Via Effective Materials Management. *AACE Transactions,* MAT.1.1 - MAT.1.5.

Mathews, J. (1996) *A project partnering approach to the main contractor - subcontractor relationship.* Unpublished Ph.D. Thesis, Loughborough University.

Mathews, J.D., Tyler, A. and Thorpe, A., (1996). Subcontracting - The Subcontractor's view. In Langford, D. A. and Retik, A.: The Organisation and Management of Construction, Vol. 2, E & FN Spon, pp. 471 - 480.

Matin, M. A. (1996). Construction Industry Productivity in Bangladesh. A Case Study: Rajuk Building Expansion and Renovation. *Productivity in Construction -*

International Experiences. Second International Congress on Construction, pp. 189-193.

Miles, R. S. (1996). Twenty-First Century Partnering and the Role of ADR. *Journal of Management in Engineering*, ASCE, Vol. 12, No. 3, pp. 165-176.

Millet, C. (1997). M&E hit Natwest Tower. *Contract Journal*, 12 February, pp. 1

Miyamoto, S., (1990). Fuzzy Sets in Information Retrieval and Cluster Analysis. Dordercht; London: Kluwer Academic Publishers.

Muehlhausen, F. B. (1991). Construction Site Utilisation: Impact of Material Movement and Storage on Productivity and Cost. *AACE Transactions*, L.2.1 - L.2.9.

Muya, M., Price, A. D. F., and Thorpe, A. (1997). Construction Materials Supply Logistics. Association of Researchers in Construction Management: Thirteenth Annual Conference, September 15 - 17, King's College, Cambridge, pp. 144 - 153.

Muya, M., Price, A. D. F., and Thorpe, A. (1998). Supplier evaluation of logistics factors and their contribution to customer service. Association of Researchers in Construction Management: Fourteenth Annual Conference, September 9 - 11, University of Reading, pp. 359 - 368.

National Economic Development Organisation (1990). *The Innovation Management Tool Kit. The Manager's Test*, London: HMSO.

Ndekugri, I. E. (1988). Sub-contractor control - The key to successful construction. *The Chartered Institute of Building*. No. 98. Technical Information Service.

NEVEM-workgroup (1989). *Performance Indicators in Logistics*. IFS Ltd.

Newcombe, R., Langford, D., Fellows, R. (1990). Construction Management 2: Management Systems. London: Mitchell (In association with the Chartered Institute of Building).

Nola, A. D., Sessa, S., Pedrycz, W. and Sanchec, E. (1989). Fuzzy relation equations and their applications to Knowledge Engineering. London: Kluwer Academic Publishers.

Nolan Norton Institute (1990). Imaging, The Imaging Tiger. White Paper

Nunn, D. (1997). Client forces Birse into partnering. Contract Journal, 15 January, pp. 6.

O'Connor, B. J. (1997). Supply Chain Competition. *Manufacturing Engineer*, Vol. 76, No. 4, pp. 183-185.

Oleson, J. D. (1998). Pathways to Agility. New York; Chichester: John Wiley & Sons, Inc.

Oppenheim, A. N., (1992). Questionnaire Design, Interviewing and Attitude Measurement. London: Pinter Publishers.

Orlicky J. (1975). Materials Requirement Planning. McGraw-Hill, Inc.

Oswald and Burati (1992). Guidelines for implementing Total Quality Management in the Engineering and Construction Industry. Construction Industry Institute.

Pearson, J. N. and Ellram, L. M. (1995, October). Supplier selection and evaluation in small versus large electronics firms. *Journal of Small Business Management*, Vol. 33, pp. 53 -65.

Peniwati, S. K. (1996). *The Possibility Theorem for Group Decision Making: The Analytic Hierarchy Process.* Katz Graduate School of Business, University of Pittsburgh.

Peters, G. (1981). Project Management and Construction Control. London: Construction Press.

Porter, M. (1985). *Competitive advantage: creating and maintaining superior performance*. Third Edition. New York; London: Free Press: Collier Macmillan.

Puddicombe, M. S. (1997, September). Designers and Contractors: Impediments to Integration. *Journal of Construction Engineering and Management*, Vol. 123, No. 3, pp. 245 - 252.

Rushton, A. and Oxley, J. (1989). Handbook of Logistics and Distribution Management. London: Kogan Page.

Rutland, P. (1996). Identification of variation generators in order to improve productivity. *Productivity in Construction - International Experiences. Second International Congress on Construction*, pp. 19-24.

Saaty, T. L. (1993). Priority Setting in Complex Problems. *IEEE Transactions on Engineering Management*, Vol. EM-30, No. 3, pp. 140-155.

Saaty, T. L. (1996). *Multicriteria Decision Making: The Analytic Hierarchy Process*. University of Pittsburgh. Pittsburgh.

Sarich, A. (1991). An Update on EDI.. *Logistics Information Management*, Vol. 4, No. 1, pp. 23-25.

Sãrkilahti, T., (1996). In Langford, D. A. and Retik, A.: *The Organisation and Management of Construction*, Vol. 2, E & FN Spon: London, pp. 404 - 413.

Saunders, M. (1994). *Strategic Purchasing and Supply Chain Management*. London: Pitman Publishing.

Seeley, I. H. (1993). Civil Engineering Contract Administration and Control, Second Edition. Basingstoke: Macmillan Press Limited.

Shapira, A. and Glascock, J. D. (1996). Culture of Using Mobile Cranes for Building Construction. *Journal of Construction Engineering and Management*, Vol. 122, No. 4, pp. 298-307.

Shenoy, D. and Bhadury, B. (1998). *Maintenance Resources Management: adapting MRP*. London: Taylor and Francis Ltd.

Sigma Management Ltd (1997). Working Together: Managing the Supply Chain within the UK Aerospace Industry.

Siegel, S. and Castellan, N. J. (1988). Nonparametric statistics for the behavioural sciences. Second Edition. New York; London: McGraw-Hill Book Company.

Singh, J. (1996). The importance of information flow within the supply chain. *Logistics Information Management*, Vol. 9, No. 4, pp. 28-30.

Smith, A. J. (1995). Estimating, Tendering and Bidding for Construction. Basingstoke: Macmillan Press Ltd.

Smith, R. C. (1986). Estimating and Tendering for Building Work. London: Longman Scientific and Technical.

Sözen, Z. and Küçük, M. A., (1996). In Langford, D. A. and Retik, A., *The Organisation and Management of Construction,* Vol. 2, E & FN Spon., pp. 481 - 488.

Stevens, A. (1988). Contractual aspects and responsibilities. In: Proceedings of the conference on *Economic construction techniques: temporary works and their interaction with permanent works,* Organised by the Institution of Civil Engineers held in London, pp. 57-66.

Stevens, G. C. (1989). Integrating the Supply Chain. *International Journal of Physical Distribution and Materials Management,* Vol. 8, pp. 3-8.

Stewart, G. (1995). Supply chain performance benchmarking study reveals keys to supply chain excellence. *Logistics Information Management,* Vol. 8, No. 2, pp. 38-34.

Stukhart, G. (1995). *Construction Materials Management.* New York: Marcel Dekker.

Stukhart, G. and Cook, L. (1989). Bar Code Standardisation in Industrial Construction. Construction Industry Publication, Austin, Texas, Source Document 47.

Tersine, R. J. (1985). *Production/Operations Management: Concepts, Structure and Analysis.* Second Edition. New York: Elservier Science Publishing.

The Aqua Group (1992). Pre-contract Practice for the Building Team, Eighth Edition. Oxford: Blackwell Scientific Publications.

The Business Roundtable (1983). *More Construction for the Money: Summary of the Construction Industry Cost Effectiveness Project.*

The Oxford English Dictionary (1989). Second Edition. Oxford: Oxford University Press.

Thomas, H. R., Sanvido, V. E. and Sanders, S. R. (1989). Impact of Materials Management on Productivity: A case study. *Journal of Construction Engineering* *and Management*, Vol. 13, No. 3, pp. 370-384.

Thompson, D. M., (1994). Using AHP to allocate Contract Incentives. *American Association of Cost Engineers (AACE). Transaction*, pp. DCL. 7.1-7.3.

Towill, D. R. (1996). Time compression and supply chain management - a guided tour. *Supply Chain Management*, Vol. 1, No. 1, pp. 15 - 27. MCB University Press.

