# A PROPOSED METHODOLOGY FOR THE DESIGN OF DECISION SUPPORT SYSTEMS IN OPERATIONS MANAGEMENT

A Thesis submitted for the degree of Doctor of Philosophy

by

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ABSTRACT

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DECISION SUPPORT SYSTEMS IN OPERATIONS MANAGEMENT

The purpose of this work is to attempt to develop a Decision Support System and a generalised Design Methodology, for the Operational Management of Industrial Organisations.

The research subject has been selected as such, because although substantial research has been carried out on the technology of solving a specific problem with quantitative decision support tools such as Operations Research (OR) or Management Science (MS), there is a significant gap on the methodology of developing and implementing these techniques as a direct operational support tool.

In recognition of operational managers' increasing needs for decision support tools and in a view of the slow progress and unsatisfactory use of OR/MS techniques, and the inability of Management Information systems to contribute to the operational decision support function, the research is set out to identify the shortcomings of existing practice, and to develop a system in the light of the resulting requirements.

A multi-disciplinary approach is adopted for the development of the system and the methodology, which is based on a conceptual framework provided by cybernetics. Theories relating to the communication, regulation and coordination within a system, and to the interactive man-machine problem solving activities provide the basis for the methodology.

The end product of the research is a System and a generalised Design Methodology for this system. The primary aims of the system are to co-ordinate the operational decision process throughout the organisation and to increase the effectiveness of the decision-making capacity of the operational managers. It is a microprocessor based modular system which is distributed to the operational decision makers. Functionally, it consists of a 'forward looking' information system which is dedicated to operational decision support, and quantitative decision models including OR/MS methods that are integrated with this system. The modular decision units are connected by this system.

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PREFACE

The work presented in this thesis includes the development of a methodology for the Design and the Implementation of Decision Support Systems which are dedicated to the Operational Management of Decentralised Industrial Companies.

The problem has been identified as a potential research area, because, due to the advances in information technology, the business environment for line managers is flowing progressively faster and the time available for analysis and evaluation of problems is therefore shortening. Furthermore, the responsibilities of line managers are increasing because of the recent trends in management practice: These trends primarily include the increasing adoption of the Just-In-Time approach by industrial managers and the increasing awareness of the need for direct involvement of operational managers with strategic decisions.

Therefore, line managers are increasingly in need of a tool which can be directly used by them and which provides them with information and analysis support facilities. The primary function of this tool is to deliver the decision support function, which is traditionally provided to the strategic managers by dedicated staff. Such traditional practices are not feasible for operational managers because of the time limitations imposed on the decision environment. Although existing Management Science methods and Information Systems are increasingly sophisticated, they fail to deliver one 'on line' operational management support function. This is because Management Science methods are implemented by dedicated technical staff and there is no time for line managers to co-operate effectively with these specialists. Many Management Information Systems which are widely used in industry are 'Backward Looking': Instead of enabling managers to innovate for better future performances, they are oriented and implemented primarily as a measuring and monitoring tool.

The end product that has emanated from the present research is a 'Forward Looking' System which is dedicated to the operational decision support function and a Methodology for Designing and Maintaining this System.

The system has a modular architecture and it is made up of decentralised decision units. That is, each operational manager is provided with a workstation including a microcomputer and dedicated software which locally delivers Decision Support Function according to the specific needs of the manager. The total system is the collection of these units, where these units are inter-related with each other according to rationalised communication patterns within the company.

A methodology has been developed for the design of the proposed support system which is dedicated to the operational management of decentralised industrial organisations.

During the design phase the development is carried out through two major phases:

The object of the first phase is to identify communication patterns between managers for whom the system is provided. Existing patterns are evaluated and rationalised and the product of this first phase is the inputs and outputs to the decision units and the communication patterns between them.

The second phase of the methodology consists of the detailed development of the workstations which will be allocated to the decision units. The design of these workstations will be according to the specific needs of the operational manager who will be responsible for the specification and the development of the unit.

During the post-commissioning phase, the system will be continually modified and developed at both general and specific decision unit levels. At the general level this is possible because the proposed system has a modular architecture. At the specific decision units level, the operational manager being responsible for the development of the unit, will know the details of the unit and therefore will be able to modify it according to his changing needs. The proposed system will therefore evolve in line with organisational and managerial demands.

The proposed system provides solutions to existing problems which are attributed to the use of Management Information Systems (MIS) and Management Science (MS) methods.

It enables operational managers to use directly and benefit from the quantitative analysis support tools, including Operations Research (OR) and (MS) methods, eliminating the need to interact with the specialist support staff.

It provides them with a forward looking information system, where the object is to provide decision makers with information which meets their needs. It therefore enables line managers to concentrate on the analysis and evaluation of the operational problem. It increases the scope of interactions between managers and contributes to the effective co-ordination of the line operations as well as co-ordinating the decision process throughout the organisation.

Unlike existing systems, the proposed system will continuously evolve in line with requirements and thus costly and stressful total replacement of obsolete systems will be eliminated. It does not have to be implemented as a one-off large scale project.

The solution is a product of substantial research in the conduct of operational research, management science and management information systems as well as substantial analysis of the related theories that are provided by cybernetics. The resulting model has evolved through the synthesis of the multi-disciplinary research and analysis that has been carried out on various fronts within a real and practical operational management environment involving problems and decision support needs of operational managers.

The historical development of this work, ironically, has not been straightforward and most of the significant issues have been grasped by the author only after substantial work had been put into the implementation of traditional management science methods. It is therefore useful to review the progression of this work from my personal standpoint.

Initially the object of this work was to develop a computer-based system, including a mathematical model, of the operational environment of the oil supply and distribution business within the scope of Management Cybernetics.
I selected the oil supply and distribution business because I have had practical working experience and the

opportunity of communicating with operational managers in this industry. My background being Industrial Engineering which is a combination of Mechanical and Systems Engineering, I was thoroughly familiar with traditional Operations Research, and Management Science techniques as well as System Science theories and methods. During my first degree course I had already implemented projects in these subjects.

During the first year of the research I worked on a simulation model about the dynamics of oil supply and distribution operations. Within the scope of the mathematical model, I investigated the potential implementation areas for Operational Research and System Science methods. From the exercise it was apparent that OR provided significant solutions to the well-defined and specific problems such as optimum allocation of the jobs between the most effective tankers. But as the boundaries of the problem increased, the model became too large and incorporated uncertainities. I had not identified substantial scope for significant implementation of the System Science methods because effective solutions could only be obtained through linear systems and as the scope of the model increased from a simplistic to a more complex form, the problem rapidly transformed to a non-linear nature which was complex and time consuming to solve.

Within the same period, I also worked in the maritime oil supply and transportation industry and soon I realised that an operational manager being subjected to continuous time pressure would not have time to try to evaluate large OR or MS methods and also he would have insufficient time to interact with the specialist staff. Such methods can contribute to operational management if they provide solutions to specific problems and if they are reliable and can be directly used by the manager. I also realised the importance of managers being provided with the information about the problem.

My views had been consolidated by readings on Management Cybernetics especially those of Beer. At that point, although the model was not fully completed, I decided to take up a literature survey on the general conduct of OR, Management and System Sciences thinking that there was a gap and therefore need for significant research in this area. This survey indicated that although substantial detailed work had been carried out with regard to the analysis and solution of specific problems, no emphasis had been given to the interface with end users.

Considering the fact that operational managers are under constant time pressure, such methods can only be effectively used if they are simple to use, and if the overall time required for setting up and solving the model is realistic when compared with the time available for responding to the problem. Therefore these methods will only be accepted by operational managers if they are designed as a tool which can be used by them.

During my employment with the Industrial Engineering division of a leading Consulting Engineering firm, I continually observed that most of the problems that are encountered during the development of a project are caused by the insufficiency of the communication between various disciplines. The most important function of Computer Aided Design systems is to provide a formal communications medium which continually provides decision makers with information and makes them aware of the changes that occur in other disciplines. It has a very important role in co-ordinating the decision process throughout the design and implementation of a project.

Relating these observations to my practical experience and general readings about the oil supply and distribution industry, it was apparent that operational management suffers from the same problem and is in need of an information system. During the execution of operational management activities the decision process is co-ordinated through the individual efforts of the managers. In order to obtain the information that he needs, an operational manager has to make an effort such as phoning another department, and allocating time to obtain the information. The decisions which are under the responsibility of one department often are the product of the decisions in other departments. The magnitude of the problem is greater in operational management because of the time pressure which is acting on the managers. The implications of not having such a system for the parent company are the loss of efficiency in co-ordination of operational decisions and the opportunity cost of not fully benefiting from the corporate resources.

Therefore I concluded that a dedicated information system which co-ordinates the decision process is the fundamental component of any operational decision support system. The analysis support function which incorporates quantitative techniques such as OR must be integrated with this system so that the information which is already in the system can be directly loaded to such models. Such an arrangement enables large operational problems to be decomposed and handled by smaller and specific models which can be effectively used by managers.

My experience with the design of the traditional Management Information Systems, which included lectures and projects during my undergraduate work, had indicated that such systems fundamentally relate to the communication and automation of well-defined information processing tasks. Implementation of the traditional Management Information Systems seemed inappropriate for operational decision support tasks because they are highly dynamic and less structured. A substantial literature survey, which indicated the failure of MIS as a decision support tool, consolidated my views. The failure has been blamed on the rigidity and the backwardness of the large and centralised MIS which can not keep up with changing managerial requirements.

The problems which are experienced during the use of an MIS can be traced back to the fact that the design of an MIS is typically based on traditional analysis applications involving the observation and simulation of a real life situation with the purpose of producing of an end product.

It was apparent to me that such approaches were not satisfactory for designing a decision support tool which will be used to co-ordinate the decision process as well as maximising the capacity of the managers in making the correct decisions. It seemed to me that a general methodology for designing decision support systems needed to be based on a multi-disciplinary approach and not just computing or management sciences.

The readings on Cybernetics pointed out the fundamental issues which are essential for successful communications, co-ordination and regulation of management operations in organisations, as well as for successfull coupling of man and machine in problem-solving activities. I was interested in Cybernetics as a theoretical framework because it addresses a range of issues which are important for the design and implementation of such a Decision Support System.

Although Cybernetics offers essential theories, I found that there are not many practical implementations of these theories and unfortunately the science does not yet provide an orthodox set of rules which can be directly applied to different problems according to a predetermined and well-defined pattern. Therefore, I had to adopt an unorthodox approach, where I identified a significant set of theories and principles which relate to the problem. I attempted to base the proposed methodology and the system on these principles. The proposed system and the methodology is in fact a product of the ideas which have emanated from the evaluation of the principles which are provided by Cybernetics.

Although the system is designed for practical applications, unfortunately it is not based on a real life case study. The main reason for this is the difficulty of obtaining sensitive operational information. On the other hand, according to the proposed design methodology , the systems is not an end product that can be designed solely by the system analyst: It is a joint effort between the analyst and the operational manager himself. In the first phase, the communication patterns between operations are defined by managers themselves. The input of the system analyst is to evaluate and rationalise these patterns according to defined cybernetic principles. Rationalised patterns are presented to the managers involved and are finalised only if they are accepted by them. It is therefore an iterative process. In the second phase, operational managers are responsible for specification and development of their own decision units according to their needs. In this phase the input of the analyst is to provide technical backup and management of the detailed work.

A real experimental implementation of this system requires the commitment of an industrial company. Because of its modular architecture and development methodology, initially it can be implemented on a small scale and can be gradually built up without causing any interruptions to the existing operational practice.

# 1. INTRODUCTION

## 1.1 Introduction

The scope of this work is to develop a Decision Support System and a generalised Design Methodology for this system which specifically caters for the needs of operational managers. The primary functions of this system are to co-ordinate operational decision processes and to support decision-making activities of operational managers. The system provides managers with a network or an information system, which exclusively communicates the information which is essential only for the planning and the execution of operational decisions. Additional analysis support facilities including Operational Research (OR) and Management Science (MS) models are integrated with this information system. These provide managers with tools, as aids to analyse and evaluate the Operational Decision environment.

Although much has been written about solving particular operations management problems by using OR and MS methods as well as the use of Management Information Systems as a decision support tool, the acceptance and the use of these methods have been unsatisfactory and relatively little or no emphasis has been given to the co-ordination of the wider decision process as a system within the organisation. For the purposes of this work it is useful to review the background and the current situation of the subjects that are included within the scope of this study:

The business environment is continually changing. Increasing international competition is forcing companies to operate nearer to their limits. Due to technological changes business is flowing progressively faster, necessitating quicker managerial response. The change towards faster and more competitive business environments is forcing management structures and practices to adapt to the requirements of the environment. Management structures are moving from rigid and hierarchical formations towards more fluid and dynamic ones, increasing the scope for interaction within the organisational structure. Management practices are becoming progressively less bureaucratic, leaving more freedom to the individual, emphasising the need for faster and more accurate response. Accordingly, the tools used by management are expected to fulfil the needs of this new managerial situation. Yang (1984), emphasises the importance of this point in Japanese industry:

" Another worry is that new technology, rapid communications and more competitive global economy requires speedier decision-making. Many large corporations that adhere to traditional practice may find it difficult to compete against smaller, entrepreneurially managed companies that rely on direct communications and quicker decision-making processes. In September 1983 according to a survey among managers by Nikkei 36.9%, of the responses listed communications and decision-making as a matter of grave concern. Indeed, communications worried more executives than any other problem. " [1.1]

The development of managerial tools has been in line with the progress of scientific and technological development. The use of Management Information Systems and analytical methods, which have been used in solving management problems, has accelerated after the introduction of computers into commercial applications.

Information systems have evolved through the substitution of manual record keeping by automated procedures. Traditional information systems have been primarily developed on corporate mainframes in order to replace clerical information processing practices. Accounting, sales order processing, inventory recording and production recording exemplify such typical applications. The main emphasis has been on transaction-based data processing with the purpose of providing information for book-keeping. These systems were complex and operated by computing-oriented technical staff. As the systems developed, the supply of management information for managerial decision-making processes has been seen as a useful added benefit [1.2]. Buchanan (1980), points out to this fact :

" Yet computer applications in general have been so specialised that many organisations have overlooked potential and more general roles for information systems. Information systems are not simply labour saving devices that support activities of people in one or more departments. Rather they are control and co-ordination devices that should fit an organisation's formal structure ." [1.3]

Quantitative Methods or Management Science includes methods drawn from areas such as 'Operations Research', 'System Science' and 'Simulation', and it provides sophisticated aids to management, especially in solving managerial problems which are structured and repetitive. Similar to the evolution of the early information systems, the design and utilisation of these methods have been delegated to scientists and systems oriented technical staff in specialised departments. Accordingly, managerial involvement with the preparation and the implementation of these methods has been insufficient and lack of communication between user-managers and management scientists has created organisational resistance preventing widespread acceptance of these methods [1.4]. Findings of research recently carried out by Woolsey (1986) confirm this point:

" The findings of the research indicate that the reason why other systems have failed is non-acceptance by user managers." [1.5]

Ball, (1986) also points out the importance of the integration of Management Science methods to management practice and systems:

" Management science is not fully appreciated or used. It needs to be an integral part of the firm management style culture and systems. The aim should be to make modelling as a part of the firm management style and system. The inability to integrate is what limits the progress, not the lack of knowledge. " [1.6]

The effective utilisation of Information Systems and Quantitative Methods by Operational Management have been restricted. The models are too complex, difficult to understand, and operate without substantial involvement of technical staff. Managerial processes are fluid and subject to frequent changes. Continual adaptation of these large systems in line with changing managerial requirements neccesitates significant manpower and development costs. Allen (1982) concludes the following:

" Whatever the reason there is general dissatisfaction with the adaptability of information systems to changing requirements. Yet flexibilty is the crucial element of information systems especially when considering their high cost and long development time. " [1.7]

The management process, being dynamic, requires frequent changes to the system. Modification of a large and centralised system is expensive and not practical.

Availability of information systems as a potential source of accurate and timely information has also influenced the dynamics of the corporate decision-making process, which has became progressively more centralised. A literature survey indicates an extensive range of symptyoms, which refer to ineffective or ill utilisation of these tools. Instead of being productive, such utilisation for the decision support function can easily become time-consuming with no significant benefit to the parent business organisation.

Advances in information technology are now providing management with increased communication, data processing and computation capacity. Widespread use of mini and micro sized computers in business applications is changing the perceptions about information systems and other managerial decision aids. For instance, in the manufacturing industry, especially in the Far East, the traditional mainframe based complex 'Material Requirements Planning', models which used to track the movements of each part in the plant are now being replaced by 'Kanban',systems where the movement of a part is monitored and regulated directly by shop floor manufacturing centres, which are also provided with local information processing capacity [1.8]. It is interesting to note that with this application, rigid and centralised control, which is executed by a few specialists from the production control mainframe, is replaced by a series of feedback loops which co-ordinate machining centres throughout the shop floor.

The release of new products for industrial applications is confirming the general tendency to move towards mini or micro computer-based modular systems, which can be co-ordinated through communication networks [1.9] [1.10]. However, in these systems ,although relatively more consideration is given to the decision support function, the main emphasis is still on automated book-keeping of common industrial practices.

The operational management process is dynamic, and is influenced by the subjective decision processes of the managers involved with the operation. Organisation of the operations may vary significantly between the different companies operating within the same industry. Because of these factors, traditional information systems and implementation of management science methods are increasingly inadequate.

The decision process is subjective and to be effectively used the capabilities of the support system must specifically match the requirements of each manager.

Finished products which are available on the market are effectively information systems designed to replace older main frame based information systems or manual practices. They do not generally deliver operational decision support functions [1.11]. They cannot deliver this function because each product needs to be tailored according to the needs of the specific organisation. McLead (1986) reports the results of a recent survey carried out among executives on how to increase the effectiveness of information systems:

" Tailor the system to fit individual needs. There is no best approach to develop an information system." [1.12]

Answering a question 'What are your most critical concerns in dealing with information systems' Singelton, Vice Chairman of $64 billion company's. replied:

" The vendors of Information Systems peddling too many off the shelf products and reworked versions of old solutions to satisfy today's MIS executives. What MIS chiefs want to do is to forge alliances with both their suppliers and users, pacts that will help them to build and structure the system and needs of the future." [1.13]

Decision Support systems are relatively recent trend. Such systems are dedicated to support managers with flexible access to models and relevant information about the decision environment. The purpose of decision support systems is to improve the effectiveness and efficiency of decision-making, throughout the business organisation [1.14]. According to Parker et al (1987):

" Decision Support Systems is a new and powerful concept, which if adopted and exploited will provide a new impetus for management scientists. It is a natural evolution in computer applications and it has emerged from MIS failure to support decision-making by managers in business. " [1.15]

Justification of the decision support system, unlike MIS, should be based essentially on the requirements of the decision-makers and the characteristics of the decision process. What is required from managers and from the organisation to increase the likelihood of arriving at correct decisions is not too clear. It can only be described by the manager himself.

Despite the fact that decision-making is the central aspect of managing, the literature surrounding decision-making has generally focused on the moment of decision, rather than on the whole, complex process of defining and exploring the many alternatives in a decision, which precedes the interaction with other decision-makers and the final act of deciding. This is considered to be a major deficiency because the success of operational management depends on the capacity of the operational management team to function as a co-ordinated and healthy system.

Since the decision process varies with managers and with organisations and it is not easily quantifiable, the development of dedicated decision support systems has been restricted. Existing applications generally include the utilisation of management information systems as an information bank, and utilisation of quantitive aids for strategic level decision-makers.

Development of communication and information technologies and availability of low cost information processing capacity increase the scope for implementation of simple, modular, easy to use, and easy to maintain support systems which incorporate quantitative aids as an integral part of the system. Application potential for such systems is especially substantial where the operational business environment necessitates co-ordinated decision-making within a semi-structured decision environment. Oil processing and maritime transportation is such an environment, where although most of the operational decisions are econometric, because of the uncertainty and the diversity of the operational scenarios, managerial decision work can not be substantially automated. [1.16]

The decision environment for operational managers is often complex, and identification of the best strategy, in terms of overall cost effectiveness, is difficult. In order to contribute to the overall operational co-ordination, a manager, responsible for a specific function in a specific regional division, needs to be promptly informed about the state of events in other parts of the firm. Effective co-ordination of the operational functions can be improved by using quantitative methods. Existing practice indicates that dedicated decision support systems are not implemented for such applications [1.17].

The rationale for the implementation of a Decision Support

System should be fundamentally different from that of a conventional system, where the emphasis is the automation of manual information processing. Analysis of the principal issues, which are associated with the success of the operational management, should precede the description of the support system which will be utilised by managers.

The issues which are associated with successful operational management are already covered by many sciences and disciplines. Essentially they relate to the capacity of managers to assess and evaluate the decision environment and also to the effectiveness of the organisational system as a co-ordinating and supporting framework. Such a system can be perceived as an organised man-machine system, which is provided with the purpose of managing a certain operation within the organisation.

The Support System must meet the needs of the individual managers and the general operational management process. The system must be easy to adapt and modify. What is needed is more than a simple product; rather a methodology indicating how the system should be designed, developed and maintained. The design of such systems cannot be covered by only computing or management sciences, it requires a multi-disciplinary approach.

Most of the issues which are attributed to decision-making are thoroughly covered by Cybernetics which is the study of the flow of information throughout a system and the way in which the information is used by the system as a means of controlling itself [1.17]. By definition, the decision-making process involves the control of information within the organisation with the purpose of directing the organisation towards its goals.

## 1.2 Proposed Solution

A methodology discussed in this thesis for designing Decision Support Systems has been developed by considering cybernetic principles about communication, co-ordination and regulation in organisations, as well as the coupling of man and machines in problem-solving activities.

The starting point is the recognition of the fact that direct operational decision support is a fundamentally important issue and requires a cohesive and dedicated support system. The system must be specifically designed for operational management activities. Therefore, the input of each manager, which contributes to the operational management process, must be abstracted from his other functions, and the support system must be designed solely for this function.

The system must be perceived at two distinct resolution levels: The main system level defines the entire support system which is provided to operational decision managers in the organisation. It is a collection of the independent units and the information communication patterns between them. The individual unit level describes the details of the support system that is provided to a specific operational manager.

This is based on the black box approach, where the line organisation which deals with operational decision-making is described in terms of decision centres. At the main system level, the details of the local decision support function are not important. The essential issue is the determination of the inputs and the outputs to each decision centre in terms of information which is significant for the decision process. The objectives and the scope of the design process which applies to this resolution level are completely independent from the second resolution level. The object is the proper co-ordination and regulation of the decision process involving a number of operational managers. Such an approach also facilitates the understanding of the existing decision dynamics in the organisation.

At the second resolution level, each decision centre, consists of different managers with different decision support needs. The system provides them exclusively with essential information about their own decision environment and quantitative decision support facilities which enable them to analyse the problem.