Turner, J. R., (1993). Integrated Supply Chain Management: what is wrong with this picture? *Industrial Engineering*, December, pp. 52-55.

Wareham, C. D. (1991). *Competitive Logistics: A Manager's Guide*. IPS.

Watson, R. G. H. (1988). Organisation and Management of Construction - A National Overview. Managing Construction Worldwide: Construction Management and Organisation Perspective. *Chartered Institute of Building*, Vol. 3, pp. 29-37.

Whitelaw, J. (1997). Joys of finding the perfect partner. *New Civil Engineer*, May, pp. 10 - 12.

Winch, G. (1989). The Construction Firm and the Construction Project: a transaction cost approach. *Construction Management and Economics*, Vol. 7, No. 4, pp. 331-345.

Wind, Y. and Saaty, T. L. (1980). Marketing Applications of the Analytic Hierarchy Process. Management Science, Vol. 26, No. 7, pp. 641 - 658.

Womack, P. J., Jones, D. T. and Roos, D. (1990). *The Machine that Changed the World.* New York; Oxford: Rawson Associates and Macmillan Publishing Ltd.

Wong, E. T. T. and Norman, G. (1997). Economic evaluation of materials planning systems for construction. *Construction Management and Economics*, Vol. 15, No. 1, pp. 39 - 47.

APPENDIX A

Workshops, Seminars and Conferences attended during the research period

Workshop/Seminar/Conference Organisers	Workshop/Seminar/Conference Title	Workshop/Seminar/Conference Date	Workshop/Seminar/Conference Venue
Construction Productivity Network	Business Systems Engineering - A Route to Improving the Construction Process	26/11/96	Royal Academy of Engineering, 26 Great Peter Street, London, SW1P UK
Engineering and Physical Sciences Research Council (Innovative Manufacturing Initiative)	Partnering Theme Day: Construction as a Manufacturing Processes	30/01/97	Church House Conference Centre, Deans Yard, Westiminister, London, UK
Construction Productivity Network	Better Supply Chain Management in Construction	24/04/97	Edgbaston Cricket Ground, Birmingham, UK
Good Decision Ltd	Decision Making for Leaders	24-26/06/97	Reading University, UK
Association of Researchers in Construction Management	ARCOM 97: 13th Annual Conference and Annual General Meeting	15-17/09/97	King's College, Cambridge, UK
Building Research Establishment	What does Supply Chain Management offer the Construction Industry?	05/11/97	Garston, UK
Association of Researchers in Construction Management	ARCOM 99: 14th Annual Conference and Annual General Meeting	09-11/09/98	Reading University, UK

APPENDIX B

Contractor questionnaire documents

1 Covering letter

2 Contractor questionnaire

3 List of sampled and responding contractors

1 Covering letter

Department of Civil and Building Engineering
Loughborough University Loughborough Leicestershire LE11 3TU UK
Switchboard: +44 (0)1509 263171 Department: +44 (0) 1509 222884

Loughborough University

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»
«Address2»
«City»
«County»
«PostalCode»

11 August, 1997

Dear Sir,

Re: **Research into Integrated Materials Supply Logistics**

This letter accompanies a national survey questionnaire which is part of my Ph.D. research into Integrated Construction Materials Supply Logistics directed at contractors sampled from the Top 100 UK Contractors listed in the 1996 Construction News. The research started in September, 1996 and will continue up to September, 1999. The programme is being supervised by Dr. A. D. F. Price and Professor A. Thorpe in the Construction Management Group at Loughborough University.

The research is intended to establish criteria construction contractors use to evaluate and select material suppliers and specialist sub-contractors taking into account developments in information and communication technologies (i.e. EDI, bar codes, etc.), contractor-supplier/sub-contractor relationships such as partnering and other factors. The focus of the research is to develop a methodology for supplier/sub-contractor evaluation and selection. This is being done by initially identifying practices, through the questionnaire, which can improve quality, reduce costs and minimise project schedule overruns resulting from problems in the supply of construction materials.

The questionnaire is divided into five sections. It is primarily designed to collect data on: **trends in the use of information and communication technologies; contractor-supplier relationships; criteria used for evaluating and selecting suppliers; and materials management.** Responding to the questionnaire will take about 25 minutes of your time and your co-operation in this exercise is earnestly being sort. I would also like to assure you that your responses will be treated confidential. Please try to reply by 25 August, 1997.

The results of the survey will be summarised and sent to the responding individual whose name will appear in Section 1.0 of the completed questionnaire. A near 'mirror-image' questionnaire has also been sent to materials suppliers and subcontractors. The results of the second questionnaire will also be made available to you. Please do not hesitate to contact me at the e-mail, telephone or fax numbers given below or my supervisors at the number above should you feel the need.

Your co-operation will be greatly appreciated.

Yours faithfully,

Mundia Muya
Research Student (Ph.D.)
E-mail: M.Muya@lboro.ac.uk, Telephone No. (01509) 223773, Fax. No. (01509) 223981

2 Contractor questionnaire

RESEARCH INTO CONSTRUCTION MATERIALS SUPPLY LOGISTICS

1.0 COMPANY INFORMATION: This section is designed to obtain general information on your organisation.

Name of respondent [ ] Position in company [ ]

Name of company [ ] Telephone No. [ ]

If you would like summary results of survey faxed to you please give your Fax. No. in the space provided [ ]

Indicate what type your organisation is from among the given categories below *(Please tick ❑✓)*

Civil Contractor ❑ Building contractor ❑ General Contractor ❑ Other (Specify) ________

2.0 INFORMATION & COMMUNICATION TECHNOLOGY: This section is designed to assess trends in the implementation of information and communication technologies in the construction industry

2.1 To what extent are the following technologies used in the internal materials management processes within your organisation ? *(Please tick ❑✓)*

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Integrated Database Management System	❑	❑	❑	❑	❑	❑
Electronic data interchange (EDI)	❑	❑	❑	❑	❑	❑
Electronic mail (e-mail)	❑	❑	❑	❑	❑	❑
Bar codes	❑	❑	❑	❑	❑	❑
Radio frequency tagging	❑	❑	❑	❑	❑	❑
Magnetic stripes	❑	❑	❑	❑	❑	❑
Voice recognition	❑	❑	❑	❑	❑	❑
Electronic document imaging	❑	❑	❑	❑	❑	❑
Others (Specify)________	❑	❑	❑	❑	❑	❑

2.2 To what extent are the following technologies used in the materials management process between the purchasing office and construction sites in your organisation ? *(Please tick ❑✓)*.

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Integrated Database Management System	❑	❑	❑	❑	❑	❑
Electronic data interchange (EDI)	❑	❑	❑	❑	❑	❑
Electronic mail (e-mail)	❑	❑	❑	❑	❑	❑
Telephone	❑	❑	❑	❑	❑	❑
Facsimile	❑	❑	❑	❑	❑	❑
Post	❑	❑	❑	❑	❑	❑
Other (Please specify)________	❑	❑	❑	❑	❑	❑

2.3 To what extent are the following used between your organisation and suppliers in the construction materials management process? *(Please tick ❑✓).*

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Integrated Database Management System	☐	☐	☐	☐	☐	☐
Electronic Data Interchange (EDI)	☐	☐	☐	☐	☐	☐
Electronic-mail (e-mail)	☐	☐	☐	☐	☐	☐
Telephone	☐	☐	☐	☐	☐	☐
Facsimile	☐	☐	☐	☐	☐	☐
Post	☐	☐	☐	☐	☐	☐
Others (Specify)________________	☐	☐	☐	☐	☐	☐

3.0 **CLIENT/CONTRACTOR - SUPPLIER RELATIONSHIPS:** This section is designed to establish the nature of relationships between contractors and suppliers (includes sub-contractors).

3.1 Please indicate the extent to which you agree to each of the following as reflection of your company's practices *(Please tick ❑✓)*

	Strongly Agree (7)	Agree (6)	Slightly Agree (5)	Neutral (4)	Slightly Disagree (3)	Disagree (2)	Strongly Disagree (1)
We know which of our suppliers are vital to our business	☐	☐	☐	☐	☐	☐	☐
We buy on the basis of lowest price alone	☐	☐	☐	☐	☐	☐	☐
We try to reduce the number of our suppliers to a minimum	☐	☐	☐	☐	☐	☐	☐
To obtain the best deal we change our suppliers frequently	☐	☐	☐	☐	☐	☐	☐
We attempt to obtain mutually beneficial relations with our suppliers	☐	☐	☐	☐	☐	☐	☐
We seek to obtain a unique advantage over our competitors through our relationships with our suppliers	☐	☐	☐	☐	☐	☐	☐
We do not believe that sharing our strategic plans with our suppliers is in our best interests	☐	☐	☐	☐	☐	☐	☐

	Strongly Agree (7)	Agree (6)	Slightly Agree (5)	Neutral (4)	Slightly Disagree (3)	Disagree (2)	Strongly Disagree (1)
We expect our potential suppliers to deliver exactly what we specify without question	❑	❑	❑	❑	❑	❑	❑
We check every delivery - it is the only way to ensure consistent quality	❑	❑	❑	❑	❑	❑	❑
We always seek the commitment of our suppliers to achieve project delivery goals of cost, time and quality	❑	❑	❑	❑	❑	❑	❑
We always involve our suppliers when tendering for projects	❑	❑	❑	❑	❑	❑	❑
Communication between us and our suppliers is open, honest and based on mutual respect	❑	❑	❑	❑	❑	❑	❑
There is trust in the sharing of project information between us and our suppliers	❑	❑	❑	❑	❑	❑	❑
We always give ample time to our suppliers to prepare bids for the supply of materials	❑	❑	❑	❑	❑	❑	❑
We pay our suppliers in time for materials already delivered	❑	❑	❑	❑	❑	❑	❑
We give feedback to suppliers on their delivery performance	❑	❑	❑	❑	❑	❑	❑

3.2 Which of the following is true for your organisation *(Please tick ❑✓)*

We do not keep a list of preferred of suppliers ❑
We keep a list of preferred suppliers which is not on a computer database ❑
We keep a list of preferred suppliers on a computer database ❑

3.3 In general terms please indicate which of the descriptions below best describes your relationships with your suppliers? (Please tick ❑✓)

Arms-length relationship ❑
Non-partnering long-term trading relationship ❑
Short-term project partnering ❑
Long-term partnering ❑
Partnership ❑
Other (Please specify)______________________

4.0 **SUPPLIER SELECTION:** This section is designed to establish those factors considered important by contractors and those factors actually used by them to select suppliers.

4.1 Please indicate the frequency your organisation uses bidding to select suppliers for the following construction materials *(Please tick ❑✓)*

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Bulk materials, i.e., off-the-shelf materials like sand, gravel, ready mixed concrete, bricks standard clay and concrete pipes, purchased in bulk and often from a single source.	❑	❑	❑	❑	❑	❑
Fabricated materials such as concrete beams iron pipes and pipes, bridge bearings made to order for a particular project	❑	❑	❑	❑	❑	❑
Specialist materials like mechanical and electrical plant in industrial facilities, structural steelworks, lifts, cladding and building services normally subcontracted	❑	❑	❑	❑	❑	❑
Falsework materials such as access scaffolds, props, trench or other excavations support ❑ systems, formwork, etc.	❑	❑	❑	❑	❑	❑
Others______________________	❑	❑	❑	❑	❑	❑

4.2 In your opinion how important are the following factors in evaluating and selecting construction materials suppliers ? *(Please tick ❑✓)*

	Extreme Importance (5)	Considerable Importance (4)	Average Importance (3)	Little Importance (2)	No Importance (1)
Reliability (ability of supplier to deliver right products of right quality and quantity on schedule without damage)	❑	❑	❑	❑	❑
Flexibility (ability of supplier to adjust to schedule, changes with right products, in right quantities)	❑	❑	❑	❑	❑
Lead time quoted by supplier	❑	❑	❑	❑	❑
Value-added service exceeding basic service requirements	❑	❑	❑	❑	❑
Cost-effectiveness	❑	❑	❑	❑	❑
Information and communication technologies(Bar codes, EDI, Database management systems)	❑	❑	❑	❑	❑
Long-term relationships with suppliers(e.g., partnering)	❑	❑	❑	❑	❑
Quoted Price	❑	❑	❑	❑	❑
Location of supplier in relation to project	❑	❑	❑	❑	❑
Capability (Financial strength, production technology, production efficiency)	❑	❑	❑	❑	❑
Quality management systems employed by suppliers	❑	❑	❑	❑	❑
Management and administrative capability of suppliers	❑	❑	❑	❑	❑
Health and Safety records of suppliers	❑	❑	❑	❑	❑
Environmental record of suppliers	❑	❑	❑	❑	❑
If there are other factors please list and rate their importance: ____________	❑	❑	❑	❑	❑

4.3 What quality standard does your organisation require its suppliers to adhere to (*Please tick* ❑✓)

ISO 9000 series	BS 7850	BS 5750	None	Others (Please specify)
❑	❑	❑	❑	________________

4.4 When evaluating and selecting suppliers, to what extent do you use the following to assess suppliers? (*Please tick* ❑✓)

	Always (6)	Very often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Reliability of supplier	❑	❑	❑	❑	❑	❑
Flexibility of supplier	❑	❑	❑	❑	❑	❑
Lead time quoted by supplier	❑	❑	❑	❑	❑	❑
Value-added service provided by supplier	❑	❑	❑	❑	❑	❑
Cost-effectiveness of service by supplier	❑	❑	❑	❑	❑	❑
Information and communication technologies	❑	❑	❑	❑	❑	❑
Long-term relationships	❑	❑	❑	❑	❑	❑
Organisational culture (Feeling of trust, commitment supplier attitude)	❑	❑	❑	❑	❑	❑
Quoted Price only	❑	❑	❑	❑	❑	❑
Location of suppliers	❑	❑	❑	❑	❑	❑
Financial stability & economic performance	❑	❑	❑	❑	❑	❑
Technology(production capability & efficiency)	❑	❑	❑	❑	❑	❑
Quality management systems	❑	❑	❑	❑	❑	❑
Health and safety record	❑	❑	❑	❑	❑	❑
Environmental records	❑	❑	❑	❑	❑	❑
Visit to supplier's premises	❑	❑	❑	❑	❑	❑
Weighted-factor rating system	❑	❑	❑	❑	❑	❑
Management & Administrative capability	❑	❑	❑	❑	❑	❑

4.5 Please indicate the methods your organisation uses to evaluate suppliers (Please tick ❑✓ the methods you use most)

Ad hoc evaluation at buyer's discretion	❑
Follow-up and evaluate based on problems or complaints	❑
Formal review of performance every year or more frequently	❑
Formal review of performance every 13 to 24 months	❑
Formal review of performance every 2 years or less frequently	❑
Others	❑

4.6 How satisfied are you with the supplier evaluation system used by your organisation to select suppliers? (*Please tick* ❑✓)

Definitely satisfied (5)	Satisfied (4)	Neutral (3)	Not Satisfied (2)	Not satisfied Definitely (1)
❑	❑	❑	❑	❑

4.7 From which departments are individuals responsible for selecting suppliers from? (*Please tick* ❑✓)

Purchasing ❑ Estimating ❑ Others (Please specify) ❑ ________________

5.0 **MATERIALS MANAGEMENT:** This section is designed to ascertain factors which can help to improve the supply of construction materials to support construction.

5.1 The following are some of the problems that are found in the supply of construction materials. From your experience, please indicate how common these problems are *(Please tick ❑✓)*

	Extremely Common (6)	Very Common (5)	Common (4)	Sometimes (3)	Rare (2)	Never (1)
Late supplier drawings	❑	❑	❑	❑	❑	❑
Incorrect supplier drawings	❑	❑	❑	❑	❑	❑
Late deliveries	❑	❑	❑	❑	❑	❑
Poor quality	❑	❑	❑	❑	❑	❑
No supplier Quality Assurance or quality programmes	❑	❑	❑	❑	❑	❑
Inadequate supplier control of lower-tier suppliers	❑	❑	❑	❑	❑	❑
Poor communication	❑	❑	❑	❑	❑	❑
Lack of conformance to requirements	❑	❑	❑	❑	❑	❑

5.2 Indicate the level of importance of the items below in helping to improve the materials management process to support construction *(Please tick ❑✓)*

	Extreme Importance (5)	Considerable Importance (4)	Average Importance (3)	Little Importance (2)	No Importance (1)
Stationing a materials manager on site	❑	❑	❑	❑	❑
Selection of suppliers	❑	❑	❑	❑	❑
Communication between Head Office & suppliers	❑	❑	❑	❑	❑
Communications between site and suppliers	❑	❑	❑	❑	❑
Materials planning by site staff	❑	❑	❑	❑	❑
Use of electronic data management	❑	❑	❑	❑	❑

technologies like bar codes,
EDI, DBMS

	Extreme Importance (5)	Considerable Importance (4)	Average Importance (3)	Little Importance (2)	No Importance (1)
Early payment of suppliers for delivered materials	❑	❑	❑	❑	❑
Management capability of site personnel	❑	❑	❑	❑	❑
Customer service level provided by suppliers	❑	❑	❑	❑	❑
Improving relationships with suppliers	❑	❑	❑	❑	❑

5.3 Please indicate the title of the individual usually responsible for controlling materials on sites run by your company *(Please tick ❑✓)*.