The object of the system is to provide 'on line' operational support. It will be directly used by managers without a need for technical staff. Although the managers are responsible for the timing and the nature of their interventions into the operations, in order to have more time for analysis and evaluation they require the information as quickly as possible. The proposed system provides a formal medium for constant communication of the information which is significant and important for the decision process. It will filter and reduce the large amount of variety generated by the environment.

Each decision unit, being specified by the operational manager himself according to his specific needs, will be directly used by him as an analysis support tool. This is a significant improvement in introducing OR and MS methods to operational management because, unlike strategic decisions, the time that can be allocated to the analysis of operational decisions is often very limited and, instead of benefiting from the scientific methods, managers often rely on 'rule of thumb', or 'educated guesses' even in assessing semi-structured problems that can dealt with by MS methods.

The system which is based on the proposed methodology provides a medium for proper co-ordination and regulation of the individual efforts of the various operational managers. Co-ordination and regulation of the decision process through computer based systems is sensitive. Over-centralisation or loss of the organisational flexibility are typical examples of improper MIS implementations which have produced in counterproductive results.

Automation and partial or full delegation of operational decisions which can be delegated to the system are included within the scope of the methodology.

In this thesis a typical implementation is developed for an oil production and distribution company in order to exemplify the proposed system and the methodology. The oil industry is now facing increasing competition. In order to keep up, companies have to increase the overall cost effectiveness of their operations. As happens in the manufacturing industry, increasing the turnover reduces the quantity of stock and the capital tied to it. Mobilisation of large volumes of crude and refined products, especially, in maritime transportation, is costly and an effective operational management has significant contributions to make to the competitiveness of the company. Operational functions including the purchase and supply of crude to the processing plants, inventory control of stocks and products, production, distribution of products to markets and sales must be properly co-ordinated. The decision process throughout the firm requires complex and continual interaction of operational managers. Oil companies, whether they are private or state-owned, are decentralised and their production plants are distributed to various geographical locations. Common utilisation of corporate resources between regional divisions, especially in maritime transport, necessitates further co-ordination of the operational decision process.

The design is carried out in the light of the methodology proposed and developed in this work. The primary objective of the system is to provide a framework, an environment for the operational management in co-ordinating and optimising the main activities associated with the marketing, transport and production functions of the company.

The system hardware consists of a network of microcomputers interlinking to various parts of the company. There is no need for a central mainframe or mini for data storage. The system will be completely independent from other information processing systems of the company and if necessary will be interphased to the other systems for extracting information. The system will not be used for functions other than decision support. Therefore, recorded and transmitted information will be kept in the system while the transaction is in progress. The relevant information will be smoothed and stored in order to provide data for decision support oriented forecasting. The system will include files, communication systems and built-in quantitative methods which are used for co-ordination and decision support.

## 1.3 Structure of the thesis

The outline structure of this work is as follows :

Chapter Two includes the definition of the problem. Briefly, it incorporates recognition of the fact that operational managers are increasingly in need of a decision support tool. The reasons that caused the failure of OR/MS methods and the MIS in delivering operational support functions are investigated. Finally the scope of requirements for a decision support system to be used by operational management of industrial organisations is defined.

In Chapter three the use of Cybernetics as the conceptual framework is justified. Contributions of Cybernetic theories to the design and development of such systems are investigated under three sections : (1) The Co-ordination and Regulation of the operational management activities within the organisation. This applies to the co-ordination of the decision process and forms the basis of the design of the main system. (2) The properties that relate to the interaction of man and machines in co-operative problem solving activities. This forms the basis for designing individual decision support units. Finally (3) The properties that the support system must have since it is a tool for a constantly changing and evolving decision process within the business organisation.

Chapter Four centres on the description of the proposed system and the proposed methodology. The aim of the methodology and the rationale of adopting the proposed system including system objectives and system configuration are explained. The methodology for developing the proposed system is explained in three sections: The first section defines the specific operational situations for which the system will be significantly useful. The second section describes the development of the system at the main system level. The outcome of this phase is the definition of the decision units, the inputs and outputs to each unit and the communication patterns between units. The third and final section describes the development of the individual decision units. This chapter also includes a description of the development of the system following its commissioning and the contributions to operational management that emanate from using the proposed system as a decision support tool.

A typical implementation is carried out for a typical oil company in order to exemplify the system and the proposed development methodology. However, it must be noted that it is not based on a real case study. Such a complete implementation requires the commitment of an industrial company because according to the proposed development methodology the system is not just an end product; it requires direct involvement of the operational managers with the design process. The typical implementation is therefore based on the exemplification of what happens in actual conditions. The information is obtained from direct communication with some operational managers, yearly reviews and other publications of oil companies and on the literature survey about the subject. This chapter mainly includes description of the business environment of oil processing and distribution companies, description of the decision environment and a exemplification of developing the first phase of a proposed methodology.

Chapter Six includes the explanation of the second phase of the proposed design methodology: The details of the individual decision units which are provided to various managers are exemplified. However, exemplification of this phase is limited because, in real life applications, each manager will be responsible for the specification and the development of the decision unit which will be directly used by him. During the post-commissioning period operational managers will also be responsible for maintaining their own units.

Chapter Seven includes discussion of the design of the decision support systems and contributions to the operational management itself are emphasised. This chapter also includes a comparison of the proposed methodology with other methodologies. Finally Chapter Eight presents the conclusions derived from our work and Chapter Nine discusses recommendations for further work.

# 2. OVERVIEW OF THE PROBLEM

## 2.1 Problem documentation

Directors or managers who are responsible for managing mainstream business operations in some industries are constantly faced with situations, where, in order to improve the performance of the operation, they need to intervene in the actual situation. Unlike a traditional strategic decision environment, where decisions are made in scheduled meetings, operational decisions have to be made within a limited time period. Therefore, often there is no time to organise and to analyse the information. Managers are forced to be closely involved with the situations. Unlike strategic decision makers they cannot afford to co-operate with the technical support people. Instead of relying on quantitative decision methods, they rely on subjective 'rules of thumbs' or 'gut feelings'. They are restricted to operating within the scope of the information which is supplied to them. If the information is not satisfactory, then valuable and limited time, which should be allocated to analysis, evaluation and co-ordination, is spent in obtaining the necessary information.

At Northwest Industries a manager states the following about his direct involvement with the corporate management support system:

" It saves a great deal of time spent in communicating with functional staff personnel. Today, for an increasing number of problems, I can locate the data I want and I can develop it in the form I want faster than I could describe my needs to the appropriate staffer. " [2.1]

In some industries, where a decision maker has to manage business operations which involve large quantities of high value products, especially in uncontrollable environments, the correctness of the decision may contribute significantly to the overall cost effectiveness of the operation and thus to the overall competitiveness of the company. Operational co-ordination, that is, collective decision processes leading to effective utilisation of common resources, is especially important where the business operation necessitates management of a number of interrelated and interdependent functions. With regard to the increasing interdependence of operational functions and the increasing need for operational co-ordination, the regional vice president of East Africa and the Middle East for a $1.2 billion division of a consumer products firm has noted the following:

" Until three years ago my six affiliates were very much self-contained operations. Today, however, I see their care as an integrated set of manufacturing resources that supply different markets with products made wherever my cost advantage is greatest. The plants in one country now must supply others located elsewhere. " [2.2]

The same paper (Buss,1982) further emphasises the role of MIS specifically in co-ordinating operational management activities.

Business organisations are provided with procedures, which are used to co-ordinate distinct operational functions. However, being based on past performances, these procedures have a time lag associated with them and they are redundant in co-ordinating the operational decision environment [2.3].

As companies are forced to be more competitive, in order to increase their competitiveness managers are obliged to produce operational decisions which result in better utilisation of the company resources.

The information needs of the managers about the environment are provided by themselves or by their staff. Internal information about the state of events is provided by the corporate management information system whose main justification is other than direct managerial support. A literature survey indicates that a traditional MIS does not cover environmental information and does not have any significant effect actual decision-making processes [2.4] [2.5].

Carter (1983) points to the fact that an MIS traditionally is a measurement tool rather than providing information for the direct operational support function :

" These characteristics put the manager in direct conflict with most formal information systems. He seeks to trigger speculative current information but the formal system gives him largely aggregated precise historical information.

Furthermore the manager demonstrates a thirst for external information whereas formal systems provide internal information. As a result, the manager must often ignore the formal system. Instead he designs his own system which provides information that he believes he needs." [2.6]

Utilisation of quantitative methods is through specialist departments where interactions of managers with technical staff are not viable for operational decisions and therefore managers do not benefit from using such methods [2.7].

A literature survey about the effects of MIS on corporate co-ordination in industrial companies indicates that significant restrictions and deficiencies are introduced into the operational co-ordination in the firm [2.9],[2.10],[2.11] [2.12].

Although technology is available, existing systems generally fail to provide significant decision support for operational decision makers. Specific reasons for this deficiency are investigated in detail in the next section.

## 2.2 Principal Causes and Symptoms of Misapplications

An extensive literature survey has been carried out as part of the work represented here to identify why computer-based information and analysis support systems are not used by industry as a significant decision support tool. According to Saleron:

" Early attempts to introduce MIS led to high hopes followed by hot debate when systems promised and failed to deliver a new era of management productivity. " [2.20]

Recent court actions against software houses indicate the importance of the problem. Harrison 1984 reports the following:

" It is noted that at least thirty court actions are brought to the suppliers and software houses alleging they have been sold unsatisfactory systems. Claims for damages run into millions of pounds and the list of cases involves some of the best known names in the computer industry. According to the experts in the consultancy field litigation has mushroomed in the last two years and is set to continue growing. " [2.13]

The philosophy behind the development of computer based systems for managerial purposes is either to replace manual book-keeping practices by automated information processing systems, or to improve the quality and the capacity of the existing automated systems [2.14]. The primary function of the corporate information system is to provide information for staff functions such as order processing, rather than providing information for operational decision makers. Therefore, the needs of the staff functions dominate the needs of the decision makers. The fundamental difference is that the staff functions are responsible for controlling and monitoring hat happened in the past, whereas the primary concern of operational managers is to innovate better future performances. Most of the symptoms are related to this fact [1.6].

Being data processing oriented, the traditional MIS is large and complex. Involvement of managers at the design phase, that is, at the software specification phase, is limited. The decision process is complex and unlike system analysis, applications are generally ill defined. If the project development is mainly carried out by systems analysts, without any substantial input from managers, the resulting system generally turns out to be unnecessarily complex and it generates substantial amounts of unneeded variety [2.13]. Therefore, limited managerial involvement with the system design results in inadequate systems.

In a survey carried out by a principal of Arthur Young & Co.,1986, a chief information officer reports that there is a lack of communication between developers and users.

" There is a lack of communication between line management and data processing people. There is a lack of credibility because in most cases line managers have not gotten what they wanted when they wanted it. " [2.23]

Singleton (1987), vice chairman of a large company, states the importance of system development where user-managers are directly involved with the development.

" I want a partnership strategy that allows us to build something unique together with the vendor. "[1.13]

In the same survey, Brezinski, vice president of Information Systems at the $ 3.7 billion Quaker Oats Co points out the fact that this deficiency is the primary cause of systems being inadequate.

On the same point Wilkington emphasises the need for direct managerial involvement in developing such systems:

" The managers who are going to use the information must be responsible for setting the specifications for these systems and evaluating the results; only they can state their own needs and degrees of satisfaction. " [2.14]

Inadequate information or deficiencies in the system either restrict the decision environment of the managers or alienates the managers from using the system which eventually becomes redundant [2.15].

Being large, such systems require long development times. Accordingly, modification of such systems requires significant resources, and eventually they lag behind the general practice. The decision process, unlike transaction oriented data processing,s dynamic and subject to change. Naturally MIS cannot keep up with the continual changes in the decision process. The upgrading of the MIS is therefore not evolutionary, but revolutionary and each replacement represents a strenuous habituation period, especially for managers who can accommodate only a limited training and learning period [2.16]. According to Allen,

" Applications frequently prove inflexible and difficult to change. A part of the problem in most organisations stems from the poor products developed in the past. That request for change gets to be a giant project that takes forever to complete and costs a fortune is a universal complaint. "[1.7]

Because of this static nature, MIS cannot be easily adapted to cope with unforeseen circumstances. This particular fact decreases the adaptability of the decision makers. In the manufacturing industry, it is not rare to see business organisations where the central information system ends up controlling the whole operation, whilst decreasing its adaptability. Martin (1983), points to the importance of the maintenance problem:

" Perhaps the biggest unforeseen danger is the difficulty of maintenance. Most business applications change over in time so the package must be modified and the customer must make the modifications. " [2.17]

Since the MIS is dominated by staff functions, it is biased towards measurable information. According to the availability of the information, some decision makers can be provided with more relevant information whereas some others are neglected. However, the operational decision process is an interrelated system, and its success is restricted to the performance of its weakest element, that is the least informed manager. Although the information system contributes to the co-ordination because of its isomorphism it can generate a large quantity of variety .

The introduction of information systems to management practice influences the control philosophy in the organisation. There are numerous examples of overcentralisation of power due to easy availability of information. Such overcentralisation in the decision process is dangerous and will modify operational business dynamics. Zuboff indicates that the MIS has implications on the actual business dynamics:

" Finally, these capacities of information systems can alter the relationships among managers themselves. A division or plant manager can often leverage a certain amount of independence by maintaining the control of key information. With itowever senior managers in corporate headquarters increasingly have access to systems that display day to day figures of distinct parts of the company. This new access raises several questions for a corporation. Managers are reluctant to make decisions on the basis of information that their supervisors receive simultaneously. " [2.18]

The provision of managers with fully organised and classified information in an ill-defined decision environment does not usually contribute to the decision process. In such environments managers provided with raw or semi-organised information can often quite effectively grasp situations. Quantitative decision aids, although extensively used at strategic decision-making levels, are not generally utilised by operational managers [2.19].

The application of quantitative techniques is delegated to technical staff and therefore there is little scope for direct involvement of managers in using such methods. Linstone (1985), points out that the real weaknesses of the OR/MS are not in the technology but in the integration of these methods to general management practice :

" The application of MS/OR type methods have acute limitations including reductionism and simplification. To overcome these limitations, perspectives other than technical área should also be used in the process. Organisational and personal perspectives should also be formally considered along with technical decision making. "[2.21]

Minch indicates the lack of user-friendliness; the difficulty due to the set up, and use of these models is often the basis for the failure of these methods being accepted by management practice:

" Despite the widespread use of management science models in decision-supporting applications, their usefuleness has been limited by several factors. Investigations into these limitations have noted that these shortcomings relate primarily to lack of user-friendliness, inflexibility of models in dynamic environments, and the absence of model-data and model-model communication. " [2.25]

The main problems which have been referred in this section relate to the fact that there is a lack of line management involvement during the design and development of the information systems. This section also relates to the inability of the systems to be adapted according to changing requirements. Lack of emphasis with respect to organisational considerations has affected the relationships between managers at the personal level such as have occurred with the emergence of over-centralisation. This section also points to the limited perceptions about the functionality of MIS in co-ordinating the management operations. The essential reason for this is the evolution of MIS from traditional systems where the object is the measurement of past events.

The failure of OR/MS methods as a management support tool is blamed on the fact that their development has been mainly on technical aspects leading to a significant gap between managers as users of these methods.

In the light of these problems, within the next section the requirements for design and implementation of operational decision support systems incorporating MIS and OR/MS methods are evaluated.

## 2.3 Scope of Requirements for Design and Implementation of Decision Support Systems

In the light of the symptoms experienced by industry, it is concluded that the MIS is not used as an effective decision support tool because it is primarily designed to fulfil the needs of the staff functions. On the other hand, quantitative techniques are being significantly delegated to management science specialists where they are used as a support tool by strategic decision makers where the decision maker is not under time pressure, but they are not used significantly by operational decision makers where there is limited time to analyse and evaluate the decision environment. Decision-oriented problems are generally perceived as self-contained ones which can be solved by one decision maker, and therefore the importance of the support facilities for co-ordinating the decision process is not emphasised.

Before defining any specific factors which contribute to the effectiveness of a decision support system, the characteristics and dynamics of the decision process must be assessed. What are the elements which increase the performance of the decision makers as a whole in the firm? A criterion for developing decision support systems or assessing their performance only be constructed only after the evaluation of the decision dynamics involving analysis of information flow between the decision makers and the decision process practised by managers has been made.

The design should proceed following the analysis of the existing decision dynamics and must cover the shortcomings of the current practice which can be classified in four main sections: Provision of information, provision of analysis support tools, provision of automation and provision of a co-ordinating framework.

Provision of information refers to the performance of the support system as a medium to provide the decision maker with the necessary information which will enable him to carry out his decisions.

The information needs of the manager are not clear and can be best described by the experienced manager himself. On the other hand, decision making is a dynamic event and changes with time and with situations. Therefore managers should be substantially involved with the development of the system which must be simple to modify and simple to maintain. Large business organisations which involve many decision makers are particularly exposed. Various parts of the system must have the capability of being developed and maintained independently.

Provision of information for staff functions results in a large system which is complex, difficult to maintain and to modify. Systems must be smaller, where information which is not relevant for decision making should not be stored. This will reduce the amount of information which needs to be processed and consequently the problems associated with the use of large systems. Systems must be set according to the requirements of the decision makers so that the generation of unneeded variety is implicitly reduced and thus keeps the system size in check. The decision maker needs to be provided only with essential information about the decision environment.

Being staff-function oriented, the MIS concentrates on some functions more than others. The emphasis and the aim of the staff functions are not always aligned with the aims of the operational management. Therefore managers should not be provided with information which is primarily organised to meet the needs of the staff functions.

A decision support system, therefore, should not be incomplete on major issues and it should not be uneven. That is, some managers should not be supplied with detailed information if other decision makers of equivalent importance are not supplied with similar information of similar quality and quantity. By the same token, the actual situation should not be reduced or significantly modified for the sake of supplying quantitative and formal information which follows a predetermined pattern. These measures will move the emphasis towards the essential information needs of the managers and the system will not restrict or influence the managerial procedures.

The reasons resulting in management science methods not being used effectively as an analysis aid, are in fact fundamentally similar to the reasons resulting in the failure of MIS as an effective decision support tool. It is primarily due to the perception of such techniques as large and complex methods which can be handled only by specialists.

Unlike strategic decision makers, managers who are responsible for line operations are continually pressurised to deliver the necessary decisions within a limited time period. To be accepted and to be effective, quantitative analysis support tools should not be complex and difficult to interact with. Such complex models are of little use to managers, because of high set up,access and response times.

In an operational decision environment, a large proportion of the operational dynamics is in fact repetitive. That is, the leading particulars of the problem are more or less similar although the details and the characteristics may be different. A major step towards the acceptance of analysis support tools by operational managers would be to prepare generalised models and to provide such models as an integral part of the general decision support system. These models should be easily adaptable to the particular needs of the operational situation. It is not too difficult for the operational manager to identify the type of analysis he needs to perform in order to improve the quality of his decisions. Therefore, provision of a predefined repertoire of robust and easy-to-set quantitative analysis tools which are likely to be needed during the course of the operational dynamics will improve the analysis capacity of the manager.

Automation of the decision making is especially sensitive. What can be delegated to machines as operational decision-making work is in fact limited. Routine maintenance oriented operations and straightforward economic comparisons subject to supervision can be delegated to the system with the purpose of focusing the attention of the decision maker on more difficult situations. However automation of decision-making work should not be treated as a traditional system analysis application because it is fundamentally different. To what extent such automation can be safely achieved should only be practised through the analysis of the decision environment vis-a- vis with the characteristics of man and machine problem solving.

The most important element which contributes to the success of operational decision making is certainly the co-ordination of decisions so that they function as a system [2.23]. The major function of the decision support system can therefore be defined as a co-ordinating framework for operational decisions. A typical MIS implementation resulting in information exchange between departments is not satisfactory in fulfilling the requirements of co-ordination function. Effective co-ordination can only be achieved by respecting the issues associated with the co-ordination and regulation of systems. The pitfalls are numerous: Overcentralisation needs to be prevented, since availability of the information provides the scope for it. The short and long term implications are significant. Over the short term, managers who are less involved with the situation are enabled to make decisions about the situation; over the long term, overcentralisation will result in loss of capability of the business organisation to adapt to the emerging environmental changes [2.24].

The aim of the support system being uniquely a decision support function, there is no need for the system to have centralised data storage files where the data can be used for other aims. In fact such centralised data storage can force the decision process to fit the pattern of the system resulting in loss of dynamism and loss of adaptability in the decision process.

The scope for requirements for improving the quality and the performance of the decision support system indicates that in general terms, a completely independent system dedicated uniquely to the decision support system is required. The system needs to compromise on various aspects of the decision process.

What are the criteria which can be used as a reference in designing and implementing such systems? What are the priorities that need to be respected in arriving at a compromise which meets the requirements of the decision makers? How can such a system be designed so that the components referring to various aspects of the problem do not have counterproductive implications?

The solutions cannot be provided by the specific disciplines which are covered by the problem. For instance the co-ordination problem cannot be addressed by management science or information technology. By the same token decision making is fundamentally different from other information processing work and therefore cannot be implemented through conventional system analysis applications. A lateral approach involving various disciplines is required so that the various functions of the decision support system can be unified within a general framework.

Analysis of the decision process should precede all attempts to define the requirements of the decision support system. As the decision processes are dependent on business dynamics and management practice, the issues associated with the management within a general context need to be included within the scope of the assessment. The theories associated with co-ordination, man-machine problem solving, and automation must be carefully examined and included within the scope of the methodology of designing and implementing decision support systems.

In order to achieve the above, it is quite clear that a multi-disciplinary approach is needed. Within that approach leading particulars of the specific methods referring to one aspect of the problem shall be addressed. In fact it should be noted that the failure of MIS and quantitative analysis tools to penetrate operational management practice is blamed on the fact that in-depth implementation of such methods has resulted in loss of focus and the detail involved with the methods has overtaken the aims of the methods.

In summary, to avoid the existing problems, the decision support system which essentially provides MIS and OR/MS methods for direct 'on line' operational decision support must conform to the following:

The design must be based on a multi-disciplinary approach where social, organisational and systemic aspects are considered as well as technical ones.

Any design work must be preceded by a thorough analysis and understanding of the existing decision dynamics and the information flow within the organisation.

The design philosophy must focus on meeting the most important needs of the managers in terms of decision support function. That is, instead of past oriented accuracy, systems must incorporate the factors that realistically contribute to the decision process despite the fact that they may be unorthodox or informal such as qualitative judgements of other managers.

Operational managers must be responsible for designing the system since the system will be directly used by them. To be effective, the system must exactly deliver the support that each manager needs, although that support function may be significantly different for various managers.

As well as providing decision support functions, individually to operational managers, the system must contribute to the effective co-ordination of the decision process.

Any OR/MS models must be easy to set and easy to use. They must be integrated to the MIS and to the other management support systems.

Systems must not create additional problems which affect the overall effectiveness of the decision process throughout the organisation such as overcentralisation of power.

Systems must be easily modifiable according to managerial requirements.

# 3. CYBERNETICS AS A METHODOLOGY FOR IMPROVING THE DESIGN AND THE IMPLEMENTATION OF DECISION SUPPORT SYSTEMS

## 3.1 Relevance of Cybernetics

What is the relevance of Cybernetics? What is the justification for using theories of Cybernetics as a reference in the design and implementation of Decision Support Systems instead of other sciences?

According to Stewart (1982),

" Cybernetics has been going on for forty years and is embarrassingly middle aged still to be called a young science. We no longer have the excuse that it is new for any lack of results." [3.3]

Cybernetics does not provide an inclusive and integrated framework of theories. The effectiveness of using Cybernetics as the sole science in the application of any system or methodology is therefore debatable.

The intention is not to claim that the whole methodology is exclusively constructed from the direct application of Cybernetic theories. However, it provides imperative principles, which are not covered by a particular science or method and which are fundamental for the design of information processing systems, co-ordinating the decision process in a business organisation. It provides a conceptual framework, which focuses on the relative importance of various issues which are traditionally used in the design of management support systems.

As the work proceeds, and details of the problem are presented, utilisation of Cybernetics as a reference frame will become apparent because designing Decision Support Systems is fundamentally a Cybernetic problem. Therefore, at this stage the relevance of Cybernetics is emphasised by indicating that general concepts associated with decision making and accordingly concepts associated with the design of decision support systems are in fact covered by Cybernetics more satisfactorily than management or computing sciences.

The aim of this work is not to teach managers about Cybernetics and how to make decisions using Cybernetics, but to provide a system, or a framework, which is designed by considering Cybernetic theories. The object of the system is to increase the capacity of the manager as a decision maker by providing him with the appropriate information and analysis tools; to enhance effective interaction between managers in assessing a decision situation; and to co-ordinate the decision-making activity as a process throughout the business organisation.

Therefore, the use of such a system addresses the decision making activity which contributes to the mainstream business operation of the firm. It does not address other decision making activities of the manager, which do not immediately relate to the mainstream business activities, such as how to motivate the staff to get the work done.

It is important to re-emphasise that the decision support system which we are referring to in this work is not a general purpose system and that it is designed to be used by the operational managers of decentralised business organisations. These operational managers shall be responsible for at least one essential aspect of the mainstream business activity. In summary, it is about operations management including the purchasing and supplying raw materials to production plants, controlling raw materials and finished goods inventories, controlling the production rates ,distributing finished goods to markets and marketing operations. The primary aim of the decision support system is to provide a framework through which various operational activities are successffully co-ordinated, because what happens to one activity depends essentially on what happens to other activities. The essential reason for having operational decision makers who are responsible for certain aspects of the business activity, does in fact indicate that at these positions there is a need for human intervention for problem-solving or decision making work associated with the mainstream business activity. Such positions can be described as decision units. Accordingly, the whole mainstream business activity can be represented by series of decision units which are connected to each other forming a system which can be analysed and evaluated by Cybernetics.

The primary characteristics of the problem, which indicate and emphasise the need for adopting Cybernetics as the reference methodology, are as follows:

Mainstream business operations involving production, transportation and marketing functions of a decentralised business organisation require substantial interaction between managers who are involved with the mainstream business operation.

The effectiveness and the profitability of the business organisation can be significantly improved by proper co-ordination of the decision-making work which is associated with the main business activity of the corporation.

Analysis of systems is a major study area for Cybernetics. Klir's description of Cybernetics (1965) clarifies this point.

" Cybernetics is a science dealing on the one hand with the study of relatively closed systems from the viewpoint of their interchange of information with their environment, on the other hand with the study of the structures of these systems from the viewpoint of information exchange between their elements. " [3.1]

Cybernetics as a science provides theories which can be used in solving problems associated with the co-ordination of the decision process as an integral system. What should be the context of the relationships between various decision makers, that is the elements of the system, how should the process be regulated, controlled, and what should be incorporated to the decision support system so that its utilisation does not restrict the flow of the decision process?

Ashby (1956) defines Cybernetics as

"The study of systems that are open to energy but closed to information and control" [3.2].

In this description Ashby points out that the essential study area for Cybernetics is systems where the control of the information which is passing between the elements of the system is the determining factor for the performance of the system. As well as the co-ordination of the decision process, the capability of the operational manager in making good operational decisions is an essential factor contributing to the effectiveness of the decision process. How should the decision support system be designed so that the capacity of the manager as a decision maker can be increased? At that level the purpose of the support system is certainly not to replace managers with computer programs. Its aim is to provide the manager with appropriate information and analysis support tools so that the manager does not waste his precious time in chasing information and, by being provided with analysis support tools, does not always have to rely on 'instincts' when evaluating the decision environment. Cybernetics investigates how a man and machine system should be coupled together as an effective problem-solving system [3.3]. It attempts to answer the question how decision making work should be apportioned between man and machine. That is, it asks what aspects of the decision making work could be effectively delegated to the decision support system without generating negative side effects. According to Stewart, value processing is differentiated from information processing. Information processing work can be delegated to machines as long as quantitative relationships may be established between the elements of the problem necessitating a decision.[3.4]. Delegation of that type of work to machines enables manager to concentrate on problems which cannot be solved by machines, problems often involving issues of value.

What should be the scope for quantitative analysis models; to what extent do the manager need to know about the details of such models? What should be the scope for the interactions of the manager with such analysis support tools?

Investigation of such issues are included within the scope of Cybernetics [3.5],[3.6],[3.7].

Business organisation evolves in line with the changing business environment. Operational dynamics and accordingly decision process about operational dynamics have to evolve according to environmental pressures. The decision support system, being a facility for the decision makers in the firm, must conform to the continually changing decision process. It should be designed so that its utilisation does not pose any restrictions on the evolution of the decision process. Cybernetics investigates the properties that contribute to the evolution of the business organisation as a system. Consideration of these properties in designing decision support systems prevents the support system from posing any restrictions on the changing operational dynamics. Beer's definition of the Cybernetic approach to designing control mechanisms for the business organisation incorporates this point:

" If one is confronted by a system such as an industrial company or economy, and if this system has many of the formal properties of a living organism as well as its critical aims and objects then these entities belong to the class of Cybernetic systems. They ought to respond to the same control mechanisms. So he looks at the internal control arrangements at the surviving and evolving arrangements, and what happens when things go wrong. Then, he creates cybernetic controls: these may be actual machines -hardware attached to the plant -or new models of organisation,information handling and decision taking among people. " [3.8]

This approach is not fully inclusive and does not incorporate certain issues which are necessary to the evaluation of the decision process in the firm and the design of effective support systems for it. But it provides a general understanding of the problem, emphasising the fact that the systems provided in business organisations for control purposes should be designed considering the fact that organisations have to change and to evolve. A brilliant system may be designed for a specific condition which outlines the requirements for a decision support system, but if the system is designed without considering the fact that conditions are dynamic and are continually changing, it will soon be restrictive and eventually will be redundant. Therefore, the decision support system should be designed so that it should be adaptable to the changing requirements of the decision environment.

As noted before, the subject of this work is how to design dedicated decision support systems which will be used primarily in co-ordinating various operational functions of a decentralised business organisation. Decision making associated to mainstream business operations is a system which needs to be co-ordinated and regulated as appropriate. Such systems, which are working properly, conform to certain rules and principles which are studied and defined by Cybernetics. To be effective, decision support systems should be compatible with the decision-making system. That is by its design it should not pose any limitations on the flow and functioning of the decision-making system. This necessitates the use of such cybernetic principles in the design of the decision support systems. Potential users of the system, who are the operational decision makers, do not have to know about Cybernetics. At this stage, it is not too difficult to point out that the issues which have been discussed in this section do in fact directly relate to some of the problems, such as the adaptability of the support system, failure of the support system in co-ordinating business operations etc which have been discussed in the previous chapter.

Cybernetics, at least at a conceptual level, is suitable for being adopted as a general methodology for analysing the decision process in business organisations and designing adequate decision support aids for it. It is justifiable to do so since, as described earlier, Cybernetics addresses all aspects of the problem much more satisfactorily then management science or computing sciences. This conceptual justification can be consolidated only when decision support systems based on Cybernetic principles are implemented in industry and their effectiveness is evaluated against conventional decision support systems.

There have been various attempts to use Cybernetics as a conceptual framework in developing models of business organisations, in designing information systems and implementing OR as a management tool.

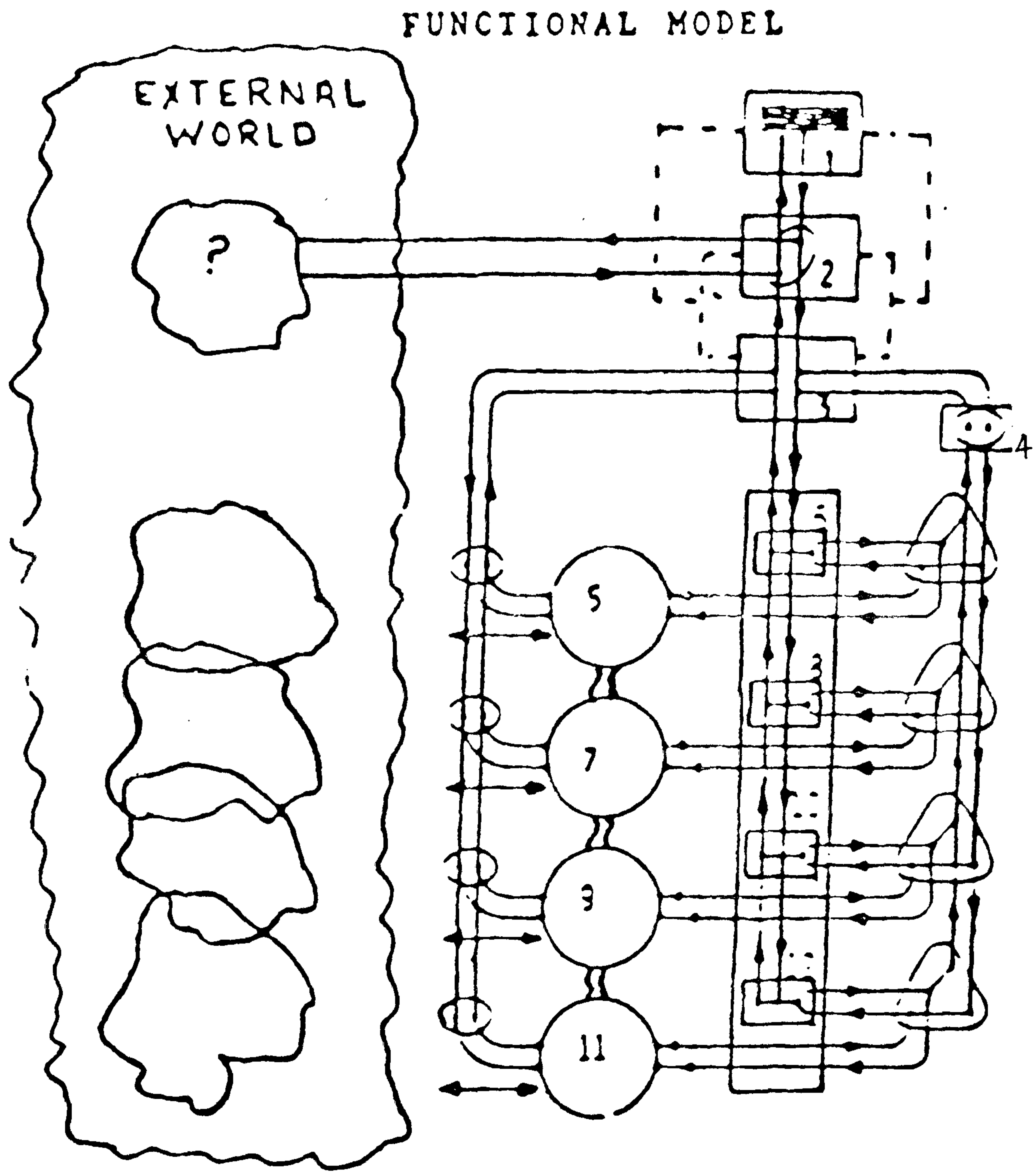
Beer proposed a methodolgy for implementing information systems where Cybernetics is primarily used as a tool to study the flow of information throughout the organisation and the way in which that information is used by the system as a means of controlling the system. In this approach the only information needed to measure performance and make subsequent decisions is included within the scope of the model. The basis of his methodology draws analogies from the central and autonomic nervous systems [3.8],[3.16].

The most recent implementation of this methodology has been carried out by Tripp et al (1986), for U.S. Airforce Logistics command including Procurement, Supply, Transportation and Maintenance Operations. Figure 3.1 indicates corporate level application of this methodology [3.10].

The selection of this methodology has been justified by Tripp et al as follows:

" Cybernetics views Management Information Control Systems as analoguous to the central and autonomic nervous systems. They make possible the co-ordinated action, the decision making, and control required for their survival and goal achievement."

Although there is no record of this methodology being further developed and implemented, he concludes that a conceptual framework based on Cybernetics is more




Functional Model: Recursion Level 1

1. AFLC Commander and Vice Commander
2. Director of Corporate Staff
3. Director of Logistics Operations Center (LOC)
4. Director of Management Information and Cont: Systems (MICS)
5. Procurement Operations
6. Procurement Manager
7. Supply Operations
8. Supply Manager
9. Transportation Operations
10. Transportation Manager
11. Maintenance Operations
12. Maintenance Manager

**Figure 3.1 Functional model for U.S. logistics command (source 3.10)**

appropriate in the machine age than a simple cause and effect approach.

For the purposes of this thesis, such a methodology is judged to be inappropriate for the following reasons.

It is a dramatic change, which is difficult and risky to implement by industrial organisations. It cannot be progressively implemented and it necessitates a sudden change to existing management practice.

It is more than a tool for operational management. It interferes with the existing organisational structure and it requires modifications to it whilst it totally disregards the importance of the existing organisation which has progressively evolved in line with the dynamics of business operations.

It requires managers to learn new evaluation methods which disregards their own needs. Each manager has distinctly personal evaluation criteria and such generalised criteria cannot be imposed on him.

This is not a rigorous criticism of Beer's approach but these points indicate the weaknesses of the methodology for it to be generally adopted by industrial organisations. However, the following outcomes are significant for development of any design methodology of operational decision support systems:

" An organisational system model could provide the management with a coherent and single picture of the total organisation identifying logical relationships and the channels of communication through which the life blood of command system information flows. The model provides a corporate focus for command and control. " [3.10]

" In addition to providing a corporate focus the organisational system model can provide management with a tool for integrating management activities. It can provide a glue for the four AFLC (e.g.,Contracting, Supply, Transportation and Maintenance) " [3.10]

These quotes emphasise the importance of the MIS in providing a co-ordinating function for the operational management process.

Other application-oriented methodologies proposed by Elohim, [3.9], address the design of management procedures. Methodologies proposed by Maarschaalk, [3.11], Mantz, [3.12], Lowe et al, [3.13] and Soumelis, [3.14], address the control function of the management procedures and they fail to deliver a detailed methodology which can be directly implemented in the design of management support systems.

A methodology developed by Baylin, 1985, applies the functional cohesion method, which is a conceptual method of identifying sub systems, to the analysis of the business

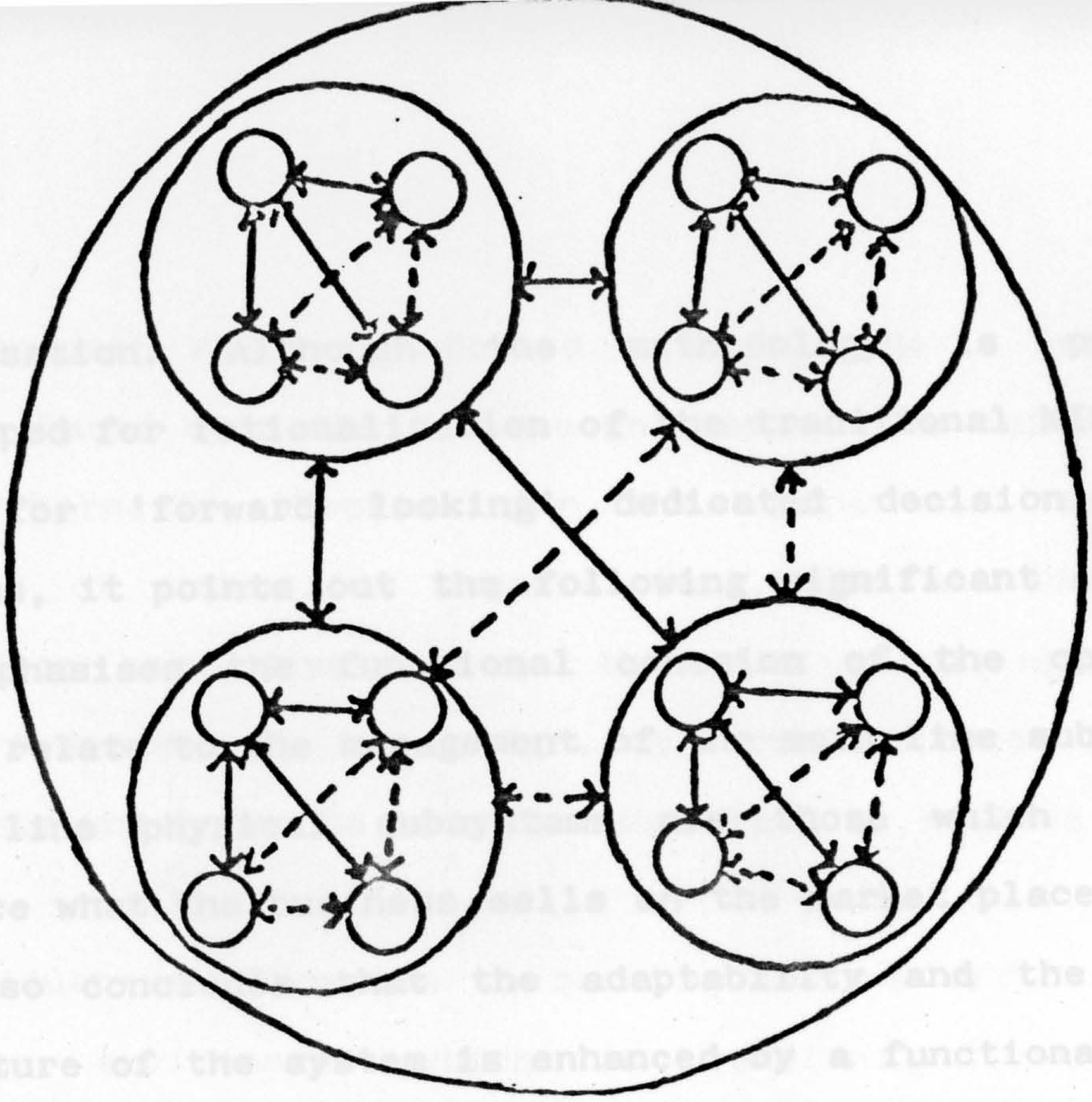


Figure 3.2 Functional Cohesion: Perception of Functional Elements (source:Baylin)

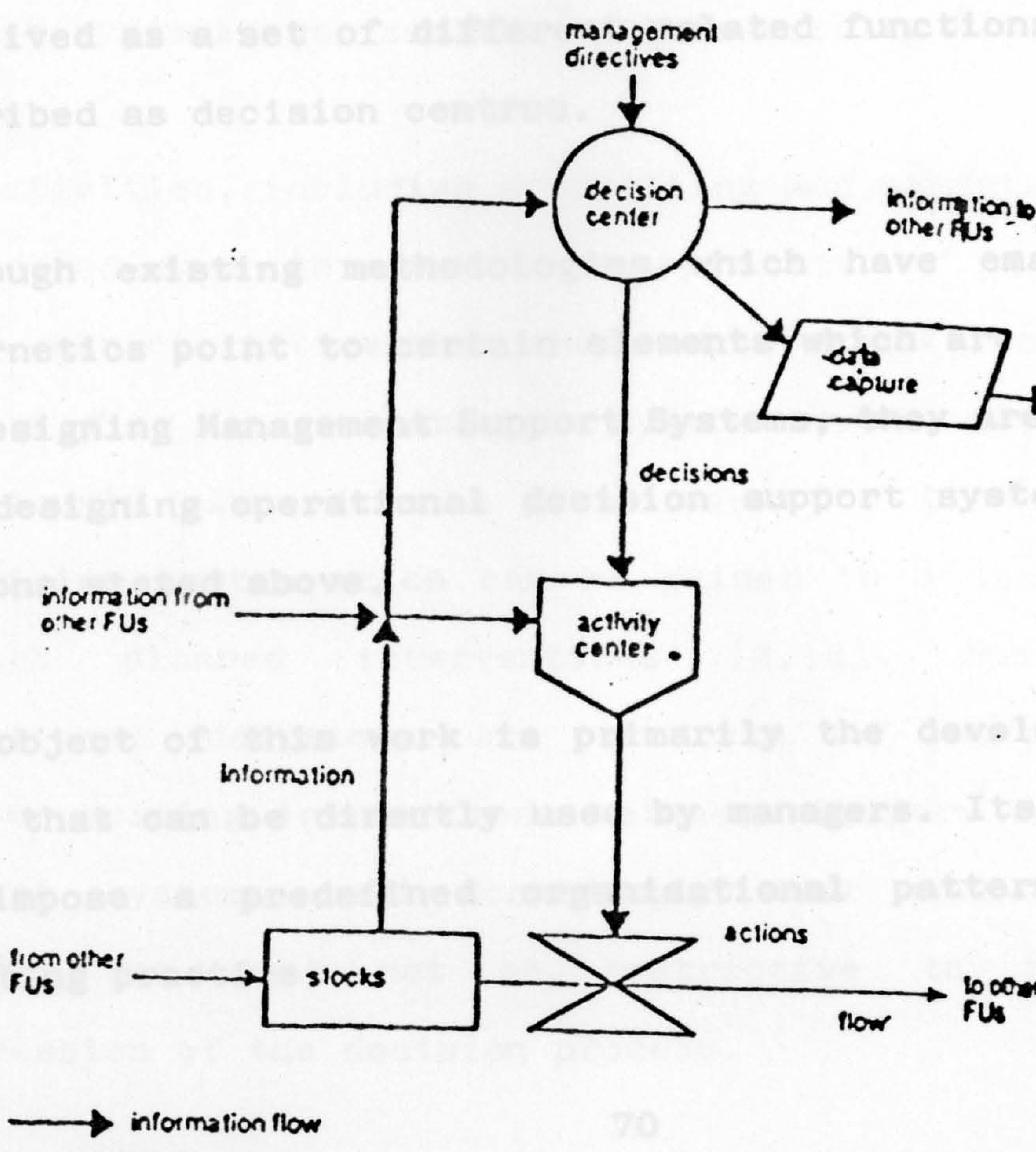



Figure 3.3 Functional Decision Unit of Bluhmental (source:Baylin)

organisation. Although the methodology is primarily developed for rationalisation of the traditional MIS rather than for 'forward looking' dedicated decision support systems, it points out the following significant concepts: It emphasises the functional cohesion of the operations which relate to the management of the main line subsystems. Main line physical subsystems are those which directly produce what the business sells on the market place [3.15]. He also concludes that the adaptability and the modular structure of the system is enhanced by a functional design approach [3.16]. Figures 3.2 and 3.3 illustrate the basic principles of his method, where the organisation is perceived as a set of different related functions which are described as decision centres.