Storeman ❑
Materials manager ❑
Site Engineer ❑
Foreman ❑
General foreman ❑
Site manager ❑
Other (Please specify)______________

5.4 If you have any specific items omitted by this survey you would like addressed please state in the space provided below.

Can your organisation participate initially by providing data by way of structured interviews and later detailed case studies ?

Yes ❑ No ❑

Your participation and co-operation in this survey has been most valuable. Please kindly put the questionnaire in the accompanying self-addressed envelope and mail it back to us.

Thank you.

Mundia Muya
Department of Civil & Building Engineering, Loughborough University
Loughborough, Leicestershire, LE11 3TU
E-mail: M.Muya@lboro.ac.uk, Tel. No.: (01509) 223773, Fax.: (01509) 223981

3 List of sampled and contractors that responded

List of contractors sampled from Construction News (1996)

	Names of companies in sample	Positions of respondents at companies that responded
1	Abbey Construction	
2	Alfred McAlpine	•
3	Allen Plc	Director
4	Amec - Building	
5	Amec - Civil	Head of Procurement
6	B S Heating Ltd	
7	Babcock King Wilkson	Purchasing Manager
8	Bachy Solanche	
9	Bainbridge & Son Ltd	Chief Estimator
10	Balfour Beaty - Civil	
11	Ballast Wiltshier	
12	Barr	
13	Barrat Developments	
14	Beazer Homes	
15	Berkely Group	Group Procrement & Technical Manager
16	Birse Construction Ltd	
17	Bowmer & Kirkland	Chief Buyer
18	Britannia Group	
19	Cala Homes Scotland Ltd	
20	Carlton Benbow	Chief Buyer
21	Chrsitiani & Nielson	Lead Estimator
22	Clugston	Chief Buyer
23	Costain House	
24	Countryside Properties	
25	Crest Homes	Purchasing Manager
26	Crest Nicholson	
27	David Mclean	
28	Dawe Roofing Contractors	
29	Dean & Dyball	Regional Quantity Surveyor
30	Dew Group	Chief Buyer
31	EBC Group	
32	Enterprise House	
33	Eve Group	Chief Buyer
34	Fair Class Homes	
35	Fitzpatrick	
36	GA	Chief Buyer
37	Galliford Midlands	Chief Buyer
38	J Breheny	
39	Jackson Civil Engineering	
40	James Longley	
41	Jarvis Construction UK Ltd	Marketing Manager
42	John Doyle	
43	John Maunders	
44	John Mowlem & Company	
45	John Sisk & Son	
46	Keller Group	
47	Kier Construction	
48	Kvaerner Construction	Procurement Manager
49	Kyle Stewart	Senior Buyer
50	May Gurney	
51	McNickolas Construction	

<u>List of contractors surveyed and sampled from the Construction News (1996)</u>
Continued.....

	Name of companies in Sample	Positions of respondents at companies that responded
52	Milne Stewart	Senior Buyer
53	Mivan International Projects	Marketing Assistant
54	Morgan Sindall	
55	Morrison	
56	North Midland Construction	
57	Norwest Holst	
58	Persimmon	
59	Pochin Group	Chief Buyer
60	R G Carter	
61	R Mansell	Group Purchasing Manager
62	Roland Bardsley	
63	Shepherd Construction Ltd	Chief Buyer
64	Simon Construction	Purchasing Manager
65	Tarmac - Civil	Purchasing Manager
66	Tay Homes	Chief Buyer
67	Taylor Woodrow	Purchasing Manager
68	Tulloch Construction Group	
69	Wates Construction	Group Buying Manager
70	Westbury	Assistant Quantity Surveyor
71	Wreckin Construction	Chief Buyer

APPENDIX C

Supplier questionnaire documents

1 Covering letter

2 Contractor questionnaire

3 List of sampled and responding suppliers

1 Covering letter

Department of Civil and Building Engineering
Loughborough University Loughborough Leicestershire LE11 3TU UK
Switchboard: +44 (0)1509 263171 Department: +44 (0) 1509 222884

Loughborough University

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»
«Address2»
«City»
«Country»
«PostalCode»

21 July, 1997

Dear Sir,

Re: **Research into Integrated Materials Supply Logistics**

This letter accompanies a national survey questionnaire which is part of a Ph.D. research I'm carrying out into Integrated Construction Materials Supply Logistics directed at suppliers sampled from the Top 25 UK Suppliers listed in the 1996 Construction News. The research started in September, 1996 and will continue up to September, 1999. The programme is under the supervision of Dr. A. D. F. Price and Professor A. Thorpe in the Construction Management Group at Loughborough University.

The research is intended to establish criteria construction companies use to evaluate and select suppliers taking into account developments in information and communication technologies, contractor-supplier relationships and other factors. Logistics management is central in maintaining long term profitability and gaining market share among suppliers. With the current emphasis on customer service in many industries being enhanced by use of information and communication technologies like EDI, and also developments in trading relationships such as partnering, it is important to establish current practices in the construction industry. Your viewpoints together with results from a 'sister' questionnaire sent to contractors will help map trends which, as suppliers you can use to map-out strategies as markets become more competitive.

The enclosed questionnaire is divided into five sections. It is primarily designed to collect data on: **trends in the use of information and communication technologies; contractor-supplier relationships; criteria used for evaluating and selecting suppliers; and materials management.** You are kindly requested to respond to the questionnaire. This will take about 20 minutes of your time. I can assure you that your responses will be treated confidential. In the event I don't hear from you by 4 August, 1997, I will ring you up to find out whether I should send you a different copy for you to fill in case you will have misplaced the first one.

The results of the survey will be summarised and sent to the responding officer whose name will appear in Section 1.0 of the filled-in questionnaire. A near 'mirror-image' sister questionnaire has also been sent to contractors. The results of this other questionnaire will be made available to you. Please do not hesitate to contact me or my supervisors at the telephone above or at the e-mail, telephone or fax numbers given below should you feel the need.

Your co-operation will be greatly appreciated.

Yours faithfully,

Mundia Muya
Research Student (Ph.D)
E-Mail: M.Muya@lboro.ac.uk, Tel.: (01509) 223773, Fax.: (01509) 223981

2 Supplier questionnaire

RESEARCH INTO INTEGRATED CONSTRUCTION MATERIALS SUPPLY LOGISTICS

1.0 COMPANY INFORMATION: This section is designed to obtain general information about your organisation

Name of respondent ☐ Position in company ☐

Company name ☐ Telephone No. ☐

If you would like the results of this survey sent to you please give your fax. number in the space provided. ☐

What nature of business is your organisation in?(*Please tick* ☐✓)

Supplier ☐ Sub-contractor ☐ Other (specify) ☐ ________________

2.0 INFORMATION & COMMUNICATION TECHNOLOGIES: This section is designed to assess trends in the implementation of information and communication technologies in the construction industry.

2.1 To what extent are the following used in the materials management process within your organisation ? (*Please tick* ☐✓)

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Integrated Database management system..	☐	☐	☐	☐	☐	☐
Electronic data interchange (EDI)............	☐	☐	☐	☐	☐	☐
Electronic mail (e-mail)...........................	☐	☐	☐	☐	☐	☐
Bar codes	☐	☐	☐	☐	☐	☐
Radio frequency tagging........................	☐	☐	☐	☐	☐	☐
Magnetic stripes....................................	☐	☐	☐	☐	☐	☐
Voice recognition..................................	☐	☐	☐	☐	☐	☐
Electronic document imaging	☐	☐	☐	☐	☐	☐
Others *(Specify)* ________________	☐	☐	☐	☐	☐	☐

2.2 To what extent are the following technologies used in the physical distribution physical process between your company and construction sites ? (*Please tick* ☐✓).