Although existing methodologies which have emanated from Cybernetics point to certain elements which are significant in designing Management Support Systems, they are inadequate for designing operational decision support systems for the reasons stated above.

The object of this work is primarily the development of a tool that can be directly used by managers. Its aim is not to impose a predefined organisational pattern upon the existing practice.

The approach which is adopted in this work is unorthodox, and is based upon the the recognition of the importance of the Cybernetic theories for the operational management process of industrial organisations. The methodology has therefore been developed so that the resulting decision support system, by its design, conforms to these principal concepts which can be briefly summarised as follows:

Any industrial firm has to survive and be efficient in a complex environment which is constantly changing in unforeseeable ways. It therefore is in a constant process of adaptation and any managerial tools including decision support systems must conform to this reality [3.17].

Any activities, including controlling and managing the firm, considered from this evolutionary point of view, display other characteristics than those which start from the basis that a firm is a rational system which can always be consciously planned in a given way. The firm is a self-organising system which can be guided to a limited extent through planned interventions [3.18]. Most of the operational decisions are products of autonomous and self-organising interactions between managers and decision support systems, and accordingly must conform to this reality and must not be restrictive to the natural progression of the decision process.

The implications and the details of these cybernetic concepts, and the details of how to apply these concepts are investigated in forthcoming sections. In each section, a different aspect of the problem is addressed : How to design a decision support system as a co-ordinating infrastructure; how to design it as an analysis and decision support tool; and how it should be structured so that it does not become redundant and does not require replacement or substantial modification.

## 3.2 Coordination of Decision Making in the Business Organisation.

The business organisation cannot be described, any longer, as a rigid and hierarchical system, where managerial responsibilities are strictly separated and delegated to different managers. In order to survive in increasingly complex and dynamic business environments, a business organisation needs to have certain qualities and capabilities which will enable it to respond and to adapt to the fast changing environment. Traditional conceptions about the organisation and how to delegate decision-making work in the organisation need to change. The business organisation will be sucessful only if each manager is successful in managing his own area of responsibility. This conception is increasingly inadequate, because the business operations are in fact interrelated and require close interaction between managers.

Ashby, states that the properties of the whole are different from the properties of the parts [3.2]. What must be accepted by management scientists is that by proper interaction between managers and by proper co-ordination of the decision processes, the capacity of the organisation in meeting environmental requirements can be increased without necessarily increasing its resources. That is compatible with the Aristotle's famous argument: 'the whole is more than the sum of its parts'. One of the main attributes of the three criteria for viable systems is defined by Beer (1967) as internal connectivity [3.8]. Due to its internal connectivity the system can achieve a larger repertoire of behaviour.

The performance and effectiveness of the business organisation can be improved by increasing the scope for interaction between managers who are directly responsible for at least one aspect of the mainstream business activity. In some industries, for instance in the oil industry, processing, transportation and marketing operations are interdependent and the majority of the decisions about one operation are in fact influenced by the state of events in other operations. According to the methodology proposed by Wild (1983), this is an essential requirement for operational decision systems.

" The operations manager's responsibility within the broad business context must include the recognition of the fact that decisions in other functions will limit his own decisions. " [3.19]

Decisions in one regional division are influenced by the state of events in other divisions. Proper co-ordination of the decision-making activities throughout the organisation and provision of an infrastructure for enhancing the interaction between operational managers and managers of different regional divisions will improve the managerial effectiveness of the business organisation and will result in more effective utilisation of company resources.

The decision support system can be designed such that the utilisation of this system by managers implicitly results in proper co-ordination of the decision process within the business organisation.

Before a decision is arrived at, a certain amount of interaction between managers does occur anyway. The degree of the interaction depends on how closely the distinct business operations are interrelated. In order to find out the state of events in other operational divisions, or in other regional divisions, managers have to communicate with other managers. Communication is achieved by direct conversation or through the circulation of formal internal reports. However, direct conversation is an extra effort on behalf of the manager and when he or she is subject to time pressure, the frequency, and accordingly the accuracy, of the communication may suffer. This kind of communication being non-formal does not guarantee the acquisition of the best available information.

On the other hand, preparation of status reports take time and naturally there is a time delay associated with the acquisition of information through such formal reports.

If the time delay is too large compared with the managerial response time, then obviously, such reports are no longer effective as a means of co-ordinating the decision processes in the business organisation.

If the manager of a specific business operation is continually provided with information about other business operations which contribute to the mainstream business activity, then during the course of evaluating the decision environment, he will implicitly consider the state of events in other operations and accordingly the decision will implicitly account for what is happening in other parts of the business organisation. Therefore, his decision shall conform as much as possible to the requirements of the other parts of the business organisation as well as his own area of responsibility.

The decision support system can be designed so that it provides this facility. It does not have to be a substitute for the conventional communication practices but, being automatically supplied with information about the other related operations or other parts of the company, co-ordination of the decision process becomes natural to the flow of the decision process. The manager can still communicate directly with the other managers, but if the communication fails for some reason or the other he will still have the information. The reasons for the failure in communicating with other managers in order to acquire his information needs are numerous and some are considered below:

Being under time pressure,the manager may not have enough time to initiate the communication. Other managers with whom he wants to communicate may not be available within the critical time period during which he is obliged to make the decision. Information may not be available or organised according to his needs and because of internal competition, or personal power struggle, he may be supplied with biased information. What is important is that the incorporation of this function to the decision support system which is available to all operational managers, will result in communication during the decision-making activity being a natural phenomenon without necessitating any managerial effort.

The design of the decision support system as a network which co-ordinates the decision process is not a simple problem and to be effective it needs to conform to certain Cybernetic theories.

Operational decision-making is in fact responsible for managing established business operations. The scope of the decisions is not of a strategic nature. Essentially the primary function of operational decision-making is to regulate business operations and to account for unexpected problems which may disturb the flow of the operations. Unlike the strategic decisions which are made at board level, it is not to direct the organisation, which includes the formulation of the long-term goals, which traditionally require a centralised system. Because of this, operational decision-making should be designed and should function as an autonomous system.

In this context autonomy refers to the absence of a rigid and hierarchical system through which its operations are centrally controlled and co-ordinated. Categorically it is defined by Malik et al (1982) as follows:

" We shall proceed from the contention that there are basically two different methods by which human action can be co-ordinated toward a common goal. The first variant consists fundementally in co-ordination through command and instruction in the context of a polycentric system through reciprocal, anticipatory adaptation and modification of behaviour by the participating persons or groups or expressed more generally, by the elements of the system " [3.18]

The classical example is the comparison of the hierarchical command structure with self-co-ordinating and self-organising structure of a football team where on the basis of the intention in both teams to win the game and possible basic strategy agreed in advance, individual players behave to a certain extent as autonomous decentralised decision makers [3.8].

Implementation of this concept for tasks that involve co-ordination and regulation is now increasing and there now exist successful and tested examples.

The effectiveness of the company in responding to the market requirements is increased by designing the system so that the business operations are regulated by autonomous interactions of the decision makers with the purpose of fulfilling marketing requirements. Marketing therefore pulls the other functions together which are interrelated with feedback loops to each other throughout the company. This approach has emanated from the 'Just-in-time' manufacturing philosophy, where traditional methods based on substantial centralised planning are replaced by a new methodology, where centralised planning is minimised and manufacturing is performed only when it is needed. This philosophy makes the manufacturing company more responsive to marketing requirements and reduces manufacturing lead times and therefore enables the company to be less dependent on forecasts [3.12]. Figure 3.4 represents the principles of the methodology. Grossman (1987) indicates the increasing move towards the implementation of autonomous control systems throughout industry:

" In conclusion, the distribution of responsibility to form self-contained semi-autonomous manufacturing mini factories is the key in accomplishing the migration from the traditional western approach of centralised control to a more localised and distributed control system which will naturally adjust to real time events and demand fluctuations. " [3.20]

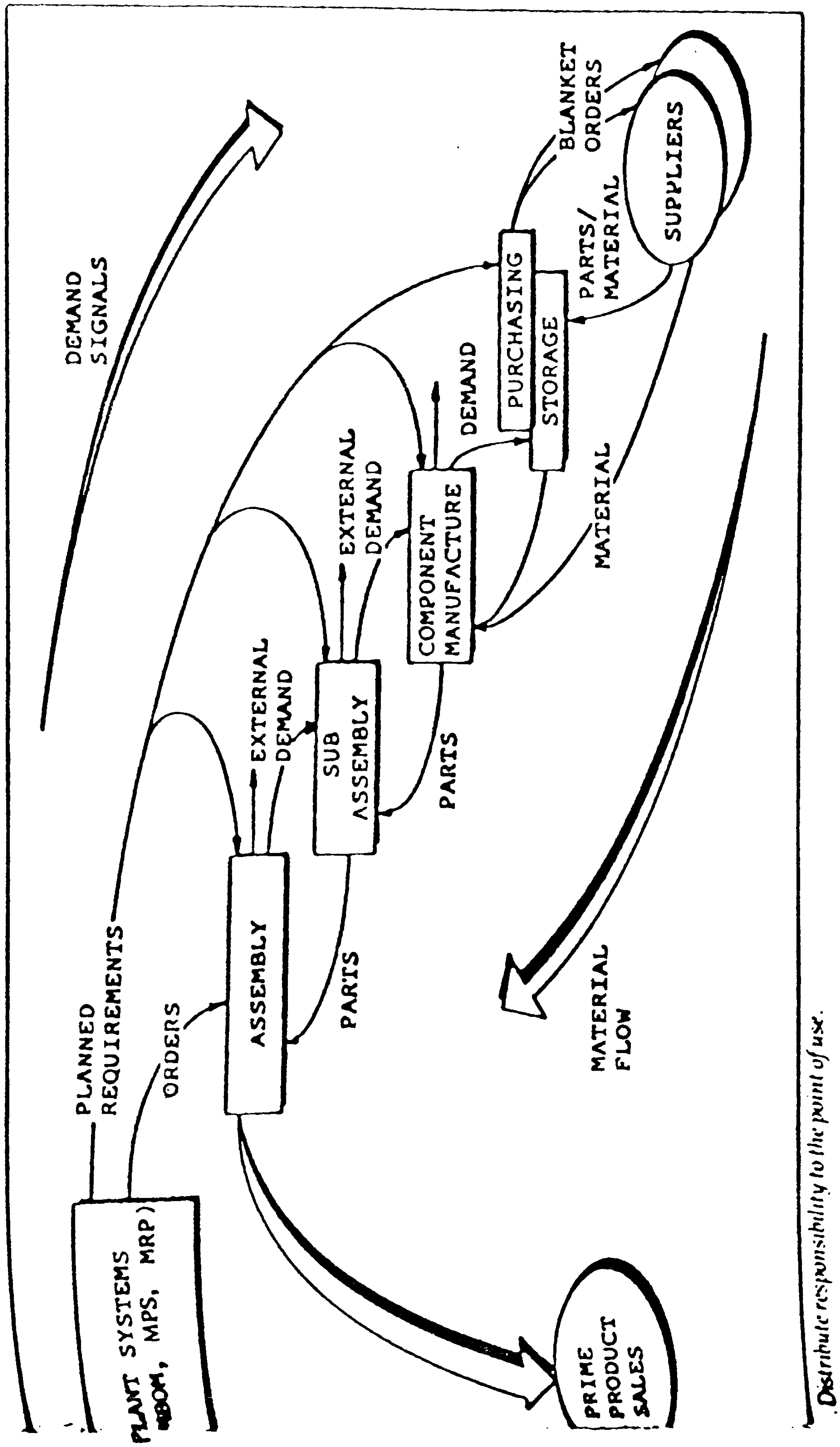
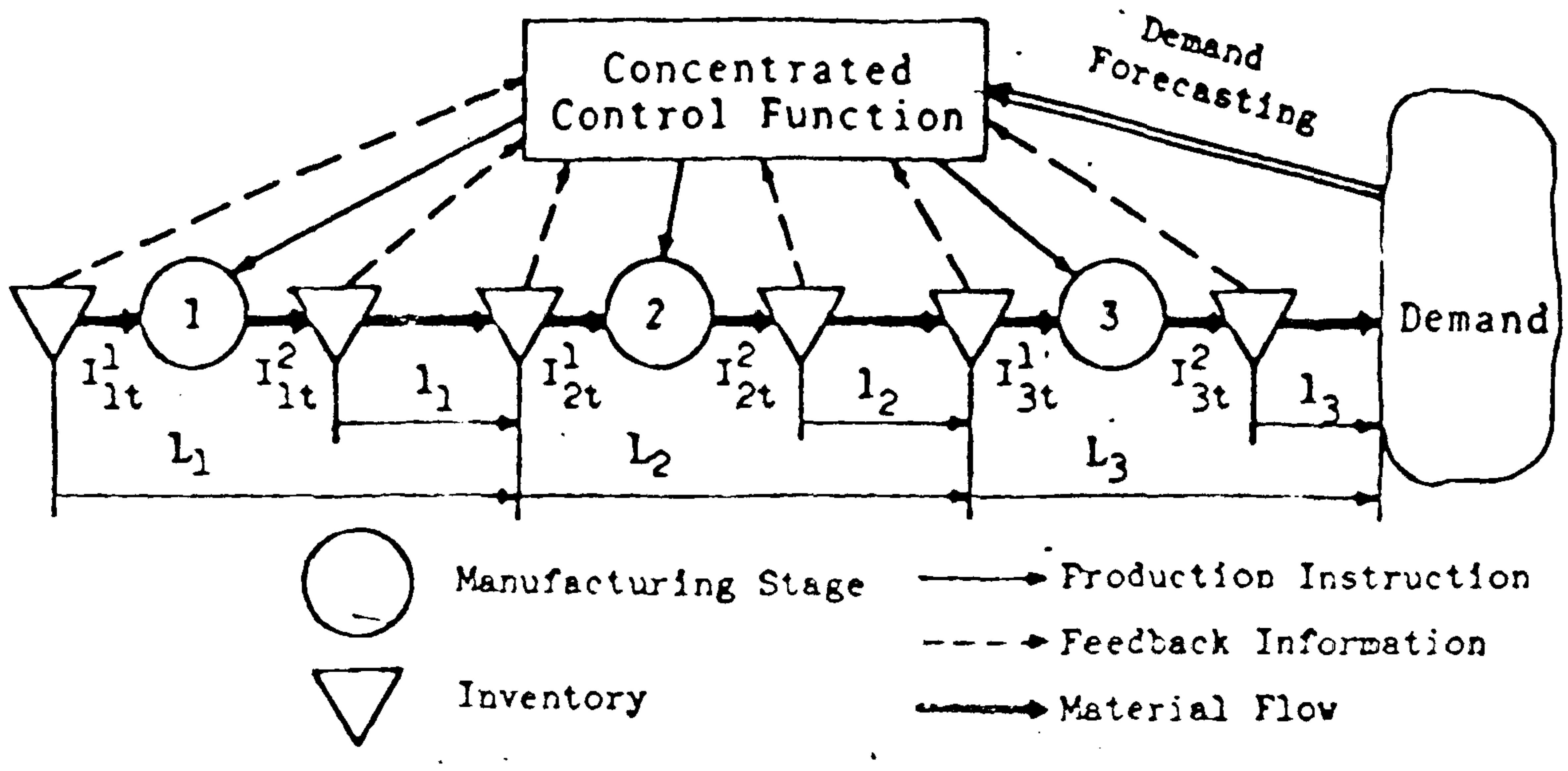



**Figure 3.4 Illustration of Just-In-Time Philosophy (source:Grossman)**

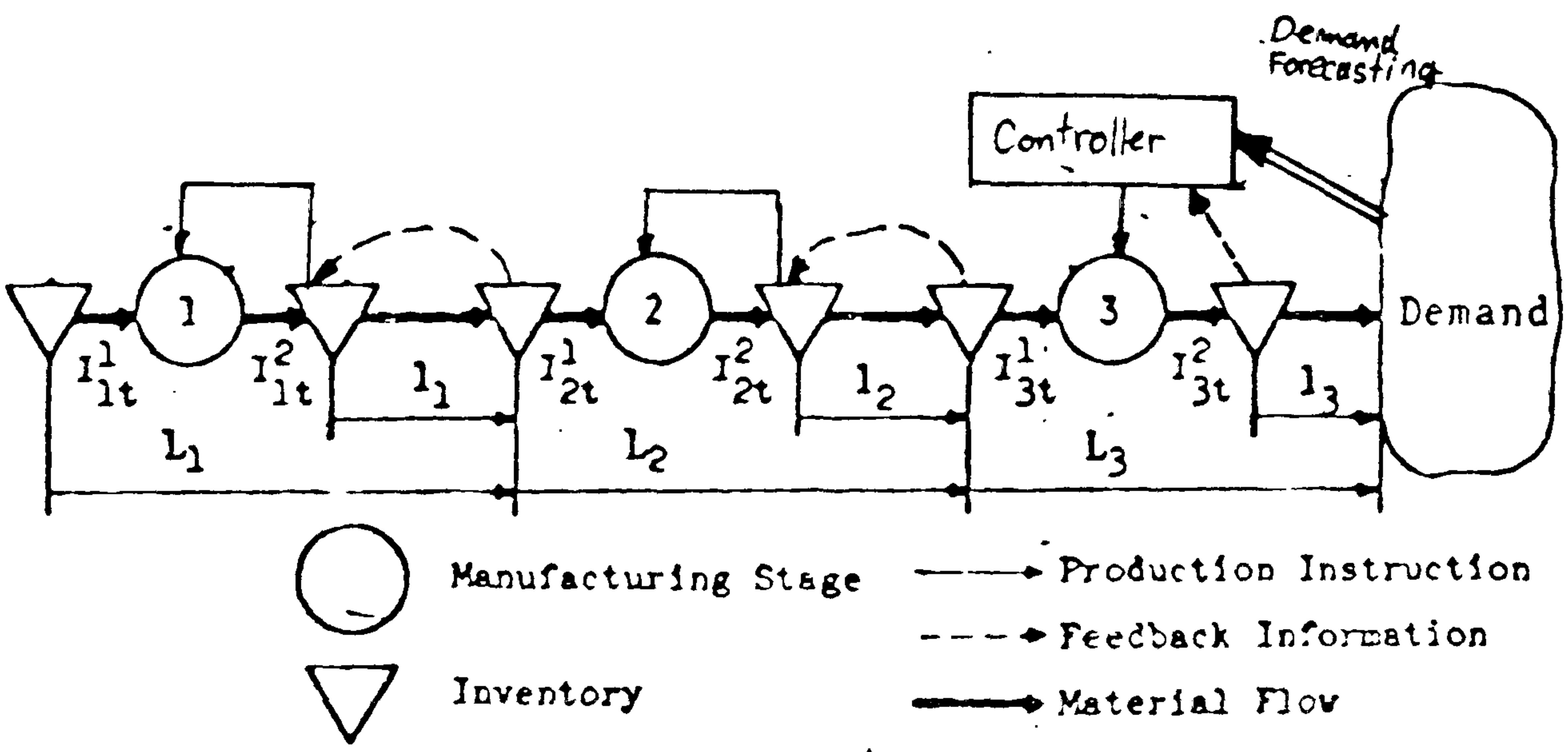
A very sucessful example of using decentralised distributed self-organising control in industry has been developed in Toyota Motor Co., in Japan which is named as the 'Toyota Kanban System'. Comparison of the this system with the traditional production management system is illustrated in Figure 3.5 [3.21].

Within an operational decision environment an autonomous decision process, to be able to function properly, necessitates the presence of certain properties.

The elements of the system should be able to interact with each other without any restrictions. Internal connectivity or a richness of connections are a prerequisite for the emergence of the Autonomy [3.2],[3.8]. Therefore, the system analysis approach, where the connections between the elements of the system are estimated and provided by an observer who is external to the system, is not valid because static information communication patterns would violate this property. Propagation of the information to other decision makers should be natural to the decision process. That is, once the decision resulting in a change is made it should be automatically transmitted by the decision support system without necessitating any effort by the decision makers. By this method the interaction between decision makers will be implicitly increased.




i- Traditional Production Management System




ii- Self organising 'Kanban' Production Management System

**Figure 3.5 Comparaison of 'Kanban' with traditional**

**Production Management Systems (source:Tamura)**

Autonomy necessitates the presence of relationships between the elements or the subsystems of the system such that the function of the subsystems or the elements compensate so that the overall performance of the system remains unchanged. In Cybernetics this property is addressed as equilibrium in part and in whole. Ashby describes this property as follows:

" The Whole is at a state of equilibrium if and only if each part is at a state of equilibrium in the conditions provided by the other part. "[3.2].

In biological systems, homeostasis functions on these principles. Certain subsystems or elements of the total decision-making system therefore need to be grouped and communicated so that this property is not violated. For instance if there is scope for common utilisation of resources, the decision support sytem should provide facilities for automatic communication of similar operations at various regional divisions.

Variety analysis of the system is essential prior to the the design of any information system. Such analysis will point out the existing potential deficiencies within the management system. Such analysis is also successfully implemented in the Deere's company in U.S. where after a decade of experience of industrial management with computer systems, the company has rationalised the entire management and control system. Vice president Lardner explains the following:

" The inherent complexity of the whole operation resulted in a situation in which the computer systems used to control factory operations were unable to deal effectively with the random production interruptions common in manufacturing. In a big horizontally integrated company with 12,000 people doing 30,000 parts and God knows how many operations the diversity and the complexity of the operation threatens to overwhelm and breakdown human management systems. Given the history of manufacturing industries that we embraced computers and computer systems, there is substantial anecdotal evidence that we computerised utter confusion and inefficiency. " [3.22]

The solution that had been adopted by the Deere Company is simply to reduce the variety that is handled by operational management through the modularisation of the production process. Lardner justifies the solution as follows:

" If you go far enough you can reduce your complexity enormously. In a factory of 5000 machines, if I create cells averaging five machines each, I've only got to manage 1000 places and if I can put two of these in a unit I'm managing 500. I have eliminated a complex central control system. " [3.22]

Any system which is designed as a management tool must therefore be analysed with the purpose of evaluating the complexity of the system. The system should inherently reduce the complexity existing in the operational environment. This can be achieved by providing continually operating feedback loops between the modular operational decision centres.

Each operation contributing to the mainstream business operation may necessitate a number of decision makers where the decision-making work is apportioned between them.

It is only natural that some managers will have more responsibilites. Although availability of such a decision support system increases the scope for autonomy, it needs to be provided with unrestrictive regulatory mechanisms which are suitable for autonomous behaviour. It is inevitable that some subdivisions will be in competition with some other subdivisions especially when they contribute to the same main function. Therefore the activities of such subdivisions need to be regulated by higher level management.

Beer states that in viable organisations, for each system there exists a metasystem which is responsible for controlling its operations [3.17]. For instance, crude oil supply operations includes management of the owned fleet, time and spot chartered fleets, and external chartering operations. Although different functions such as production marketing and transportation should at the same level behave as an autonomous system, if subdivisions of the transport function are not properly regulated, the decisions taken by the managers of these subdivisions may contribute less to the overall effectiveness of the company as a whole than to the performance of their own subdivision.

In practice such regulation is executed at the level of crude transport management, where according to the market situation an operating plan is issued to the subdivisions indicating the reference for practice. The traditional practice is to base the plan primarily according to the status of the owned and the time chartered fleets and to use spot chartering and external chartering as positive or negative buffers.

Such plans naturally are not always in phase with the market conditions and accordingly do not always result in optimal combinations. They also provide managers of the specific subdivision with freedom to pursue their own goals. Implementation of stringent controls delegating resonsibilities to the transport manager eventually results in loss of contact between the decision maker and the environment which is symptomatic of overcentralisation.

A proper control function must be provided by introducing feedback loops between the controlling level and the competing subdivisions, where the information communicated to the upper level can be co-ordinated to maximise the benefits for that level. Subsequently operational boundary conditions, which result from the higher level management, can be communicated back to the subdivisions. Boundary conditions must be provided by the manager responsible for the higher level. Therefore managers of the subdivisions are provided with information about the limits which they should not exceed since that would not be profitable for the higher level division. Within these limits they will have the freedom and therefore the interest and the eagerness to apply good management practice

The design of such a decision support system, covering the issues which are stated above, necessitates a specific methodology. The development of such a methodology is a Cybernetic problem itself. How effective is the MIS which is generally based on a software specification prepared by the data processing department involving internal or external consultants communicating with managers? Such an approach, which is suitable for systems analysis applications where the object is to automate a manual information system, is fundementally inadequate for designing decision support systems. Managers should have the responsibility of defining their own information needs.

The following principles which have emanated from the concepts which are covered in this section are as follows:

The systems designer needs to abstract a set of operations for which the decision support system will be designed. These refer to the identification of the operations fundamentally contributing to the mainstream business activity.

The operational support system must be provided only to the managers who are responsible for these activities. There is no point in trying to co-ordinate all business activities without assessing their relative importance. Unlike traditional MIS projects, the information which will be processed in the system will not be used for purposes other than co-ordinating the decision process and providing decision support function for the decision makers. The size of the support system must therefore be checked and the available capacity must be allocated to the operations which directly contribute to the mainstream business operation. In terms of system science and control theory this is in fact analoguous to identifying the state variables which are the smallest set of variables which can be used in describing the behaviour of the system [3.23].

If the mainstream business operation in fact consists of a number of distinct operations, decision process for each operation should be treated as distinct systems. Should there be interactions between the operations, distinct decision support systems must be co-ordinated as appropriate. For instance, similar operations are performed in various regional establishments. Instead of treating operations of all regional divisions as one system, each regional division should be treated as a subsystem. Once the decision support systems are developed independently for each division, they can then be co-ordinated according to the pattern of the interactions between the business operations of each division.

Once the set of activities contributing to the mainstream business organisation and managers responsible for these activities are identified, then the interaction patterns between managers during the course of managing the operation must be established. Unlike the development of traditional MIS projects, this exercise cannot be delegated to systems analysts who are the observers for the system. The complexity of the system and the richness of the interactions will beat the observer [3.2]. Instead, letting operational managers define typical situations necessitating a decision with the information required to evaluate the decision environment, therefore the pattern of interaction with other managers, will result in an abstract schematic of the dynamic relationships between managers which occurs during the course of the decision process. The resulting schematic may indicate that an activity which has been judged to be negligible is in fact important or otherwise.

The design of the decision support system should be based on the careful analysis of the resulting abstract schematic.

It is essential that the details of how variety is actually reduced during the course of managing the operation should be emphasised and provisions in the decision support systems should be made according to the actual life situation.

Advances in information technology are now providing management with increased communication, data processing and computation capacity. Widespread use of mini and micro sized computers in business applications, is changing perceptions about information systems and other managerial decision aids. Microprocessors do provide the general hardware for a decentralised decision support system.

Managerial processes are fluid and subject to frequent changes. Continual adaptation of these large systems in line with changing managerial requirements necessitates significant manpower and development costs. Avaliability of information systems as a potential source of accurate and timely information has also influenced the dynamics of the corporate decision-making process, which has became progressively more centralised. Literature survey indicates an extensive range of symptoms, which refers to ineffective or ill-utilisation of these tools. Instead of being productive ,such utilisation for decision support function can easily become time consuming with no significant benefit to parent business organisation.

## 3.3 Interaction of Man and the Machine in Co-operative Problem Solving.

As is previously indicated in Chapter Two, the slow progress of OR/MS methods being accepted by line managers as a decision support tool is blamed on the fact that whilst too much emphasis is given to the technology of how to solve a problem through these methods, very little or no emphasis is given to organisational and psychological considerations. The important point which seems to be significantly missed by the OR/MS and MIS practitioners can be summarised as follows: The aim of management support systems is to augment the manager's decision-making capacity.

The primary functions which are required from a decision support system must be recognised as the real-time control of the decision process system in the firm, and the augmentation of the manager's decision making capacity. These functions are different. The control and co-ordination of the decision process is achieved through information exchange and communication between various parts of the system. Augmentation of any decision-making capacity addresses the interaction of the manager with the system.

The augmentation quotient of human intelligence is defined by Dohety et al, (1987) as follows:

" We propose the metric AQ, or augmentation quotient, as an estimate of the actual knowledge work accomplished by a person with a given intelligence in a given time period, when aided by a computer, divided by the knowledge work accomplished in the same time period by the person alone. " [3.24]

In the same paper, Dohety et al, indicate that the use of computers as a tool to augment the memory and reasoning capacities of staff members, has increased the quality and the quantity of the individual researcher's work by factors of 2 to 6 during the past during the past twelve years.

Although such an approach provides a wider reference than the traditional OR/MS approach, which is only concerned with developing the technology in solving specific problems, it is still inadequate in evaluating how much a support system contributes to the decision process.

Malik et al (1982) point out the fact that the use of such systems may be restrictive and counterproductive, if they are designed according to such criteria.

" In the ability to act in the light of the situations and yet guided by general behaviour rules, lies the real adaptability of the firm, and extensive use of certain methods, which in themselves may appear completely rational and logical may destroy precisely this adaptability." [3.18]

In order to be successful, the design of the decision support system must be based on a generalised framework which includes all the components which are necessary for the effective coupling and functioning of the man and machine system as a unit.

In their attempt to develop a conceptual framework for designing an effective model-based decision support system for financial control, Srinivasan et al point out the importance of this point:

" Academic research, however, has primarily focused on providing analytical tools to solve well structured problems that are relatively isolated in nature. Conspicuously, no attempt has been made to integrate the various sub-problems of cash management explicitly recognising interrelationships between sub-problems and other financial decisions. More importantly there is an even greater need to provide a framework that in addition to recognizing the above interrelationships will enable the cash manager to recognise a more inclusive set of dependencies that exist in practice." [3.28]

However the literature survey has failed to identify an inclusive taxonomy of such components.

In their paper, where the progress on man-machine interface is reviewed, Palmer et al [1.16] conclude that existing work focus on certain specific aspects of the problem and substantial work is needed in order to provide a conceptual framework.

Minch and Burns (1985) have recognised the importance of the man-model co-operation in problem solving and they have developed a conceptual framework for the design of the Decision Support Systems utilising Management Science models [2.25]. However as can be observed from Figure 3.6 this approach only addresses to the effective communication of the user with the model which constitues just one aspect of the problem.

Similarly, in their work, as can be observed from Figure 3.6 Seagle et al (1986) concentrate on the concepts of communication with such systems [3.26].

The work developed by Ghiaseddin (1986) concentrates on the technical development of the support systems which are dedicated to managerial problems having the following characteristics:

" 1 the problem is continually changing, 2 the answers are needed quickly, 3 data are continuously changing from a variety of sources, 4 data must be processed into different kinds of data representations, 5 computer support is more concerned with rapid implementations rather than long term efficiency. " [3.25]

Although the work is within the boundaries of the problem, it represents a typical traditional system application approach and concentrates on the technicalities such as prototyping, development language, systems analysis and design etc.

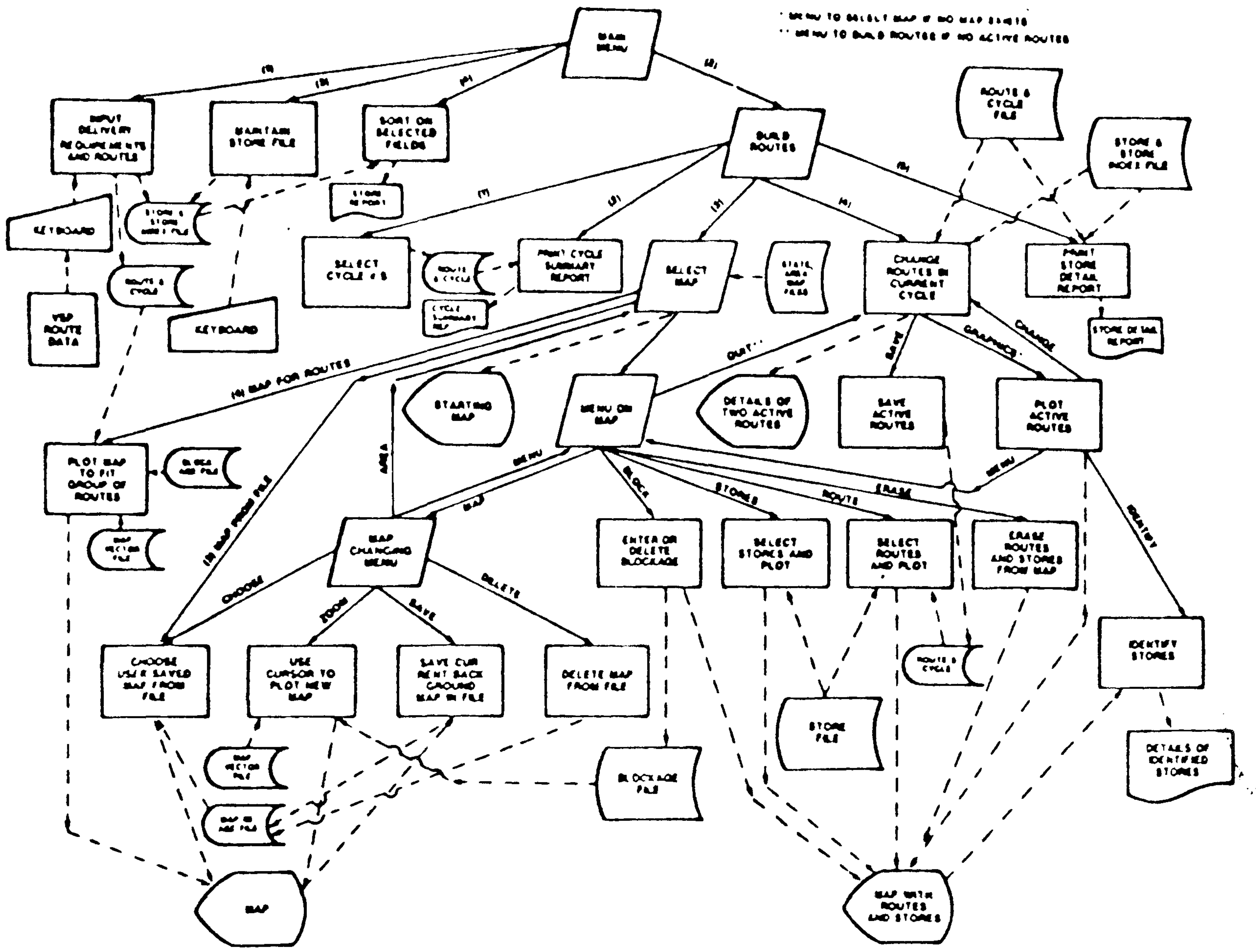


Figure 3.6 Feature Chart: A tool for analysis of Decision Support Systems (source:Seagle)

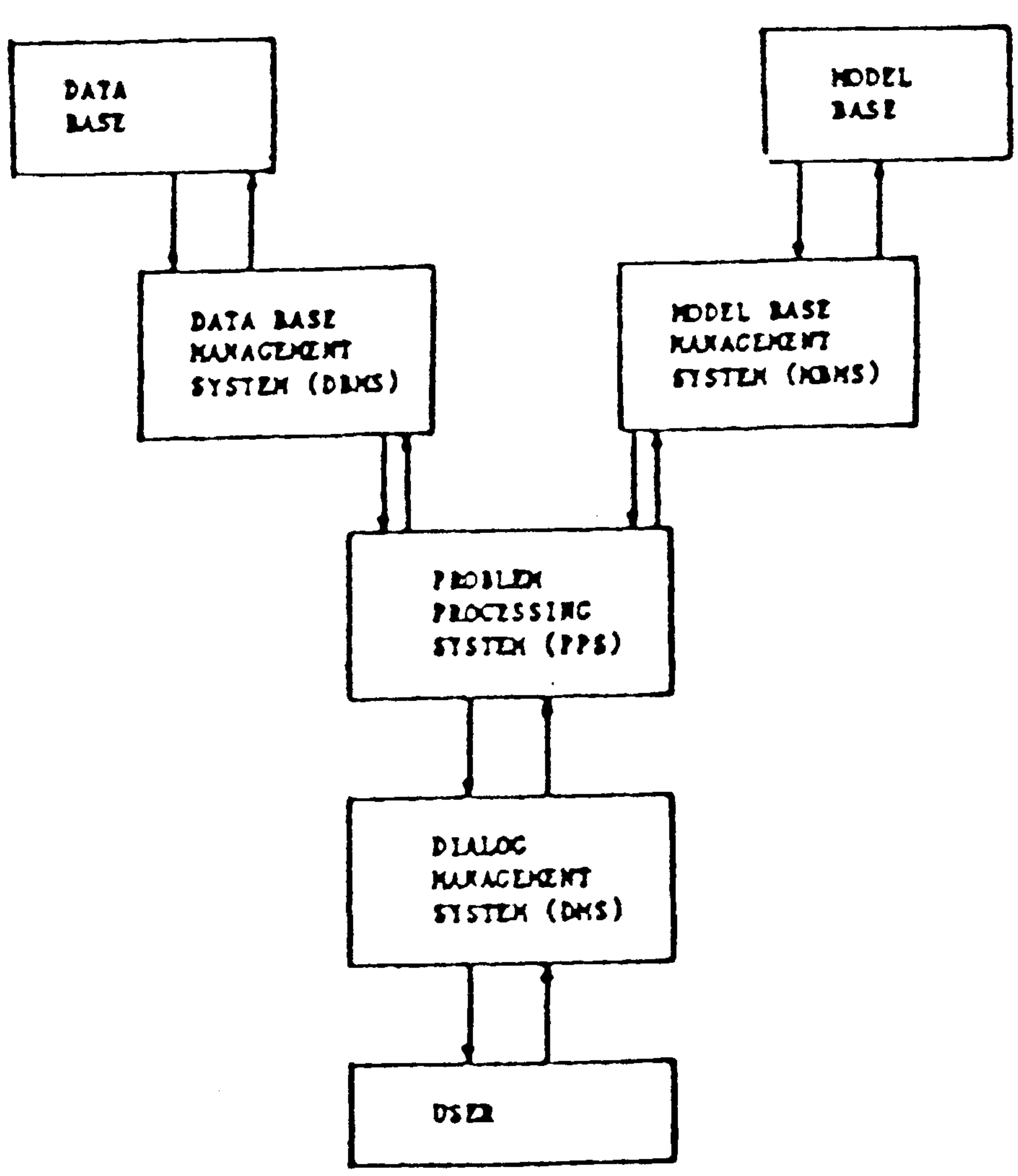



Figure 3.7 Conceptual design of Decision Support Systems utilising Management Science models (source:Minch)

The literature survey indicates that the progress of the existing trend in the design of Decision Support systems is increasingly specialising within a particular area: technical model development for facilitating user interactions.

This is not a rigorous critisism of the existing attempts to develop a conceptual framework for support systems for co-operative man/machine problem solving and is only referred to here with the aim of indicating that they address different aspects of the problem without being based on a general framework.

The cause of this may be blamed on the fact that the components of the problem of how to design interactive man/machine decision-making systems can not be addressed by a single discipline but require an interdisciplinary approach. Although Cybernetics does not provide a comprehensive set of theories which can be used to build a conceptual framework, being an interdisciplinary method, it does emphasise certain important points which seem to be missed by traditional scientists.

A proposed taxonomy of the major components which contribute to this problem is described as follows:

1 Identification of the decision maker's significant needs,

2 Allocation of the decision-making work between the decision maker and the system,

3 Provision of the support function within the critical time period as required by the operational environment,

4 Direct system accessibility by the decision maker,

5 Recognition and positive utilisation of the secondary effects.

This taxonomy may not be inclusive, but it provides the outline guidelines which need to be considered in designing man/machine problem-solving systems. Existing work only constitues a specific portion of this taxonomy. Since each component is judged to be essential, a balanced approach is essential for the effectiveness and the success of the man/machine problem-solving system.

Detailed consideration of each component is as follows :

In order to be accepted and effectively used, any artifact must meet the specific requirements of the user. It must be natural to the user to use the artifact as a tool during the process of carrying out a task. This is a most important property which applies to the design of any product and is difficult to achieve.

The design of computer systems for repetitive lower order information processing tasks is relatively easier and can be achieved by software specification because the aim of the lower order information processing tasks can be clearly defined.

However, it must be recognised that a support system for higher order information processing tasks which are more likely to be used by managers cannot be achieved by using the same methods and techniques.

Parker et al (1987) note the following,

" Many decision support systems can come from managers themselves. They must be based upon the needs and styles of problem that occurs not the tools and perspectives of problem solvers. Some people see the inability of MS/OR and MIS to achieve their full potential and provide the services required of them on certain areas." [1.15]

Only a manager himself can describe what he needs in carrying out a problem-solving or decision-making task by drawing upon his own experience. He must be personally responsible for the development of any such tool which will be used by himself.

However such tasks having a large variety and being dynamic, make, it very difficult to define what is needed at a specific point in time.

Carter points out this fact:

" With information of this nature the interviewer depends on the memories of the managers which are not reliable and they could put excessive weighting on certain information needs because of ease of recall of the information completely. " [2.6]

On the other hand managers often encounter unforeseen conditions where they do not know what they need. Therefore, it is essential that a system must be easily modifiable so that the needs of the manager are easily implemented.

The Nevell-Simon Information Processing System (IPS) provides a conceptual framework for identifying specific decision support needs of the managers. It is a research methodology for inquiring into the entire decision process on a stage-by-stage basis. A brief description of the method is provided by Barron, as follows

" First, take verbal protocols from subjects (decision makers) while they are making decisions (or, in general, involved in a particular decision subprocess, such as problem finding or structuring). Construct an IPS model of each situation. The model specifies the information inputs, memories from storing information, the elementary information process for operating on the information, and the programs which sequence the process. The model simulates the subject's cognitive processes. Next, determine the adeguacy of the model and possible generalities across the subjects " [3.43]

The second important component of the taxonomy addresses to what extent the decision-making work can gainfully and reliably be delegated to the support system. It covers the essential issue of apportioning the decision-making work between managers and the system.

" The Theory of Ternality " as proposed by Stewart, 1982, although it is new and subject to debate, provides an interesting concept, in differentiating the decision-making work which can be allocated between the decision maker and the support system.

The basic principles of this theory are described by Stewart as follows:

" A primary domain, which is that of matter and energy in motion, a secondary domain, which is that of differentiae or distinctions in motion; and a third domain, which is that of imparities in motion. What we normally call descriptive information will fall into the secondary domain, whereas evaluative information, some aspects of goal-setting and various other cybernetically interesting things will fall into the tertiary domain. " [3.27]

Information processing can be successfully delegated to machines since they are much faster and more accurate than the human mind. If independent problems can be rationally translated to a common base, then the scope and the justification of delegating the work to machines is justified. But any discontinuity in translation necessitates an input from the manager who has the capacity of evaluating situations which cannot be translated to a common base and therefore are not directly comparable. For instance, architectural design of buildings involves many components such as cost, aesthetics, and functionality which are difficult to translate to a comparable base. In managerial situations the evaluation of problems of that nature should be left to the managers.

In operational management situations most of the decisions can be translated to a comparable base. The difficulty involved is essentially the complexity of the relationships. Especially when a change in one particular part is delegated to another part of the organisation whereby the necessity for evaluating the implications of the changes in other parts increases. A rational evaluation method is needed since very large amounts of variety will be generated. Coordination of the business operations enables operational managers to account for the opportunity cost, which is especially important when there is scope in the organisation for common utilisation of the resources.

However, evaluative decision-making work, including for instance preparation of the operational strategy, should not be delegated to the machine system.

Attempts to delegate the decision-making work involving values processing or comparison of different dimensions is viable. On the other hand, leaving managers with information processing work which can be succesfully achieved by machines will prevent them from concentrating on decision making work involving values processing or evaluation of different dimensions. The object of the system should not be just to maximise the amount of work which can be delegated to machines but specifically to increase the capacity of the decision makers in making the correct decisions. As previously emphasised, this point is very important since it may not be fully compatible with the computer or system analysis culture, where applications generally involve automation of manual information processing tasks.

Decision making should only be delegated to the machines for lower order information processing tasks, where there are direct relationships between elements. However, purchase of a significant capital investment item being closely related with the survival strategies and tactics of the company and also affected by counter-activities generated by competitors, should not be delegated to the system. What is a useful compromise is to use the system as an analysis aid in order to clarify the problem and understand at least relative magnitudes but leave the decision to the managers.