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Integrated Database management system..	☐	☐	☐	☐	☐	☐
Electronic data interchange (EDI)............	☐	☐	☐	☐	☐	☐
Electronic mail (e-mail)...........................	☐	☐	☐	☐	☐	☐
Telephone..	☐	☐	☐	☐	☐	☐
Facsimile	☐	☐	☐	☐	☐	☐
Post	☐	☐	☐	☐	☐	☐
Other (Please specify) ________________	☐	☐	☐	☐	☐	☐

2.3 To what extent are the following used in your organisation for receiving orders or sending quotations in the construction materials management process? (Please tick ❑✓)

	Always (6)	Very Often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Integrated Database management system..	❑	❑	❑	❑	❑	❑
Electronic Data Interchange (EDI)...........	❑	❑	❑	❑	❑	❑
Electronic mail (E-mail)...........................	❑	❑	❑	❑	❑	❑
Telephone..	❑	❑	❑	❑	❑	❑
Facsimile...	❑	❑	❑	❑	❑	❑
Post	❑	❑	❑	❑	❑	❑
Others (Please specify)________________	❑	❑	❑	❑	❑	❑

3.0 **CONTRACTOR-SUPPLIER RELATIONSHIPS:** This section is designed to establish the nature of relationships between contractors and construction materials suppliers and sub-contractors.

3.1 Please indicate the extent to which you agree to each of the following as reflecting your company's practices (*Please tick* ❑✓).

	Strongly Agree (7)	Agree (6)	Slightly Agree (5)	Neutral (4)	Slightly Disagree (3)	Disagree (2)	Strongly Disagree (1)
Contractors know which of their suppliers are vital to their business	❑	❑	❑	❑	❑	❑	❑
Contractors buy on the basis of lowest price alone	❑	❑	❑	❑	❑	❑	❑
Contractors try to reduce the number of their suppliers to a minimum	❑	❑	❑	❑	❑	❑	❑
To obtain the best deal contractors change suppliers frequently	❑	❑	❑	❑	❑	❑	❑
Contractors attempt to obtain mutually beneficial relations with suppliers	❑	❑	❑	❑	❑	❑	❑
Contractors seek to obtain a unique advantage over their competitors through relationships with suppliers	❑	❑	❑	❑	❑	❑	❑

	Strongly Agree (7)	Agree (6)	Slightly Agree (5)	Neutral (4)	Slightly Disagree (3)	Disagree (2)	Strongly Disagree (1)
Contractors do not believe that sharing our strategic plans with our suppliers is in our best interests	❑	❑	❑	❑	❑	❑	❑
Contractors expect suppliers to deliver exactly what they specify without question	❑	❑	❑	❑	❑	❑	❑
Contractors check every delivery to ensure consistent quality	❑	❑	❑	❑	❑	❑	❑
Our commitment is always sort to achieve project delivery goals of cost, time and quality	❑	❑	❑	❑	❑	❑	❑
We always get involved during development of project goals	❑	❑	❑	❑	❑	❑	❑
Communication between us and contractors is open, honest and based on mutual respect	❑	❑	❑	❑	❑	❑	❑
There is trust in the sharing of project information between us and our customers (contractors)	❑	❑	❑	❑	❑	❑	❑
We are always given ample time to prepare ❑ quotations in cases where we bid for jobs	❑		❑	❑	❑	❑	❑
We get paid in time for materials already delivered	❑	❑	❑	❑	❑	❑	❑
We get feedback from contractors on our delivery performance	❑	❑	❑	❑	❑	❑	❑

3.2 Please indicate whether the name of your company is on a list of suppliers maintained by contractors (Please tick ❑✓)

Name not on contractors' list of suppliers ❑
Name on list of contractors' preferred suppliers ❑

3.3 Generally, indicate which of the descriptions below best describes your relationships with contractors or clients you consider closest to you (Please tick ❑✓)

Arms-length relationship ❑
Non-partnering long-term trading relationship ❑
Short-term project partnering ❑
Long-term partnering ❑
Partnership ❑
Other (Please specify)____________________

4.0 **SUPPLIER SELECTION:** This section is designed to establish the factors considered important by contractors and used by them to select suppliers.

4.1 Indicate in general terms what materials your organisation deals in *(Please tick as many boxes as is true ❑✓)*

Bulk materials, i.e., off-the-shelf materials like sand, gravel, ready mixed concrete, standard clay and concrete pipes, tiles, bricks, etc. purchased in bulk and often from a single source. .... ❑

Fabricated materials such as concrete beams iron pipes and pipes, bridge bearings made to order for a particular project.. ❑

Specialist materials like mechanical and electrical plant for industrial facilities, structural steelworks lifts, cladding and building services normally subcontracted............. ❑

Falsework materials such as access scaffolds, props, trench or other excavations support systems formwork, etc. .... ❑

Others (Please state)____

4.2 How important are the following factors for evaluating and selecting you as construction materials suppliers by contractors (*Please tick ❑✓*)

	Extreme Importance (5)	Considerable Importance (4)	Average Importance (3)	Little Importance (2)	No Importance (1)
Reliability(ability of supplier to deliver right, products and quantity on schedule without damage)	❑	❑	❑	❑	❑
Flexibility (ability of supplier to adjust to schedule, changes with right products, in right quantities)	❑	❑	❑	❑	❑
Lead time quoted by supplier	❑	❑	❑	❑	❑
Value-added service exceeding basic service requirements	❑	❑	❑	❑	❑
Cost-effectiveness	❑	❑	❑	❑	❑
Information and communication technologies (Bar codes, EDI, Database management systems)	❑	❑	❑	❑	❑
Long-term relationships with suppliers (partnering)	❑	❑	❑	❑	❑
Quoted **Price**	❑	❑	❑	❑	❑
Location of supplier in relation to project	❑	❑	❑	❑	❑
Capability (Financial strength, production technology, production efficiency)	❑	❑	❑	❑	❑
Quality management systems employed by suppliers	❑	❑	❑	❑	❑
Management and administrative capability of suppliers	❑	❑	❑	❑	❑
Health and Safety records of suppliers	❑	❑	❑	❑	❑
Environmental records of suppliers	❑	❑	❑	❑	❑
Others (Please specify)______________	❑	❑	❑	❑	❑

4.3 Indicate the quality standard your organisation adheres to (Please tick ❑✓)

ISO 9000 series	BS 7850	BS 5750	None	Others (Please specify)
❑	❑	❑	❑	____________

4.4 To what extent do you think contractors use the following for assessment when selecting suppliers? (Please tick ❑✓)

	Always (6)	Very often (5)	Often (4)	Occasionally (3)	Rarely (2)	Never (1)
Reliability of supplier	❑	❑	❑	❑	❑	❑
Flexibility of supplier	❑	❑	❑	❑	❑	❑
Lead time quoted by supplier	❑	❑	❑	❑	❑	❑
Value-added service provided by supplier	❑	❑	❑	❑	❑	❑
Cost-effectiveness of service by supplier	❑	❑	❑	❑	❑	❑
Information and communication technologies	❑	❑	❑	❑	❑	❑
Long-term relationships	❑	❑	❑	❑	❑	❑
Organisational culture(Feeling of trust, supplier attitude)	❑	❑	❑	❑	❑	❑
Quality	❑	❑	❑	❑	❑	❑
Quoted Price only	❑	❑	❑	❑	❑	❑
Location of suppliers	❑	❑	❑	❑	❑	❑
Financial(financial stability, economic perform)	❑	❑	❑	❑	❑	❑
Technology(production capability/efficiency)	❑	❑	❑	❑	❑	❑
Quality management systems	❑	❑	❑	❑	❑	❑
Health and safety record	❑	❑	❑	❑	❑	❑
Environmental records	❑	❑	❑	❑	❑	❑
Visit to supplier's premises	❑	❑	❑	❑	❑	❑
Weighted-factor rating system	❑	❑	❑	❑	❑	❑
Management and administrative capability	❑	❑	❑	❑	❑	❑

4.5 Please indicate the methods contractors use to evaluate your organisation as their suppliers (Please tick ❑✓ the most commonly used methods)

Ad hoc evaluation at buyer's discretion	❑
Follow-up and evaluate based on problems or complaints	❑
Formal review of performance every year or more frequently	❑
Formal review of performance every 13 to 24 months	❑
Formal review of performance every 2 years or less frequently	❑
Others (Please specify)________________________	❑

4.6 How satisfied are you with the evaluation system used by contractors to select suppliers? (Please tick ❑✓)

Definitely satisfied	Satisfied	Neutral	Not Satisfied	Definitely Not satisfied
(5)	(4)	(3)	(2)	(1)
❑	❑	❑	❑	❑

5.0 **MATERIALS MANAGEMENT:** This section is designed to ascertain factors which can help to improve the supply of construction materials to support construction.