Even in engineering where the decision environment is not necessarily competitive and the decision criteria are often restricted to the selection of technically feasible solutions with minimum cost, computers are used for analysis and the design decisions are always made by project engineers.

Most of the existing work is within the subject area of the the third and the fourth component of the proposed taxonomy. The capacity of the manager in making correct decisions can be significantly improved by providing him with more accurate and timely information and analysis aids which will help him to assess the decision environment. Improving the quality of the information provided to the manager will naturally improve the quality of his decisions. Analysis aids are successfully used by strategic decision makers because there is generally available time for carrying out the analysis. Such techinques are delegated to the specialist staff. Therefore, although many mathematical modelling techniques such as operation research or system simulation can be successfully used in strategic planning, their application is not suitable for operational decision support because, being too sophisticated, they can only be used by specialists and they necessitate long evaluation times. Kitchener et al (1986) indicate the following:

" OR had some big successes during the 1950's in the fields of production and distribution, but it failed where large business models were concerned because it took too long to develop. " [3.30]

As Beer points out, most management problems can be solved with relatively simple models with a sacrifice of accuracy. [3.8] The law of diminishing returns also applies in using mathematical modelling techniques as decision aids. Eighty per cent of the benefit should be gained by twenty percent of the effort. To what extent is it justifiable to implement the sophisticated models which necessitate a large input of manhours but at the same time result in smaller gains in accuracy? Furthermore, successfull utilisation of such large and sophisticated models is simply impossible as an effective operational decision support tool because they necessitate long preparation times. By the time that the model is being run and evaluated the situation necessitating the analysis may not be any longer effective.

The following extract from computerised manufacturing, (1986), is very significant in indicating the recently accelerated move throughout industry in eliminating data processing specialists:

" When SSP Pumps installed a computer integrated manufacturing system it wanted to make sure that its departemental managers and their staff would see the new computers as their own responsibility. For this reason the company has tried to steer clear of computer specialists and a separate data processing department. " [3.29]

According to the production director of the firm, a data processing department tries to justify its own existence and further complicates problems.

Analysis support tools should be designed in such a way that they should be directly accessed, used, and even modified by managers. A large proportion of the operational management problems can be covered by such an approach. Design of the support system should incorporate a repertoire of the analysis support tools which are suitable for handling a large proportion of the operational management problems of the company.

Provision of facilities which will enable managers quickly and easily to set up input data and reorganise the information which is already available in the system is essential. In order to cope with situations where a significant operational management problem occurs frequently, such mathematical models can be set up so that they carry out the analysis automatically at suitable time intervals without necessitating any managerial effort. Such implementations can also be useful in problems associated with co-ordination throughout the organisation. Since the managers contributing to the operation will be provided with the system, and since the relevant information will be continually exchanged between managers through the system, mathematical models which run automatically at predetermined time intervals can be built into the system.

It is up to the managers to make the decisions. However this facility indicates important issues for overall profitability for the operation, rather than highlighting the interests of a specific subsystem. Therefore, it enables managers to differentiate the relative significance of certain operations and leads to better understanding of the co-ordination function.

Traditional OR/MS practitioners, being too much involved with specific technicalities of these methods, have totally failed to notice and develop the potential importance of such techniques as an indirect decision support tool which forms the last component of the proposed taxonomy.

Such models which are integrated within an information system can be used to check managers, subjectivity:

Co-ordination of the decision process will enhance the scope for interaction between managers. Operational managers, as with any other person, have a model of their environment which is unique and based on their subjective interpretation of their environment which may be biased. Interaction of the manager with other managers will improve his own interpretation, since he will have the opportunity of observing the response of other managers to similar problems.

Such systems can be used as a guide to the manager in evading the effects of the irrational decision process:

According to Beer, the brain functions under various moods. [3.5]. Under each mood the reference criteria used by the manager are different. If the outlook is optimistic, then managers seem to take more risky decisions. If the outlook for business seems pessimistic then managers avoid high risk situations. If the environment rapidly deteriorates, managers may operate under crisis mood where instead of rationally handling the problem they try to avoid the problem, or, irrationally, they try to eradicate themselves from the situation. In such situations rational decision-making processes might be replaced by irrational processes where the prime objective becomes to escape from the crisis. This is analogous to the animal behaviour manifests itself when there is a threat to the survival of the animal. Animals cope with such situations by generating unitary, that is well formed patterns of behaviour, which are already in its repertoire [3.44]. There is a potental scope in providing the decision support system with a facility enabling managers to use it where it is needed as a rationality bank.[3.45] That is, managers provide the system with analysis and evaluation criteria about the decision environment while they are not subject to any particular pressure, later when they are subject to pressure or operating under, for instance, a crisis environment, they can refer to the system and use it as a guide in evaluating the actual decision environment.

Especially, considering the rapid growth of communications technology, external information can be incorporated into the model enabling managers to anticipate environmental conditions: According to Johnson, the primary function of managers is to sense situations of growing novelty by making active efforts to increase the resolution of their view until they feel they know what is happening and what the appropriate response should be [3.31].

In certain situations a manager will not have enough time for adequate exploration of the meaning of the incoming data. Anticipation is therefore essential and the manager should be able to interact and experiment with the system so that he can grasp the decision environment. According to Beer, all systems exist in environments, which are in turn viable systems in other environments. Acquisition of the information about significant environments as well as internal information should be provided as an essential facility of the decision support system. Mathematical modelling techniques can be used to provide support for analysing the decision environment and to predict future situations. Models for predicting the environment should generally be based on past performance since, interactions being too complex, a model accounting for relationships resulting from a change in the environment would be too large and would necessitate large resources for its development.

Models simulating well-defined internal environments may be viable, since constraints and relationships are well defined and observable. However, should there be discontinuity in the observability that is, for instance, if the relationships contributing to a specific function are not clear, then for the sake of providing an integral model that function should not be included within the scope of the model and should be left to the judgement of the manager himself.

## 3.4 Business Organisation as an Evolving System in the Competitive Environment

Business organisation is subject to competition and in order to survive it has to conform to changing environmental conditions. Business operations and the decision environment affecting the operations are dynamic and therefore a decision support system should have certain properties which enable it to cope with change and also to enhance the evolution of the business organisation.

Typical MIS implementations are generally large, integral and centralised systems and therefore are not compatible with the decision support function. Often, by the time the system is commissioned it may already be completely or partially out of date. In some industries or situations, even where the rate of change is relatively slow, the system is eventually bound to be replaced and total replacement of the system is often practised because it is cheaper than modifying the existing system [3.27]. Changes are revolutionary rather than being evolutionary and introduce strain to the organisation and reduce its effectiveness. While the actual situation change, the requirements from the system also changes, and accordingly either the system becomes progressively redundant or its utilisation by managers introduces bias to the decision process. This is a common event in MIS applications.

Decision processes being more dynamic, decision support system applications necessitate the perception of the business organisation and the decision process in the business organisation as a dynamic system, subject to change.

This point is emphasised by Young:

" Organisation is not structural bureaucratic hierarchical and described by a fixed set of authority relationships but a set of flows of information, men, material, and behaviour. Time and change are the critical aspect. "[3.33]

Festenmaker, also emphasises the importance of change through defining business organisation:

" The firm is a dynamic system which undergoes a process of learning and adaptation. "[3.34]

Beer defines a property which is attributed to the long-term success of the organisation. He defines this property as viability which is the capacity to preserve an independent existence:

" A viable system survives and coheres and remains integral. It is homeostatically balanced both internally and externally and it has mechanisms and opportunities to grow, to learn and to adapt in order to become more potent in its environment. " [3.35]

Cybernetics indicates that the capacities to grow, to self organise, to learn and to adapt are the essential properties associated with the successfull evolution of any system whether biological or corporate, which has to survive in competitive environments whether ecological or economical.

The change of the business environment which necessitates the adaptation of the business organisation is fundamentally different from random variations and disturbances. All systems are designed to exist when subjected to a series of disturbances and variations. Internal regulatory mechanisms ensure that such disturbances are counteracted and do not affect the operation of the important functions which are essential to the survival of the system. Ashby attributes this property exclusively to regulation [3.36].

In biological systems for instance, temperature variations which are within certain limits are counteracted by autonomous physiological control mechanisms such as concentration of the blood to the inner parts of the animal's body. If the temperature variations exceed certain limits then the animal changes its behaviour, for instance, it searches for shelter. But if the changes exceed critical limits then the animal dies and if such changes are permanent, then by the ecological selection mechanism, the internal organisation of the off-spring evolves to meet the new conditions. Similar dynamics apply to corporations which have to exist within economic environments. At the end of the previous section it was concluded that a repertoire of the fixed control strategy which is prepared during the design stage by the system analysts or management consultants is not adequate since it is not possible to cover all cases during the design stage. It is only through autonomous interactions of the operational managers that such unforeseen changes can be counteracted [3.37].

However, the environment can generate gradually increasing changes, such as the emergence of a strong competitor, or abrupt but permanent changes, such as a technological discovery resulting in a revolution in production processes, or a major political change creating a new market for the corporation. In all cases the business organisation has to adapt to the new conditions. This may necessitate reorganisation of the internal structure which will influence the decision process and naturally the decision support system.

The structure of the decision support system should therefore conform to such changes. That is, for instance, the case of demolition of a line department, creation of a line department, or organisational restructuring, should not cause a problem for the decision support system and such events should be natural to the maintenance procedures of the support system. The context of the system, that is organisation of the information or analysis support tools, should also be easily changeble without necessitating a large amount of extra work, and execution of such changes should also be natural to the maintenance of the system. It is very interesting to see that the resulting model of the decision support system, which was previously presented as a solution for the the co-ordination and regulation of the problem, does also provide the best solution to the long-term adaptation problem.

Instead of large and integrated models, adoption of a modular structure and provision of line managers with a dedicated module enables total responsibility of development and maintenance duties to be delegated to the operational managers. Being personally responsible in the preparation of the support system and being directly responsible for its maintenance, managers can realistically modify existing systems. As, for example, when there is a change of organisational levels such as an organisational reshuffle, growth, contraction,etc. at a decision making unit level, when for instance there is a change in business practice.

In the case of organisational restructuring, the scope of the modification work is simply restricted to provision or demolition of certain information links between managers or, for instance, addition of new modules to the model as the organisation grows.

Reorganisation will be restricted to the modules which are directly affected by the change. Such modifications can easily be implemented through using technical staff who will be applying the modifications to the model according to the requirements of the line managers who will also be responsible for maintaining their own modules. With this configuration the maintenance involves continuous modifications to the decision support system, which is viewed as natural, and therefore does not necessitate a substantial amount of work and also does not cause strain in the organisation since it evolves gradually in line with the business organisation itself.

Long-term adaptation has traditionally been perceived as a strategic planning activity and its preparation and execution has been totally delegated to the top management.

Recently, primarily caused by the Japanese experience, strategic planning has fallen out of fashion. Japanese corporations are successful and they do not prepare strategic plans [3.38].

Porter (1987) describes the main ingredients which have contributed to the failure of strategic planning as follows:

" Total delegation of the strategic planning activities to the top management, long lead times between the preparation of master plans -five year development plans- are still in operation even for developed countries. " [3.39]

Further typical problems are lack of feedback links between the planning and the execution phases of the plans, and exclusion of the operational line management from the planning phases [3.40].

From a cybernetic point of view, these ingredients are very explicit. Total delegation of the strategic planning activity to the top management eventually results in the distortion of the information provided and amplification of bias by intermediate managers who are responsible for providing the top management with strategic information. Top managers, not being directly involved with the line management work, cannot have a good grasp of the internal dynamics of the immediate environment within which this specific line management group operates. Therefore their solution strategy is often not in phase with the changes occurring within a specific environment. This in fact indicates the centralisation of the strategical planning activity.

Lerner points to the fact that centralised control reduces adaptability of the system:

" It is also pointed out that a distinguishing feature of a system with centralised control is a high degree of rigidity of structure, because adaptation to both random changes and changes caused by evolution of the system and the environment does not take place in the individual parts of the system but only at its central control point. " [3.41]

Long lead times and absence of the relationship between the planning and executing parties result in the loss of contact between the plan and the reality. Long-term forecasting, which is usually practised between one and five years, cannot be justified because of the complexity of the business environment. Therefore, it is obvious that strategical plans based on long-term forecasts cannot be very reliable. Lack of strong links with the execution phase, and failure in using substantial input from the outcome ofthe implementation, do not improve the quality of the plans.

Wilk (1987) indicates that the concept of forecasting needs to be replaced by the concept of feedforward control, where the forecasting period is limited to a period which can be predicted with confidence and the model is continually updated in line with the feedback obtained by the implementation [3.42].

In fact, such considerations indicate that operational line managers should be directly involved with strategic planning activities. This is compatible with Porter's conclusions 1987:

" If strategic planning is to be reborn as an indispensable management tool, it must change its ways. Many companies have recognised the shortcomings in their planning process and tried to correct them. Yet few have done so effectively.

To be effective, strategic planning must use a proper process, because strategy cannot be separated from the implementation. Strategic thinking cannot occur only once a year according to a rigid routine. It should inform the company's daily actions. Strategic planning must therefore become the job of line managers, not of head office staff. " [3.39]

Such a drastic change in the perception of the strategical planning activity, which addresses the long-term corporate adaptation problem and delegation of the strategical planning work to the operational managers, necessitates that the decision support system which will be used for operational management activities also be used for strategic management activities. Therefore, it should incorporate information and analysis support capacity for the strategic management activities as well as for operational management activities.

Therefore the system should be provided with facilities for evaluating the strategic posture of the company. These facilities should provide the manager with the following information:

Continuous assessment of the industry within which the corporation competes; extraction of the relevant information so that its future can be predicted; sources of competitive advantage such as lower costs or differentiation relative to competitors; existing and potential competitors who may affect the company; and information about the company's competitive position.

# 4. A PROPOSED METHODOLOGY FOR DESIGN AND IMPLEMENTATION OF DECISION SUPPORT SYSTEMS

## 4.1 The Aim of the Methodology

A generalised methodology is provided so that it can be used as a reference in designing and implementing systems dedicated to providing management support functions to the line managers of decentralised industrial corporations.

The methodology consists of a set of concepts, principles and a generalised model which is prepared in light of the needs of rapidly evolving management practices. The aim of the methodology is to enable corporations or independent management consultants to design systems so that the pitfalls which are caused by adopting traditional system analysis practices are avoided, and the capacity of managers in evaluating the decision environment and arriving at correct decisions is increased and various operational activities are co-ordinated.

## 4.2 Rationale of the System

### 4.2.1 The Objectives of a Support System

As indicated in the previous chapters, in order to cope with increasing competitiveness, management practice is adopting new concept methods. Accordingly, organisational structures are changing from rigid formations to more dynamic ones and the demand for sophisticated management tools is naturally increasing.

In Chapter Two it has been identified that decision support systems which are prepared according to the traditional system analysis and quantitative management science applications are not adequate for providing an effective decision support function for operational management.

During the design process of a support system, by adopting certain concepts which have been investigated in Chapter Three, a more potent decision support function can be provided for operational line management of decentralised industrial corporations. The aim of providing a support system as a facility for operational decision makers should be to increase the effectiveness of the corporation as a whole, as well as the capacity of individual decision makers in making better decisions for the corporation.

Fundamentally the role of the decision support system is not to monitor or to track down what happened in the past, but to provide line managers with a facility which is designed to increase the scope for interactions between them, to co-ordinate the decision making as a process, and to provide a support function enabling managers to innovate for better future performances.

As indicated in Chapter Three, perception of the business organisation as a dynamic and interacting system is fundamentally different from the traditional perception of the organisation as a rigid system where managerial work is strictly apportioned between different departments. In such systems the need for communicating with other departments is either at the beginning or at the end of the management activity. The activity therefore is based on the input information and the system has no means for accommodating for compromise or for consensus. Changes of the situation and the input data are always associated with a time lag.

In the construction industry the lack of interaction between structural, mechanical and electrical disciplines is a typical example. Any change caused by decisions in one discipline generates further changes in other disciplines. During the time period over which the change is communicated to the other discplines, work carries on according to the previous situation. Eventually activities are co-ordinated but this is in fact one of the most significant causes resulting in inefficient practice. Furthermore there is always a possibility of not communicating a significant change which results in a design error. Such changes are constant sources of frustration. Considering the fact that the nature of the design process is often iterative, the most important function of a CAD system, which is effectively a decision support system, is to co-ordinate the design process. It provides a general framework and any change in one discipline is instantly communicated to the others [4.1].

The problems associated with the operational line management of industrial companies incorporating a number of functions are in fact similar. The relationships between functions are iterative and similarly the decision support system can be used as a co-ordinating network. Provision of such a support system will be increased if certain other concepts and principles investigated in the previous chapter are incorporated in its design, such as the degree of autonomy that can be delegated to the operational decision process as a whole. That is, operational management activities do not have to be executed strictly according to the master plans which are prepared before the execution time. As referred to in Chapter Three, with increasing autonomy the flexibility of the organisation, and thus its capacity of responding to unforeseen conditions, increases.

This necessitates a shift of emphasis from using centralised MIS systems as support systems, which being primarily measurement tools need to be punctually correct, and which lack facilities for processing unorthodox managerial judgements which are inevitable in a decision making environment.

In order to respond to market demand, managers of operations, including for instance production and transportation, have to interact with each other. Interactions are iterative and completion of one activity requires action with regard to a different activity.

Provision of the decision maker with information about the situation in other departments, as for instance maximum operational capability, increases the awareness of the manager of the capabilities of the other departments.

A system can be provided with certain checks so that decisions which are acceptable in one department will be rejected by the system if they are not acceptable to other departments. Such facilities will result in the decisions taken by the managers implicitly satisfying the homeostasis principle, which has been investigated in Chapter Three, where corrective action is acceptable to all sub-systems and a specific section compensates for another so that overall capability remains unchanged. As indicated in the previous chapter, strategic decision making is now perceived as a line management activity. Accordingly support systems should provide a support function for strategic decisions as well as operational ones. Effectively, the support system should be designed so that while executing operational control, the manager is also supplied with information which is strategically important for the business organisation. This especially refers to the provision of information about the external environment and provision of analysis models which will enable the manager to investigate the environmental information from the long-term strategical point of view. For instance, marketing information about sales and tenders, should also supply progressive demand figures for end products and information about the main competitors. Incorporation of extra information which does not relate to operational management but has great importance in terms of strategic management, such as the performance of the main competitors, is essential.

Provision of decision support to line managers is obviously a major objective. This specifically refers to supporting the decision process of managers with flexible access to models and to relevant information. The emphasis is the analysis of key decisions with the aim of improving both the effectiveness and the efficiency of the decision making. As was discussed in Section Three, the aim is more than the computerisation of well-structured repetitive problems.

Most important decisions, being unstructured, require support systems to be provided, the analysis tools that maximise the performance of the man and machine problem solving system. That is, operational research, systems simulation, econometric analysis, and forecasting models should be provided with the system as general purpose tools that can be easily set and adapted to any problem.

Furthermore, the support system will provide substantial advantage by provision of facilities which enable the decision maker to incorporate decision rules; either quantitative, that is for instance, mathematical ratios about the various aspects of the decision process, or qualitative that is complete sentences about how to proceed in certain conditions especially at crisis times. Similarly availability of a facility for storing and retrieving information about significant experiences is essential.

### 4.2.2 System Configuration

The system will consist of a set of decision support units. Each unit will be designed according to the needs of the decision process as a total y s t e m and according to the needs of the decision maker who is responsible for managing a specific section of the business organisation. Physically, the system consists of a network of interlinked microcomputers which are provided for certain managers of the business organisation. Each unit is supplied with a filing system, software which is suitable for communications, for numeric and alphanumeric data processing, and for providing mathematical modelling capacity. Should the corporation have other computerised information systems containing relevant information, the support system can be connected to the existing system in order to extract information from it.

Each line manager will be provided with a decision unit. According to its relative position in the organisational structure, a decision unit will communicate with other decision units in the other parts of the organisation either vertically or horizontally or both. The main application area for this system is business operations which regularly interact with each other and therefore require continuous co-ordination.

Therefore, the system should be primarily effective for companies where the business activities necessitate constant interaction.For such companies, the coordination of the various functions which contribute to the mainstream business operation is a significant problem.Figure 4.1 illustrates the concept.

A decentralised business organisation will be perceived as a system. The first order subsystems are defined as those parts of the organisation which are capable of producing a mainstream business organisation. That is, each subsystem is provided with a number of operational line functions and in itself is a completely viable business organisation. For instance, multinational corporations have companies at various geographical locations of the world which are responsible for company activities within the boundaries of the geographical location.