5.1 Indicate the level of importance of each of the items below in helping to improve the materials management process to support construction *(Please tick ❑✓)*

	Extreme Importance (5)	Considerable Importance (4)	Average Importance (3)	Little Importance (2)	No Importance (1)
Stationing a materials manager on site by contractors	❑	❑	❑	❑	❑
Selection of suppliers by contractors	❑	❑	❑	❑	❑
Communication between Head Office and suppliers	❑	❑	❑	❑	❑
Communications between site and suppliers	❑	❑	❑	❑	❑
Materials planning by site staff	❑	❑	❑	❑	❑
Use of electronic data management technologies like bar codes, EDI, DBMS	❑	❑	❑	❑	❑

Early payment of suppliers for delivered materials by contractors	❑	❑	❑	❑	❑
Management capability of site personnel	❑	❑	❑	❑	❑
Customer service level provided by suppliers	❑	❑	❑	❑	❑
Improving relationships with contractors	❑	❑	❑	❑	❑

5.2 If you have any specific items omitted by this survey that you would like addressed by this research please state in the space provided.

Can your organisation participate initially by providing data by way of structured interviews and later detailed case studies ?

Yes ❑ No ❑

Your participation and co-operation in this survey has been most valuable. Kindly put the questionnaire in the accompanying self-addressed envelope and mail it back to us.

Thank you.

M. Muya
Department of Civil & Building Engineering, Loughborough University
Loughborough, Leicestershire, LE11 3TU
E-mail: M.Muya@lboro.ac.uk, Tel. No.: (01509) 223773, Fax. No.: (01509) 223981

3 List of sampled and responding suppliers

List of suppliers surveyed and sampled from the 1996 Construction News and from Construction and Civil Engineering Index CD - ROM.

	Names of companies in Sample	Positions of respondents at responding companies
1	AA Fabrications	Estimator
2	Aggregates Industries Plc	
3	Alumasc Building Products Ltd	Technician
4	ARC Central	Customer Services Manager
5	ARC Ltd	Technical & External Affairs Manager
6	Armstrong (Concrete Blocks) Ltd	
7	B P B Industries	
8	Blue Circle	
9	British Steel Plc	
10	Calder Industrial Materials Ltd Metal Roofing Products Division	Sales Manager
11	Callenders Ltd - Construction Products Division	Marketing Manager
12	Cameron & Moore Ltd	
13	Cape Ceilings	Senior Sales Administrator
14	Cape External Products Ltd	Director
15	Capitol Tile Designer Studio	Director
16	Caradon Plc	
17	Carlton Main Brickworks Ltd	
18	Caunton Engineering Ltd	Director
19	Central Elevator Company Ltd	
20	Colas Ltd	
21	Contelic Supplies Ltd	
22	Contract Flooring Sales Ltd	Marketing & Administration
23	Elkay Electrical Manufacturing Company Ltd	Marketing Manager
24	Elliot Group Ltd	
25	Eurobrick Systems Ltd	General Assistant
26	Fairoak Timber Products Ltd	Managing Director
27	Firestone Building Products	Manager
28	Forticrete Ltd	Division General Manager
29	Galliford Roadstone	
30	Gelson Industries	
31	Genesis Tilemates Ltd	
32	Hemsec Manufacturing Ltd	
33	Hepworth Building Products	
34	Hepworth Heating Ltd	
35	HW Systems	
36	Ibstock Brick Leicester Ltd	
37	IMI Norgren Ltd	
38	Internal sales	

List of suppliers surveyed and sampled from the 1996 Construction News and from Construction and Civil Engineering Index CD - ROM. *continued.....*

	Name of companies in sample	Positions of respondents at responding companies
39	International Transformers, Ernest Lee (Electrical Services) Ltd	Director
40	Ist Saxon Property Services Ltd	
41	Jackson & Son Ltd	Sales Manager
42	Jewson Ltd	
43	John Laing Plc	
44	Leofric Building Systems Ltd	
45	Lochnivar Ltd	Field Sales Manager
46	Mable Flooring Specialists Ltd	
47	MaCarthy & Stone (Developments) Ltd	
48	Marcel Guest Ltd (Building Products and Paints Division)	
49	Marley Building Products	
50	MHS Boilers Ltd	Office Manager
51	Mivan International	
52	Newman Tonks Plc	
53	Pilkington	
54	Redland Aggregates Ltd	Internal Sales Manager
55	Redland Roofing	
56	Ringway Group Ltd	
57	RMC	Marketing & Public Affairs Manager
58	Ruberoid Company Ltd	
59	Rugby Cement	
60	Saint-Gobain Glass UK Ltd	
61	SIG	Marketing Executive
62	Spring Ram Bathroom	
63	Tarmac Quarry Products Ltd	Business Services Manager
64	The Graham Group	
65	Travis Perkins	Group Purchasing Director
66	Wade International (UK) Ltd	Company Secretary
67	Ward Building Products	
68	Wath Concrete Products	
69	Watson Steel Ltd	General Manager
70	Wavin Buiding Products Ltd	
71	Wavin Industrial Products	Sales Office Manager
72	Wellington Tile Company	
73	WF Electrical Distributors Plc	
74	Willan Building Services Ltd	
75	Winchester Tile Company Ltd	Managing Director
76	WP Metals Ltd	Sales Director

APPENDIX D

Contractor interview documents

1 Covering letter

2 Contractor open-ended questions

3 The analytic hierarchy process model

1 Covering letter

Department of Civil and Building Engineering
Loughborough University Loughborough Leicestershire LE11 3TU UK
Switchboard: +44 (0)1509 263171 Department: +44 (0) 1509 222884

Loughborough University

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»
«City»
«County»
«PostalCode»

4 November, 1997

Dear Sir,

Structured interviews into Construction Materials Supply Logistics

Following our telephone conversation, I enclose the outline format of the proposed discussion.

The purpose of the interview is twofold. **Part One** of the interview will relate to the various materials management processes, types of systems in use, the nature of your company's relationships with suppliers and the factors which affect such relationships. **Part Two** of the interview will involve you providing expert pairwise comparison judgements, with the aid of a highly user-friendly software package called expertchoice, in order to evaluate the importance you attach to various logistics elements in improving customer service level provided by suppliers.

Please find enclosed both **Parts One** and **Two** of the interview. The interview will not last more than 2 hours. It should take even less time if you complete **Part One** in advance. There are altogether 10 construction companies involved in the exercise. Rankings of the logistics factors generated from the model by all the participating companies will be made available to you, though the names of the other companies will be kept anonymous. You can be assured that whatever information you provide will be treated confidential. I will ring again in the near future to make an appointment for our discussion.

I would like to express my gratitude for your offer to take part in these structured interviews and for the time you have made available for this exercise.

Yours faithfully,

M. Muya

2 Contractor open-ended questions

Part One

SECTION 1

1.0 This section is designed to solicit general details about interviewees and their companies.

1.1 Company details

Name of Company:______________________

Type of construction activities: (*Please tick*)

Building ☐
Civil ☐
Building & Civil ☐
Process Industries ☐
General ☐

Company size:

Turnover: _______________
Workforce: _______________

1.2 Interviewee's details
Name of Interviewee:____________________
Position in Company:____________________
Years of experience in the Construction Industry:________________
Type of experience in Construction Industry:____________________
Any other experience outside Construction Industry:_______________

SECTION 2

2.0 **Information and communication technologies:** This section is designed to assess benefits and obstacles to the use of information and communication technologies in materials management by contractors.

2.1 What benefits has your organization experienced from the implementation of information and communication technologies?

2.2 What factors hinder introduction of information and communication technologies in materials management processes in your organization?

2.3 What general comments do you have about implementation of information and communication technologies in materials management processes in the construction industry?

SECTION 3.0

3.0 **Relationships:** This section is intended to establish factors which influence contractor-supplier relationships and benefits and difficulties associated with such relationships.

3.1 What factors hinder formation of long-term relationships, such as partnering, between your organization and suppliers?

3.2 What benefits does your organization derive from any long-term relationships such as partnering arrangements which it has with construction materials suppliers?

3.3 How does your organization give feedback to suppliers on their delivery performance?

3.4 What general comments do you have about contractor - supplier relationships?
(Please use remaining space below).

3 The analytic hierarchy process model

Part Two

The Analytic Hierarchy Process Model for Evaluating logistics factors

Objective of the model:	The objective of the model is to evaluate relative importance contractors attach to logistics performance indicators and enablers in improving customer service in the delivery of construction materials.
Role of expert:	To provide pairwise comparisons which lead to ranked assessment of importance of logistics performance indicators and enablers.
Mode of making pairwise comparison judgments:	A highly user-friendly computer package called Expert Choice on a lap-top was used to make comparisons of relative importance of logistics performance indicators and enablers
Use of model:	The model can be a useful decision support tool in supplier management (such as evaluation and selection of suppliers) and development of materials supply logistics.
Output results of model to be made available to to you:	Summarized rankings of the various logistics factors by all the participating companies, though names of the other companies will be kept anonymous for confidentiality.

A schematic presentation of the AHP model is given in Figure 11.2.

The 9 point scale used in the pairwise comparisons is given in Table 11.1.

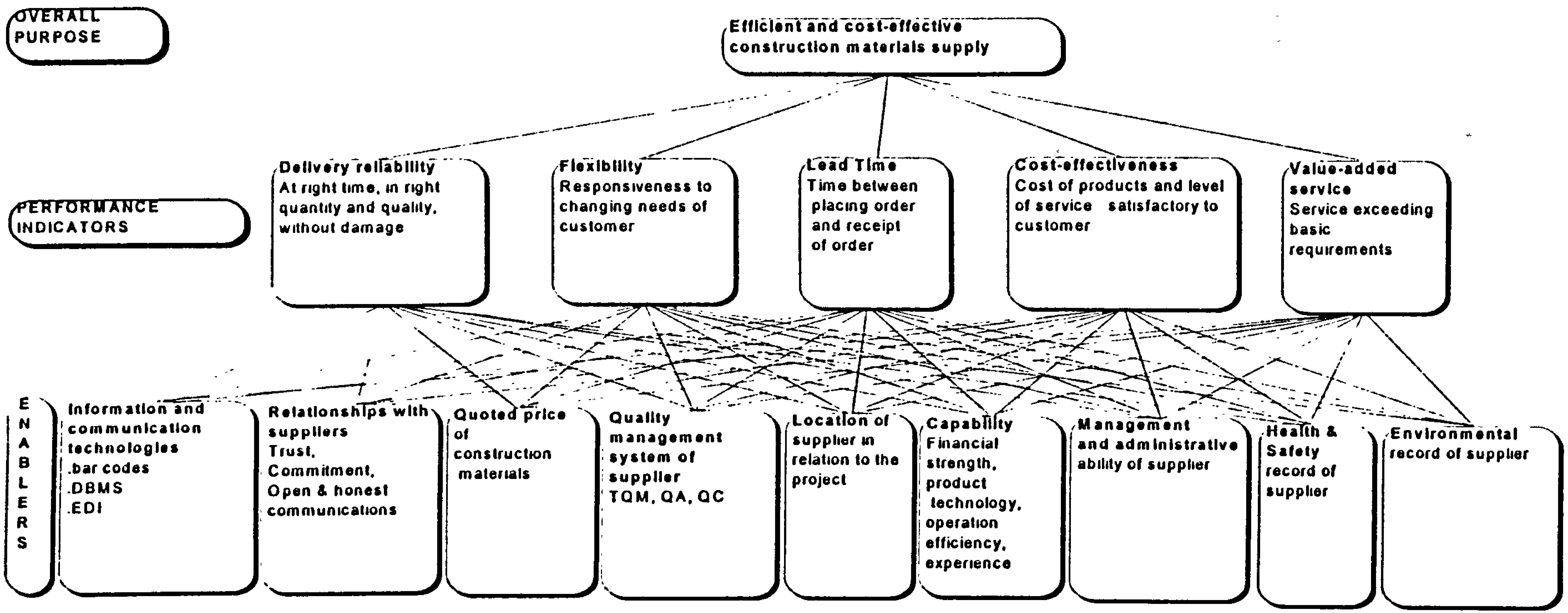

Figure 11.2: Analytic Hierarchy Model for construction materials supply logistics

Table 11.1: The AHP response scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one activity over another	Experience and judgement slightly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest order of affirmation
2, 4, 6, 8	Intermediate values between the two judgements	When compromise is needed
Reciprocals of judgments	If activity i has one of the above numbers assigned to it when compared to j, then j has the reciprocal value when compared to i.	

APPENDIX E

Supplier interview documents

1 Covering letter

2 Supplier open-ended questions

3 The analytic hierarchy process model

1 Covering letter

Department of Civil and Building Engineering
Loughborough University Loughborough Leicestershire LE11 3TU UK
Switchboard: +44 (0)1509 263171 Department: +44 (0) 1509 222884

Loughborough University

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»
«City»
«County»
«PostalCode»

4 November, 1997

Dear Sir,

<u>Structured interviews into Construction Materials Supply Logistics</u>

Following our telephone conversation, I enclose the outline format of the proposed discussion.

The purpose of the interview is twofold. **Part One** of the interview will relate to the various materials management and physical distribution processes, types of systems in use, the nature of your company's relationships with contractors and the factors which affect such relationships. **Part Two** of the interview will involve you providing expert pairwise comparison judgements, with the aid of a highly user-friendly software package called expertchoice, in order to evaluate the importance you attach to various logistics elements in improving customer service level provided by suppliers.

Please find enclosed both **Parts One** and **Two** of the interview. The interview will last no more than 2 hours. It should take even less time if you complete **Part One** in advance. There are altogether 6 supplier organisations involved in the exercise. Rankings of the logistics factors generated from the model by all the participating companies will be made available to you, though the names of the other companies will be kept anonymous. You can be assured that whatever information you provide will be treated confidential. I will ring again in the near future to make an appointment for our discussion.

I would like to express my gratitude for your offer to take part in these structured interviews and for the time you have made available for this exercise.

Yours faithfully,

M. Muya

2 Supplier open-ended questions

Part One

SECTION 1

1.0 This section is designed to solicit general details about interviewees and their companies.

1.1 Company details

Name of Company: ______________________

Type of supplier organisation (*Please tick*)

Manufacturer & Supplier ☐
Manufacturer, Supplier & Subcontractor ☐
Supplier ☐
Supplier & Subcontractor ☐
Subcontractor ☐

Please specify type of materials your organisation deals in:

____

Company size (Please specify):
Turnover: ________________
Workforce: ________________

1.2 Interviewee's details
Name of Interviewee: ______________________
Position in Company: ______________________
Years of experience with the construction industry: ____________
Type of experience: ______________________

SECTION 2

2.0 **Information and communication technologies:** This section is designed to assess benefits and obstacles to the use of information and communication technologies in materials management and physical distribution functions by suppliers.

2.1 What benefits has your organisation experienced from the implementation of information and communication technologies?

2.2 What factors hinder introduction of information and communication technologies in materials management and physical distribution processes in your organisation?

2.3 What general comments do you have about implementation of information and communication technologies in the construction industry?

SECTION 3.0

3.0 **Relationships:** This section is intended to establish factors which influence contractor-supplier relationships and benefits and difficulties associated with such relationships.

3.1 What factors hinder formation of long-term relationships, such as partnering, between your organisation and contractors?

3.2 What benefits does your organisation derive from any long-term relationships such as partnering arrangements with contractors?