Communication between different regions is of a lateral nature. That is, the state of affairs in one particular decision unit should be communicated only with the same decision unit in the other regional divisions, or subsystems. For instance, if raw material can be purchased from markets at different geographical locations the information about its cost, availability etc. will be communicated between marketing functions of the different

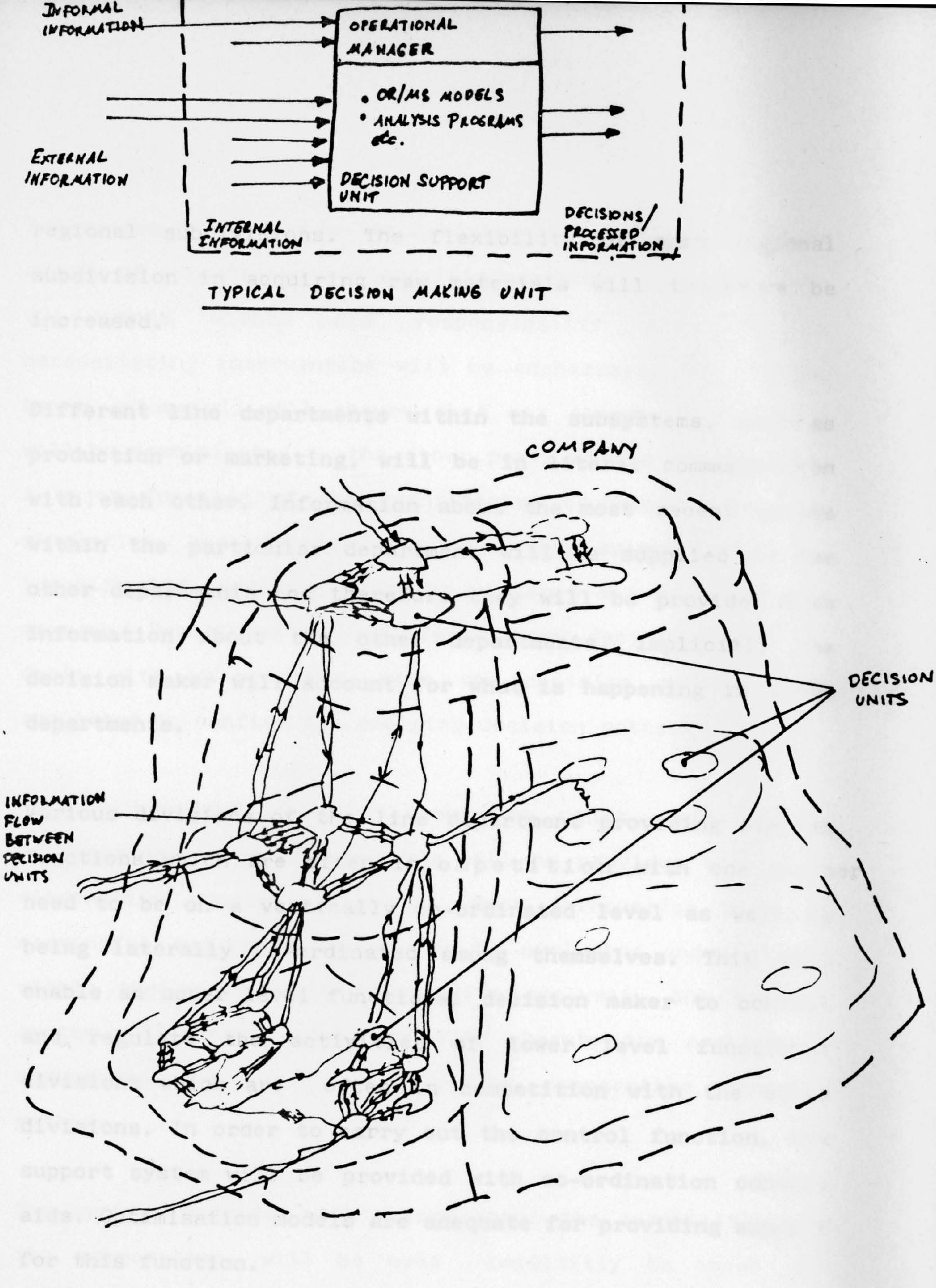



**Figure 4.1 Conceptual Illustration of the proposed system**

regional subdivisions. The flexibility of each regional subdivision in acquiring raw materials will therefore be increased.

Different line departments within the subsystems, such as production or marketing, will be in literal communication with each other. Information about the most recent events within the particular department will be supplied to the other departments and therefore they will be provided with information about the other departments. Implicitly the decision maker will account for what is happening in other departments.

Various divisions of the line department providing similar functions which are often in ompetition with one another need to be on a vertically co-ordinated level as well as being laterally co-ordinated among themselves. This will enable an upper level functional decision maker to control and regulate the activities of lower level functional divisions which are often in competition with the other divisions. In order to carry out the control function, the support system will be provided with co-ordination control aids. Optimisation models are adequate for providing support for this function.

During the course of managing, the system will be used by managers at various phases of their decision activity:

The system will provide the decision maker with a constant supply of external and internal information about the state of events within his responsibility area. Events necessitating intervention will be emphasised. The system, being automated, will ensure that any change in one part will be communicated to the other parts of the corporation. A major function of the quantitative techniques, such as simulation and forecasting, will be automatically to identify and predict developing patterns and to alert the manager. Repetitive and straightforward decisions will be dealt with by programs, with the decision makers being requested to confirm the emerging decision patterns.

Through having information about the other parts of the corporation, the decision maker will be provided with more alternative courses of action. Such information will be meaningful and useful if it can be evaluated and included within the scope of a comparative analysis. The support system will be used as a facility whereby the problem is structured and evaluated by using comparative analysis methods.

The system, provided with checks about the capabilities of the corporation, will be used implicitly to check the compatibility of the decisions that are made in different departments. That is, the system will not permit the decision maker to specify incorrect decisions. This facility will reduce the likelihood of making wrong decisions. However, the system will record the occurrence of such events and supply such data as a form of strategic information. The system will automatically search for bottlenecks and capacity shortages.

Any activity which has necessitated an intervention from the decision maker will be kept in the system, and, should there be critical changes in the situation, the decision maker who has initiated or contributed to the activity will be alerted. This will provide a feedback loop between the activity and the decision maker and will enable the decision maker to monitor the post-decision environment.

The system will be provided with a knowledge storage facility. This will be a built-in data base library which will enable any manager to enter complete sentences about any experience which he may judge to be significant. Information about any particular group of events will be quickly stored and retrieved, enabling managers to access it directly and within limited time periods.

## 4.3 Methodology for Designing a Proposed System

### 4.3.1 The Basis of the Methodology

As indicated in the previous chapter, traditional management information systems, and OR/MS models, are not adequate for providing operational decision support functions.

However, the state of the art in the development of decision support systems indicates that such systems address only one aspect of the operational decision support function which involves increasing the specialisations of communication with the model and management of it.

Being an inter-disciplinary approach, Cybernetics offers an interesting background. But, as indicated in the previous chapters, the conceptual models that have emanated as an end product from Cybernetics are not satisfactory and focus more on the control aspects. There also is a significant gap in Cybernetics between the theoretical backround and the practical implementations with proven results.

A brief review of the traditional approach based on current understanding of decision support systems is as follows.

According to Ross, a management information system is

" A group of people, a set of manuals, and data processing equipment to select, store, process and retrieve data to reduce uncertinaty in decision making by yielding information to managers at the time they can most efficiently use it" [4.2].

This traditional description does specifically refer to a system including dedicated staff with the purpose of providing managers with information. It does not refer to other functions of the information systems and therefore states the main aim of the system as an automated information supply base. According to Tricker, predominant use of information systems has been in transaction-based data processing and management information, and the use of the data for decisions has been perceived as an added benefit. He specifically refers to the lack of emphasis on external information and lack of perception of the system as a strategic tool influencing the organisation's long-term survival and adaptation to environmental conditions [4.3].

The traditional role of MIS has predominantly been control or monitoring of what happened in the past instead of enabling managers to innovate for the future, which is the essential requirement for an operational decision support system.

However, current categorical descriptions of decision support systems do not emphasise this fact and only indicate that decision support systems are dedicated to top level strategical decisions which are less structured.

McCosch et al define decision support systems (DSS) as systems supporting the decision process of managers with access to analysis models and necessary information. He emphasises the fact that DSS concentrates on a few key decisions which are strategically important and which aim to improve the efficiency of the decision making. He categorically differentiates DSS from MIS and indicates that MIS has had very little effect on the kinds of decisions and the ways in which they are being made by managers [4.4].

This description indicates that traditional DSS is being perceived and implemented as a tool for handling strategically important key decisions. It does not address the essential concepts of communication, co-ordination and integration of the business organisation as a viable whole.

Quantitative analysis tools, including MS/OR and Systems Simulation, are used to solve specific managerial problems. As was addressed in Chapter Two, such methods are generally used for handling strategic decisions where there is plenty of available time for evaluating complex problems. If properly prepared, such systems can substantially contribute to the decision support function and in fact they can be directly used as primary tools for facilitating business organisations. However such methods are only end products and can only be integrated in a more generalised methodology.

As has been indicated in Section 4.2.2, the aim of the proposed system is not fully covered by any of the methods referred to or their combined usage, without paying attention to certain properties that the business organisation and its systems need to conform to. In fact, as has been discussed in Chapter Two, the attempts to use large and centralised management information systems as a decision making tool for future innovation have proved to be unsuccesful, and quantitative analysis tools has not been accepted by line managers.

The proposed methodology differs from any of the above methods and approaches.

The methodology is based on the issues which are essential for its main purpose, which is <u>to increase the overall operational-effectiveness of an entire business operation</u>. To achieve this:

i.there must be effective co-ordination of the operational decision process,

ii.there must be augmentation of the decision-making capacity of the operational managers who contribute to the collective decision process,

iii.In providing this service, as with any other capital management tool, it must be cost effective and therefore justifiable to develop, to use and to maintain.

The proposed system and the development methodology have evolved from the guidelines which have emanated from the analysis and synthesis of the principles referred to and investigated within the previous chapter.

The proposed methodology consists of two phases for the initial development. The development process is, however, continuous and implicit in the system after its implementation.

The object of the first phase is to obtain a 'forward looking' information system which contributes to the effective co-ordination of the decision process. The system is dedicated to the processing and conveying of information which is significant and actively used in the decision process.

The object of the second phase is to develop decision support units complete with the traditional quantitative analysis methods such as OR/MS.

The characteristics of the system, and the development methodology, enable the continuous development and evolution of the system to be a feasible and realistic objective.

### 4.3.2 Conditions Necessitating the Implementation of the Proposed System.

What are the conditions which necessitate and justify the implementation of the proposed system? For which industries and management practices is the system substantially useful? What would be the gains to the corporation of implementing the proposed system ?

As previously described, the objective of the proposed system is different from the traditional information system applications.

The aims of the proposed system have been specified in Ssection 4.2.2 as to the need to co-ordinate the decision process by providing a framework to increase the communication and the scope for interaction between managers and to enable the business organisation to conform to the properties which are vital to its good strategic performance. The aim, with regard to maximising the decision- making capacity of the individual line managers, is always relative to the total system.

In order to justify the implementation of the proposed system, the problem area should predominantly indicate a need for co-ordinating the various parts or functions of the business organisation. Maximising the decision-making capacity of individual managers is in fact a problem common to all firms. However, the principles, especially on how to integrate quantitative design tools into the decision support system, will improve the effectiveness of traditional decision support systems.

The general properties indicating the type of potential implementation area for the system can be summarised as follows:

The business organisation necessitating the implementation of the system should operate under dynamic and versatile market environments and the business operation should be market oriented. That is, its performance should be sensitive to market fluctuations. Therefore, industries or companies operating in consumer-oriented markets represent potential implementation areas for the system.

Line management should necessitate constant interaction between various departments. The line management should have a high degree of interdependency between its departments.

Although being decentralised, the products produced by the business organisation, and the facilities for production and logistics should be of a similar nature. That is, the business organisation should present a need and offer scope for co-ordinating its line management activities between regional divisions as well as between various functions so that, for instance, products produced in one division can be used in other divisions, or raw materials can be bought from other divisions.

Main line management decisions should require constant communication with other parts, in terms of information exchange, and should necessitate substantial managerial judgement. The decision environment should therefore be semi-structured necessitating the use of quantitative analysis tools in the managerial judgement. Should the environment be totally unstructured, which is unlikely for most of industrial line management environments, then the system can be used mainly as a communication and co-ordination tool.

The emergence of stategically important issues must be identified and directly communicated to the manager so that the manager is able to incorporate them into the strategic plan. Therefore, the time lag between the occurrence of the issue and h e corresponding adjustment to the plan is minimised.

The specific implementation philosophy should be to innovate for the future rather than to monitor what happened in the past. Modern management practice, unlike traditional practice, enhances the scope for interaction within a more dynamic and fluid business organisation and points to the need for partial delegation of strategic management activities to line managers [4.5]. Industrial management practice indicates the tendencies for decentralised self-organising apportioning of the control work [4.6]. Generally, the scope for implementing the proposed system will increase as recent tendencies in management methods are accepted by a wider proportion of industry.

Typical industries where the proposed system is needed have been identified as follows:

In the oil industy, large decentralised integrated oil processing and distribution companies present most of the conditions which indicate that implementation of the system would be fundamentally useful. Production, processing and logistics facilities are interdependent and there is substantial scope for co-ordinating line management operations at various regional subdivisions. Interdependence between marketing, processing, storage and transportation functions is substantial and line managers of the various fuctions do continually interact with each other in order to reduce line management costs. Market conditions involving products, the transport environment, and raw materials are volatile and necessitate rapid responses. Costs may vary significantly many times during the day disabling the successful execution of predetermined management strategies.

Due to the time lag associated with it, centrally co-ordinated production control proves to be inadequate. Consumer-oriented decentralised industrial firms such as large textile manufacturing companies also present similar characteristics. In such firms the emphasis is on marketing and production operations. The product turnover is large, requiring transportation of a large volume of products. Fluctuations in market conditions are very volatile and specific to the regional subdivision, and change with factors such as weather and fashion. Goods can be swapped between markets, and raw materials can be acquired from different markets.

The dynamics of the line management necessitate continual decisions and intervention in order to minimise operation costs. There is a high degree of interdependence between managerial functions. Marketing, production, and transportation functions are iterative and they need to be closely co-ordinated. Sales information needs to be fed back to production so that waste is minimised. Should there be a demand for products in a regional division, and surplus of the same product in a different division, surplus products can be supplied to the division where they are required. Capacity to evaluate such conditions necessitates that quantitative analysis tools are available to the decision makers. It is interesting to see that the success of the Benetton company is attributed to its management support system which co-ordinates sales, shops, distribution centres and production facilities.

Large decentralised retailing conglomerates such as Marks & Spencer, Sainsbury, etc. present similar characteristics and are potential areas for implementation of the proposed system. In the retailing industry, the emphasis is primarily on the co-ordination of the marketing and distribution functions. The characteristics of the business dynamics are in fact very similar to the previous cases: The operation is substantially influenced by the fluctuations of market conditions. Also in the retailing sector there is a scope for substantial savings through proper co-ordination of the various functions such as purchasing, distributon and sales. In the retailing industry, there is a high degree of interdependency betweeen the various functions and thus there is a constant need for line managers to intervene in the operations.

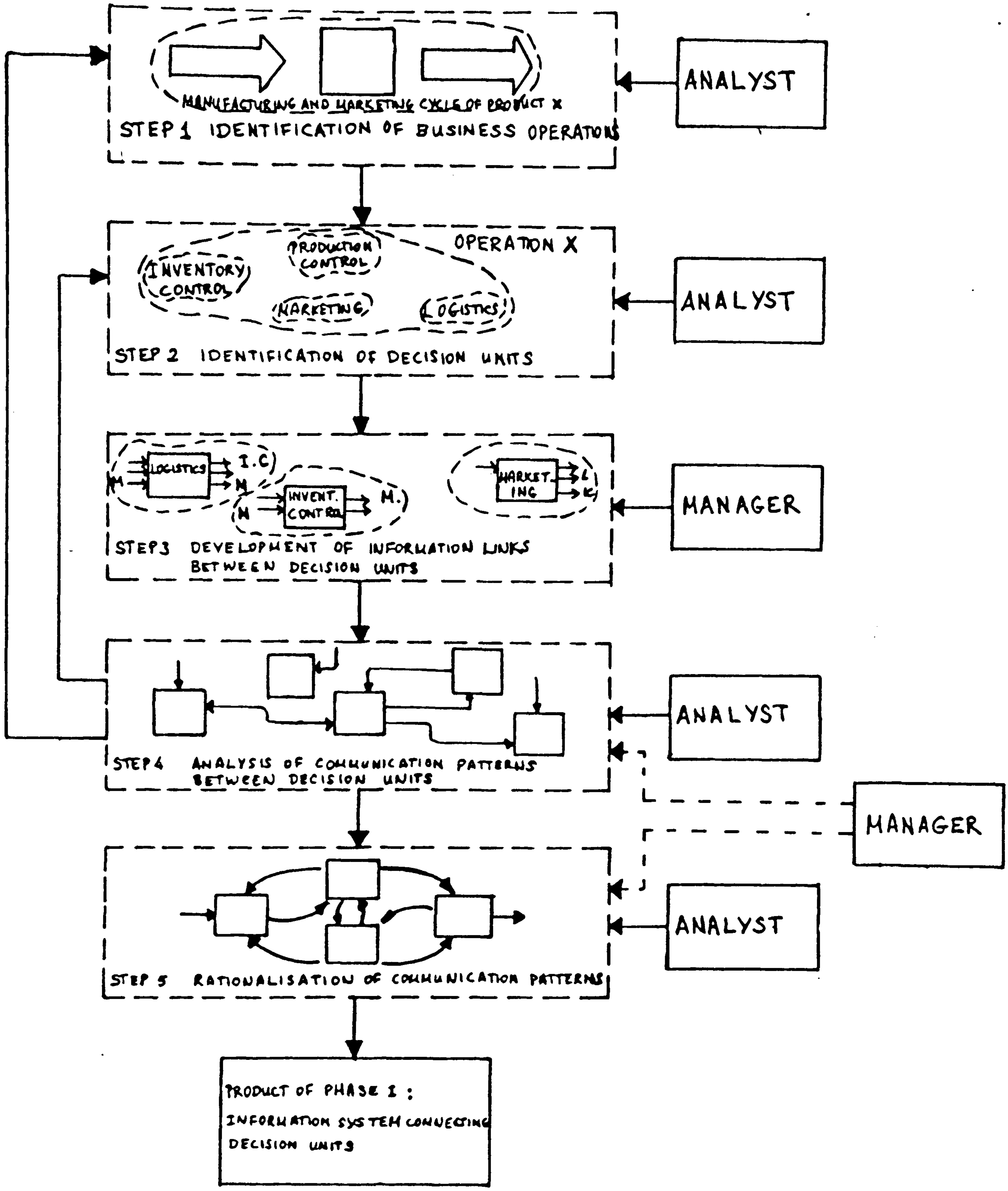



Figure 4.2 Conceptual illustration of the proposed methodology:Phase 1

### 4.3.3 Methodology for Designing the Total System

As described in the previous section, the aim of the proposed system is to provide line management with a decision support tool which contributes to the co-ordination and regulation of the primary line management activities. It therefore needs to be supplied to the line managers where their area of responsibility does significantly contribute to the mainstream business organisation. Figure 4.2 illustrates the principal steps of the Phase I development methodology.

A description of each step is as follows:

The aim of the first step is to identify a group of business operations for which the system is required. Unlike traditional implementations, the system should be designed around the business activities rather than the business organisation.

The nature and the context of the business activities obviously vary with the business area but for a typical industrial organisation they are mainly related to the following:

Purchasing and delivery of raw or semi-finished materials, raw materials inventory management and connections with suppliers, production control, finished goods inventory management, distribution of finished goods to warehouses or agents and marketing activities. Typical mainstream functions are illustrated in Figure 4.3.

The emphasis obviously varies according to the type of the industry.

The aim of the second step is to establish the decision units of the business operations. As suggested by Baylin, the business operation is described as a set of functional units [3.15]. The system should only be supplied to a selected number of managers who significantly contribute to the business operation which is defined in the first phase. In large complex systems this may prove to be difficult. Therefore the relative significance of the line managers is evaluated by justifying their presence. That is to asess whether or not a discontinuity will be introduced into the decision process, and accordingly into the management of the business activity, should their post be eliminated. It is important to note that such an approach enables gradual development of the system and development costs are minimal because the system is only provided to key managers. As a result of this step decision units which contribute to the business operation are defined.

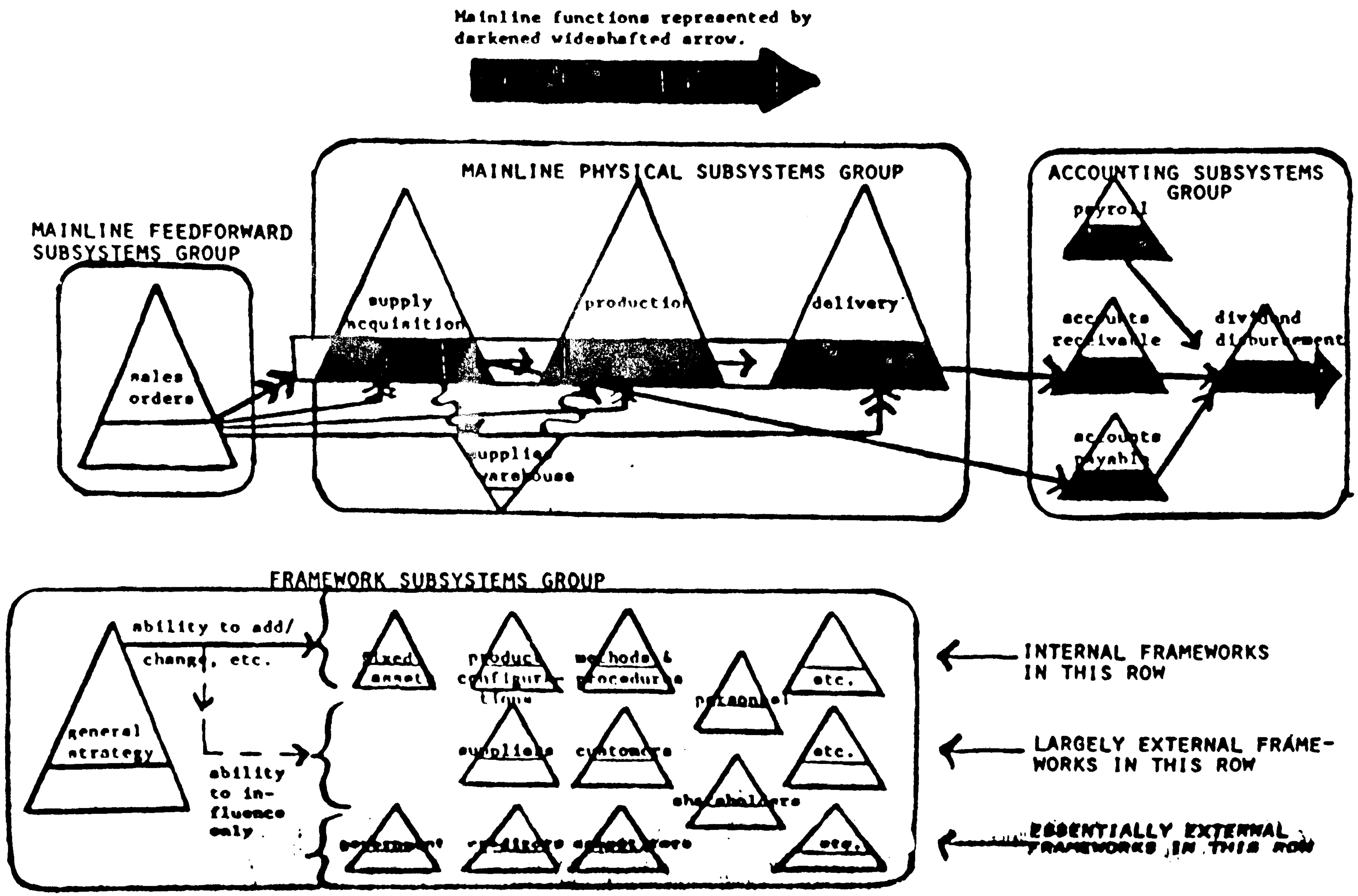



Figure 4.3 Illustration of the functional cohesion method (source:Baylin)

The object of the third step is to evaluate information communication patterns between decision units.

Selected groups of managers should then be asked to describe their normal decision environment. This includes their information requirements from the other parts of the organisation and the decision criteria that they apply to the situations they deal with. They should also be asked to describe how to increase the scope of their decision environment and accordingly to describe their additional information needs. As Carter points out, it is not realistic, to assume that this information can be obtained from managers during the course of a few interviews.