3.3 How does your organisation receive give feedback from contractors on delivery performance?

3.4 What general comments do you have about contractor - supplier relationships?
(Please use remaining space below).

3 The analytic hierarchy process model

Part Two

The Analytic Hierarchy Process Model for Evaluating logistics factors

Objective of the model:	The objective of the model is to evaluate relative importance suppliers attach to logistics performance indicators and enablers in improving customer service in the delivery of construction materials.
Role of expert:	To provide pairwise comparisons which lead to ranked assessment of importance of logistics performance indicators and enablers.
Mode of making pairwise comparison judgements:	A highly user-friendly computer package on a lap-top will be used to make comparisons of the logistics factors
Use of model:	The model can be a useful decision support tool in developing materials supply logistics by construction materials suppliers
Output results of model to be made available to to you:	Summarised rankings of the various logistics factors by all the participating companies, though names of the other companies will be kept anonymous for confidentiality.

A schematic presentation of the AHP model is given in Figure 11.2.

The 9 point scale used in the pairwise comparisons is given in Table 11.1.

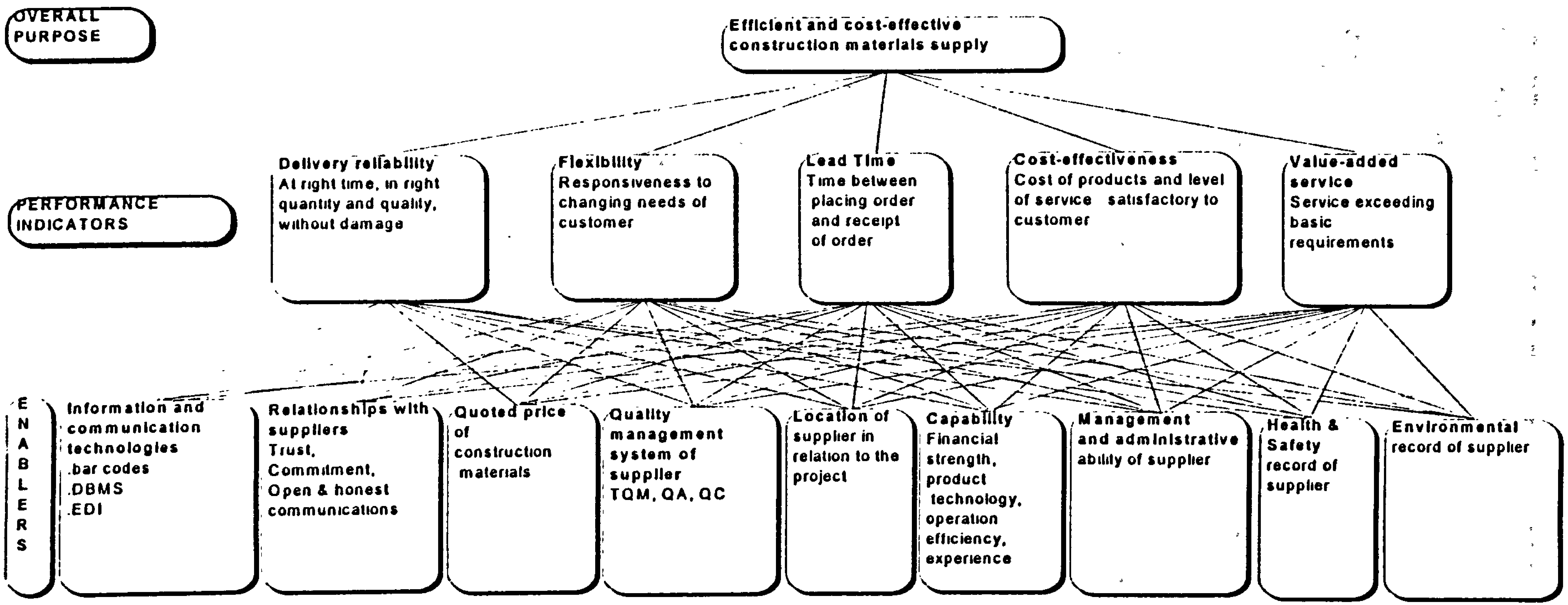

Figure 11.2: Analytic Hierarchy Model for construction materials supply logistics

Table 11.1:
The AHP response scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one activity over another	Experience and judgement slightly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest order of affirmation
2, 4, 6, 8	Intermediate values between the two judgements	When compromise is needed
Reciprocals of judgments	If activity i has one of the above numbers assigned to it when compared to j, then j has the reciprocal value when compared to i.	

APPENDIX F

Supplier management process map validation questionnaire documents

1. Covering letter
2. Supplier management process map validation questionnaire
3. List of sampled and responding contractors
4. Supplier management process model in Figure 12.1 (pp. 274) was also included as an accompanying document.

Department of Civil and Building Engineering
Loughborough University Loughborough Leicestershire LE11 3TU UK
Switchboard: +44 (0)1509 263171 Department: +44 (0) 1509 222884

Loughborough University

7 August, 1998

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1» «Address2»
«City» «County»
«PostalCode»

Dear Sir,

Validation of process map for improving materials supplies into construction processes

This follow-on questionnaire marks the end of a research project into Construction Materials Supply Logistics that begun in October, 1996 in which you earlier participated by completing a survey questionnaire.

The enclosed process map, which is an output of the questionnaire survey results and subsequent structured interviews, outlines structured supplier management activities which if implemented by contractors should result in improved delivery of construction materials. The process map proposes to effect improvements in materials delivery via:

- more structured selection of suppliers at both company and project level;
- development of long-term contractor-supplier relationships; and
- more structured assessment and feedback on performance of suppliers.

The purpose of writing to you is to give feedback on the information that you provided and request your assistance in the validation of my research findings. Validation will assess the functionality, usefulness and user-friendliness of the process map as a tool that could assist contractors in improving the delivery of construction materials. It is intended that completion of the accompanying questionnaire about the process map can be done over the telephone and your kind participation in this exercise is being sought. Please kindly study the map and the accompanying questionnaire. I will make initial contact by telephone to arrange a date and time when you can complete the questionnaire with me over the telephone.

Yours faithfully,

M Muya

Supplier management process map validation questionnaire

This questionnaire is intended to validate the functionality, user-friendliness, usefulness and industry acceptance of the outlined supplier management process map as a tool that can assist improve performance in the delivery of construction materials. Please kindly study the enclosed model and complete the questionnaire by ticking or filling the spaces provided where applicable

1. Name of company

2. Position of interviewee in company

3. What type of work does your company generally undertake? (please tick)

Building	Civil	Building & Civil	Other
☐	☐	☐	☐

4. Have you previously come across a supplier management process map similar to the one outlined here? (Please tick)

Yes	No
☐	☐

   If 'Yes', please identify (give details) in space below

5. To what extent do you find the procedures involved in the outlined supplier management process map easy to follow? (Please tick)

Easy	Not Easy
☐	☐

   If 'Not Easy', please briefly explain in the space below

6. Does your company have a structured supplier management program? (Please tick)

Yes	No
☐	☐

   If 'Yes', please briefly give details in space below

7. If your company has a supplier management programme, is it similar to the one outlined in this model? *(If there is no supplier management programme, please skip this item)*

Yes	No	Not applicable
☐	☐	☐

8. If your company were to implement an improved supplier management programme, could you base it on the one proposed here? (Please tick)

Yes	No
☐	☐

   If 'No', please explain in the space below

9. If your company were to implement an improved supplier management programme, would you base it on the one proposed here? (Please tick)

Yes	No
❑	❑

If 'No', please explain in the space below

10 Do you think that implementing the proposed supplier management process map would improve performance in the delivery of construction materials via:

	Yes	No
more structured selection of suppliers at both company and project level?	❑	❑
development of long-term contractor supplier relationships?	❑	❑
more structured assessment and feedback on performance of suppliers?	❑	❑

11. To what extent do you accept that implementation of the outlined supplier management process map can help your company improve performance in the delivery of construction materials? (Please tick)

Accepted	Not Accepted
❑	❑

12. If your company were to manage construction materials suppliers as proposed in the outlined supplier management process map, which of the following benefits would you expect from the suppliers? (Please tick)

	Yes	No
Improved customer service	❑	❑
Improved reliability	❑	❑
Cost-effective materials supplies	❑	❑
Improved flexibility	❑	❑
Improved value-added service	❑	❑
Improved relationships	❑	❑

13. Do you think the effort and cost in terms of time and resources associated with implementing the outlined process map would justify the improvements gained? (Please tick)

Yes	No
❑	❑

If 'No', please briefly explain in the space below?

14. Do you have any other comments? (Please use space below)

THANK YOU FOR COMPLETING THE QUESTIONNAIRE