Therefore operational managers will be supplied with worksheets which guide them through well-defined questions about their decision environment. They will be requested to fil in these sheets at a suitable frequency, such as once a day, over a suitable time period.

At the completion of this step, the following will be obtained from all managers:

Definition of the existing and foreseeable scenarios which require their intervention.

Identification of what information is needed from which information department so that the manager can effectively intervene the situation. In description of the supply frequency, and relative importance of the information for effective intervention in the situation.

The information can be an estimate or a judgement which is made by a different manager. The aim of the proposed methodology is to identify existing communication patterns as well as missing ones. For instance, the finished goods inventory manager of a specific division may informally know that generally a specific product, which has peak demands, can be in surplus in other divisions but the fact that he does not have the specific information about the availability of the product, nor the means of evaluating the financial attractiveness of delivering the product from the other divisions, will lead him not to attempt to obtain the product from those sources.

The availability of information and the comparative evaluation facility will enable such activity to be practised by the business organisation. But the fundamental issue that needs to be pointed out is that the kind of interaction between, for instance, inventory and transportation managers requires distributed decision making which needs to be properly co-ordinated.

That is, the decision about supplying material from a different division requires decisions from both production and transportation managers. To be able to evaluate the issue, managers must be provided with analysis support facilities as well as information about the availability of both product and shipping capacity. This analysis facility enables them to evaluate the attractiveness of the situation. Obviously, the decision about supplying the product should also be attractive to the manager concerned and there should be available feasible transport capacity for the specific instance.

What is also important is that there may be considerations other than just financial ones and that such decisions can only be made by managers and cannot be delegated to machines. But it is important to note that the availability of the information and the comparative evaluation tools will enable managers to consider opportunities which would not be possible otherwise, and the overall effectiveness of the corporation will improve.

The data which results from the descriptions of the selected line managers will indicate the existing decision processes within the group of business activities for which the support system is being prepared. This would be in the form of an abstract chart which would emerge from this exercise and would indicate the patterns of information exchange between managers. The decision environment of line managers, and the requirements of each support unit, will also be defined. The methodology for designing decision units is described in the next section.

The chart will indicate what potential improvements can be made to the existing system. It will also point out the necessity of including other line managers who may be ommitted during the pre-selection phase; or conversely, will indicate that some managers who have been included are not really significant. Obviously, provision of the system will increase the scope of the line management. Being provided with timely information, decision makers can more thoroughly evaluate certain situations. The design of the proposed system can influence the way in which augmented decision processes would be co-ordinated and would function.

As a result of this step misjudgements about the operation may be detected, analysis may show that some managers are omitted or some managers are unnecessarily included wihin the scope of the exercise. In this case the process is repeated by returning to the first or the second step as appropriate until a satisfactory model which describes communication patterns of the key existing operational management process is obtained.

The final and the fifth step is the rationalisation of the chart which has been obtained as follows :

The object of the rationalisation is to improve the degree of compatibility of the decision process with the actual operational business dynamics, which results in better co-ordination of the management process.

The pattern of the operational decision process, and therefore the information flow between the decision units throughout the firm, should be as close as possible to the pattern of the actual business dynamics. Business dynamics are not a function of specific firm and therefore the analyst can develop his experience on the dynamics of a particular business.

The design criteria should aim to identify the natural operational business dynamics at a certain level which is critical for the survival of the company. The business dynamics of any firm operating in a free enterprise environment are of a self-organising and self-regulating nature which necessitates a similar decision process.

As referred to in the previous chapter, increasing implementation of the Just-in-time operations control philosophy indicates increasing recognition of this reality throughout the industry.

Unlike the traditional practice, the co-ordination of the line management activities should be of a self-regulatory nature. This can only result from the interaction of line managers between themselves. This is only possible by designing the support units and total system so that self-regulatory feedback loops are introduced between line managers.

In order to enhance the conformity of the business organisation to market conditions, the system should be set up with the aim of aligning the business operations with the market requirements. That is, starting from sales, any decision will present the requirement for other decisions and accordingly the whole business operation will be 'pulled' by market requirements.

Decision processes will be triggered by marketing information and gradually will generate a train of decisions which will laterally flow backwards through the line management activities.

A feedback loop will communicate sales information to the products inventory and distribution managers respectively and in order to fulfil requirements they will have to decide how much to supply, and from what location or source, and using which transportation facilities. Decisions on how to supply products from the finished goods inventory will influence the stock levels of the product within the division or within other divisions. That, in turn, will necessitate a decision from the production management. The raw materials depletion rate will necessitate a decision on inventory management which in turn will generate decision requirements in purchasing and in the transport divisions.

The whole process, being automatic and continual, will mean that the need for central planning will be minimised. Business activities will therefore be co-ordinated through self-regulatory loops. Further co-ordination between regional divisions will be possible by providing a communication link between the support units of different divisions. To cut down the variety, such interdivisional links should be established between identical functions.

The details of the communication patterns should be assessed according to the following characteristics:

The communication frequency should be realistic and compatible with the requirements of the decision scenario. Information which is supplied from decision units of the sub operations should have the same frequency so that it can be evaluated simultaneously.

The variety of the decision environment should be gradually reduced and for any manager should not exceed a limit above which the manager would become incapacitated.

Communication patterns of information with strategic content should be rationalised, as well as those for one operational level. If such communication does not exist then it must be provided. This is essential because strategic management will increasingly be delegated to the operational managers [4.7].

### 4.3.4 Methodology for Designing Decision Units

The design process should proceed at two distinct resolution levels. During the design of the total system, as previously described, the design process must primarily concentrate on the relationships between the decision support units, where each unit needs to be treated as a black box, where only inputs and outputs to the unit are considered. The detailed design of the support units should therefore follow the design of the total system and accordingly the relative importance of each unit within the total system can be emphasised. Figure 4.4 illustrates development of Phase II of the proposed methodology.

The design of the total system as a whole would initially be based on the protocols prepared by line managers. Therefore, the design process is in fact iterative. The emphasis can be shifted to the design of the individual decision units only when the information needs, that is the inputs and outputs which are derived from independently prepared protocols, are successfully co-ordinated. It is important to note that such an iterative design methodology will ensure the co-ordination process even though the design of each unit will be carried out independently at the various parts of the organisation.

The detailed design of each support unit will be under the


Figure 4.4 Conceptual illustration of the proposed methodology:Phase 2

direct responsibility of the line manager who will be responsible for using the system. The analyst will directly report to the line manager. Although the details of each unit obviously vary with the decision environment of the specific decision unit, there are certain principles which are common to the design process of all units.

The detailed design process should proceed according to the proposed methodology, where such principles should be taken into consideration. The progress of the design should conform to the following pattern:

There are two main functions that the system needs to fulfil, primarily it should be used as an operational decision support tool but it should also provide information for strategic planning activities. As an information base for strategic management activities, the system should enable the direct extraction of information with strategic content from the line management activities.

Strategically important situations need to be identified and the system needs to be provided with a facility which will extract and save information for future reference. For instance: bottlenecks in storage, production or transportation; excess capacity; movement of market trends, should all be abstracted when the situation indicates their strategic importance.

This will provide continuous feedback for the strategic plans, and automatic recording of the information will enable line managers continually to monitor the profile of their function from a strategical point of view without substantial overhead costs. This obviously necessitates provision of permanent files and decision rules which will extract information when its value is progressively changing over a time period.

As a decision support system for direct line management activities, the system should conform to the following methodology:

The detailed design of the system as an operational support tool should deliver total support function for expected and foreseeable decision environments but it should also be supplied with facilities that would provide the support function for likely but unforeseeable situations. In practical terms this refers to the provision of general purpose facilities such as a general comparative analysis tool or to the capacity to request new information throughout the system.

As described previously, the specific aim of the detailed design of the decision support units is to increase the decision-making capacity of the manager. The design therefore should concentrate on how to integrate the skill and the knowledge of the manager with the communication system, the quantitative decision support models, and the necessary hardware so that a harmonious and effective decision-making system, which includes the manager and the system, can be obtained. Traditional decision theory does in fact address the problem of the integrated design of the subject and object systems [4.8]. In our interpretation the subject system is not only the manager but the manager and the support unit and the situation that necessitates intervention is the object system. The first two steps of the proposed methodology are based on Newell-Simons' method which simulates the subject's cognitive process [3.43].

The sixth step of the methodology, or the first step of the second phase, is identification of a range of scenarios that require operational decision making.

Operational managers will be provided with a different set of worksheets where the worksheet guides the manager through the exercise. The aim is to identify frequent scenarios which require dedicated models. The output of the first step is a range of scenarios.

The seventh step is to analyse the decision process of the manager for a given scenario. Essentially its aim is to establish quantitative and qualitative considerations that are used in the decision process. The aim of the analyst is to the components which can be delegated to the system. The outcome of this step does in fact outline the requirements for the quantitative analysis models such as OR/MS.

Traditional implementations address only the quantifiable and measurable aspects of the rational component. The contributions of a decision support system increase as the problem environment becomes more structured. According to Mc Cosh, in unstructured problem environments a human decision maker plays a vital role in providing judgement and evaluating capacity as well as bringing insights to problem definition [4.4]. The degree of structure varies with the problem but it is essential that the use of the support system should not adversely affect the influence of other components and, unlike traditional applications, should emphasise the total decision situation instead of only the quantifiable and measurable rational component.

The eighth step is a cost/benefit analysis for the required models. This is effectively a cost evaluation of developing a specific model to the requested level of detail. As Beer indicates, the eighty/twenty rule also applies to model development where eighty percent of the benefit is obtained by twenty percent of the method.

If the required model proves to be too costly then it is returned to step seven.

The ninth step is the evaluation of the effectiveness of the model with respect to organisational considerations.

According to Simon, the primary components of the decision process are rational, psychological, social and cultural [4.9].

Obviously, the support system can primarily be used for handling relatively more structured problems which can be tackled by rational criteria. But the system must not undermine the presence of other components, and where it is necessary and feasible it must deliver support functions for these other components. Therefore, it is imperative that such developments must be a multidisciplinary effort.

The psychological component includes personality, capability and experience, values, perceptions, aspirations and the manager's own perceived role of his function [4.10]. The system cannot influence personality, capacity and aspirations, but can deliver effective support function for psychological components including values and perceptions which form the basis for subjectivity. It must be noted that this is a complex subject but further research is not included within the scope of this study. Temporary exchange of the support units between managers responsible for the same type of function in different parts of the organisation will enable the managers to evaluate the decision environment of their counterparts, since the design is based on protocols prepared by both decision makers. The previous experience of a manager can be made available to others by providing a facility which enables the managers to record situations using meaningful sentences.

The social component addresses the informal interactions between managers and the relative importance of the goals and values of the other decision makers in the decision processes of a specific manager. Informal communication links do significantly contribute to the decision process. For instance, during the evaluation of the problems involving inter-organisational politics, the decision will be influenced by the political situation and the information about the situation will be communicated through the informal communication links. Traditional implementations ignore this factor and the delegation of the decision rules to machines is especially affected by this neglect.

If the utility of the model is undermined by such factors, there is no benefit for further development and the model requirements should be reviewed by returning to the previous step.

The tenth step involves technical considerations: This covers the definition of man-model communication characteristics including, for instance, model access time and access to certain data bases. The following are the principal details of such reqirements:

The support system, as previously described, contributes significantly to the rational component where the decision environment can be quantified and the principles of the detailed design cover information inputs and quantitative analysis capacity.

Before, provided to the decision maker, information which is being incoming to the decision unit must be organised according to the needs of the analysis work that is required by the manager. It is essential that the information must be directly input to the analysis models.

The eleventh step is actual system development. This will essentially consist of modifying a standard library of models to bring them into line with the user needs.

Strategic management requires analysis tools and methods for predicting the future performance of the environment and business organisation. Forecasting models are essential for evaluating strategic developments in the environment because they do not require a knowledge of the internal dynamics and are based on historical data. Managers must be provided with such models to assess environmental conditions such as price fluctuations, or expected demand.

The analysis needs of operational management often involve comparison of alternative options and co-ordination of the lower level sub operations. In order to be regularly used analysis support tools must be quickly and rapidly available for use. Operation research and engineering economics models are useful for optimisation and co-ordination functions and can be set and used within restricted time periods. Systems modelling and simulations require substantial development times. To be effective the dynamics of the operation that is being modelled must be clear and well understood. Understanding of the results also necessitates significant time, and so generally they are not suitable for operational management support. The complexity of the model provided for the system must be dictated by the accuracy that is required from it and by the time available for analysis.

The final twelfth step is model validation and it will be executed by the manager.

While the design of the workstation is in progress, each person who is responsible for the design process must be supplied with specific information about the development time of each model, if this is not included within the standard system library.

Validation should be done by using on-the-job trials conducted by the manager for whom the model is being prepared.

## 4.4 Further Development at Post-Commissioning

A significant advantage of the proposed system is its capacity to be continually modified and developed after the completion of design and commissioning. That is, once the system is up and running, it can easily be adapted to the total system and individual decision support unit levels.

This is possible because the system has a modular architecture and each support unit is designed and specified directly by the line manager of the management operation for which the system provides support function. Figure 4.5 illustrates continuous evolution of the system.

During the post-commissioning period, the system should be maintained according to a methodology ensuring evolution of the proposed system in line with the changes in the organisation of the operations and the decision process involved in the operations.

Once the system is commissioned, line managers who were responsible for designing support units will be appointed to be responsible for maintaining their support units. Line managers, being responsible for a specific unit of the system, which is not necessarily large and complex, and being responsible for its design and thus knowing the internal details of the system, are capable of introducing

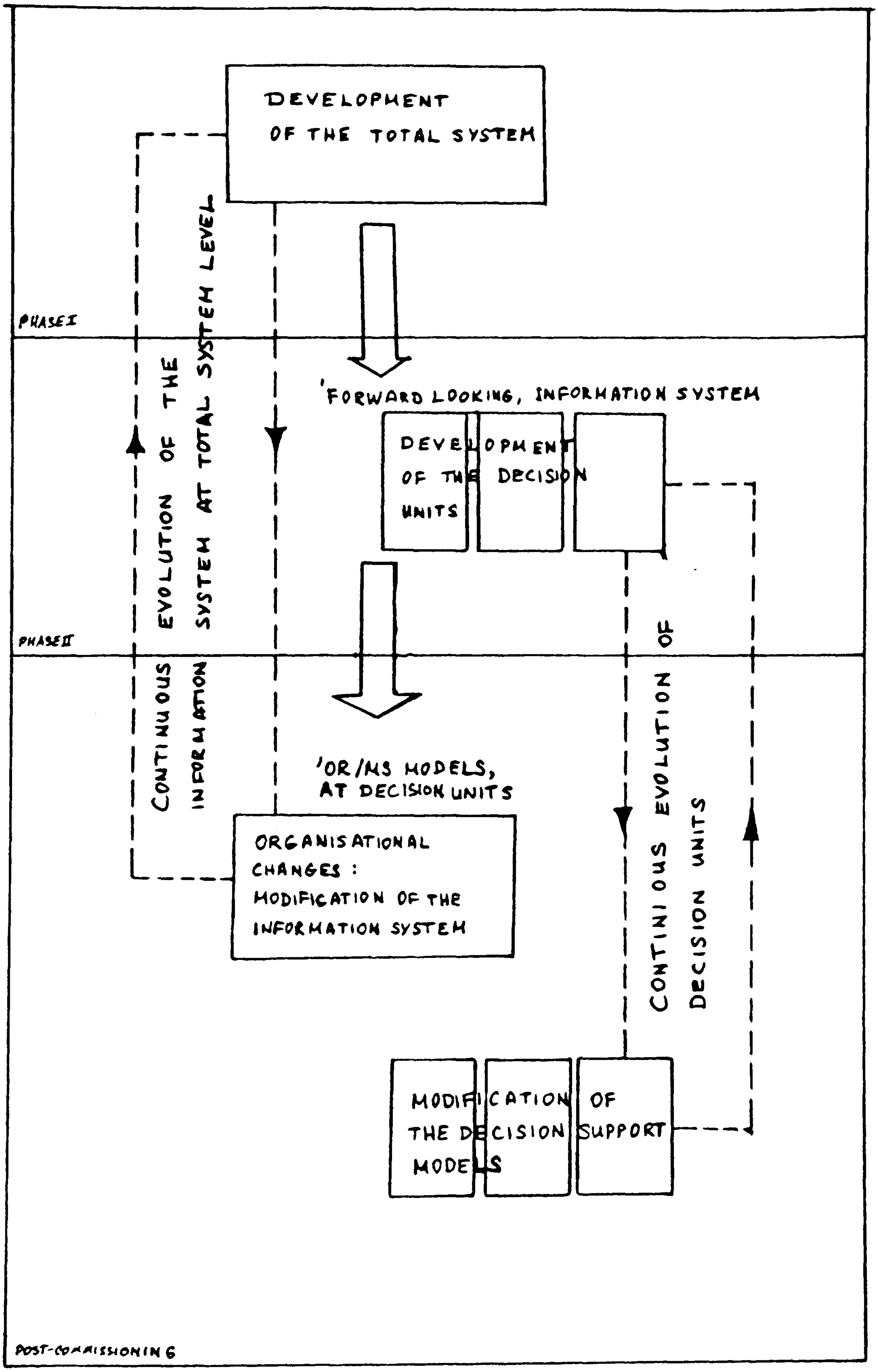



**Figure 4.5 Conceptual illustration of the development methodology**

further modification and development of their units according to their own changing needs. As previously indicated in Section 2.2, users cannot contribute to the maintenance and further developments of corporate information systems as they are large and complex, and the internal details on how the system works are not known by the users.

Development of the system during the post-commissioning period is feasible at distinct resolution levels. At the total system level, the decision support system as a whole has to evolve in line with the organisational changes. Having to survive in a competitive environment, the business organisation has to adapt to changing environmental conditions. Accordingly, business operations and organisation of the management activities change. According to market fluctuations a product may be discontinued, the corporation may diversify into new business areas, or it may grow in size etc. From the system point of view, all such changes either necessitate the addition of new modules or discontinuation of some existing modules or modification of the communication patterns between modules. Any of these requirements can be met effectively because any modification to the system as a whole, like the addition or discontinuation of new modules, or modification of the communication patterns, do not necessitate substantial modification of other decision units. Like, for instance, if the corporation grows and new managerial posts are generated within the line management system, the support system as a whole is required to deliver support function for the managers of these new posts. A new decision support module can be added without necessitating modifications of the other support units. It only requires modifications to the communication patterns.

Since the evolution of a business organisation is a continuous process, during its post-commissioning period, the system would be in a continuous state of adaptation and development. Since changes in the support system will necessitate new communication patterns between support units, a managerial post which is responsible for co-ordinating information requests of different managers needs to be generated. This will replace the function of the original designers which evaluate the system performance as a whole and will make sure that any new information need of a manager is met by other support units. This obviously necessitates minor modifications in the information transmission system. If, for instance, the unit is new and information does not exist, then, minor modification needs to be implemented to other units from which information is expected.

If a manager leaves his post, then the support system can be initially used by the new manager as a tool for speeding up the training process. If the new manager, being responsible for its development, is not satified with its performance, he can modify it or redesign it according to his own needs.

At the specific unit levels each manager will be responsible for maintaining his unit. This is feasible because the manager himself will know the specific internal details of his unit. As the manager becomes more experienced, his perceptions and decision-making process may change, necessitating modifications to the support system. He may require new information or new analysis support tools. The software providing the total support function should be modular and should be easily modifiable. According to his specific needs, the manager should be free to buy and use any analysis support software that he may need. Standard software should be supplied and it would enable him to specify the pattern of information that he needs. Information handling and transmission should be set up so that the communication of new information with other units should not necessitate significant modifications to the existing system.

The domination of the decision process by the existing support system will therefore be prevented and, as happens with the traditional systems, users of the system will not be able to blame the existing system since they will also be responsible for its development.

## 4.5 Contributions of the Proposed System to the General Management Process

The contributions of the proposed system to the management process as a whole will be more than just those got from providing information for the decision makers of the business organisation.

The philosophy of the end use of the system is fundementally different from traditional information systems. The primary system objective is not to monitor what happened in the past with extreme accuracy but to enable its users to innovate for the future. The methodology ensures that during the design phase emphasis and resources are concentrated on the effective utilisation of the system in providing support functions for line managers who will be engaged in solving future oriented problems with limited information within an uncertain environment. Information stored and processed in the system will have strictly no other function than to increase the decision-making capacity of the managers. Therefore all information processed in the system will have a significant meaning for the managers.

Implicit in its utilisation, the system not only delivers decision support tools for the decision makers but fundamentally contributes to the co-ordination and regulation of the business organisation as a whole. By providing information and analysis support tools it enables managers to consider alternatives which they could not consider previously.

The proposed system is in line with most recent trends in industrial management where the emphasis is on the distribution of responsibility and, as quoted by Grossman, is aimed at accomplishing a distributed control,

> "The object is to migrate from the traditional western approach of centralised control to a more localised and distributed control. " [4.11]

This philosophy is confirmed by the increasingly popular just-in-time manufacturing philosophy which is described by Wilson as a

> " system driven by the final product demand so that the right product is produced at the right time in the right quantities." [4.12]

Information flows backwards throughout the organisation through feedback loops starting from sales and reaching to purchasing, initiating a flow of materials forward starting from the purchasing function. Central to its philosophy is that all inventories are undesirable and should be eliminated or minimised. This methodology introduces a new dimension to marketing that involves purchasing and sales and delivery functions [4.13]. The information needs of the managers operating under the just-in-time methodology and who have to respond fast are greatly increased.

The proposed system is very compatible with the implementation of this methodology. According to the industrial business area, the proposed system can be interphased with other general or dedicated information systems such as computer-aided production planning, including a master production schedule, material requirements planning, production control, marketing information systems, and cost planning systems. Each module can extract the necessary information from such systems since most industrial companies will increasingly acquire such systems.

Unlike the traditional decision support systems, the design of each support unit will be based on the protocols prepared by line managers and the design will not only consider the rational or secondary level information processing aspects but other aspects such as psychological ones contributing to the decision process. Problems of inefficient implementations caused by attempting to delegate decision-making work to machines, where the decision-making process is not only governed by rational and quantitative comparisons but, for instance, also involves social aspects such as internal office politics, will be prevented.

The system being dedicated to the decision-making work of line management activity means that information which is processed in the system is significant and therefore the system does not need to store large volumes of information. Being small, the system does not require much support from the operational staff, thus increasing the cost effectiveness of the implementation. The transmission of the information between support units and therefore managers is automatic, leaving managers more time for analysis and evaluation.

The design of the support units, enabling managers to load the decision-making information directly into the relatively simple and easy to use analysis support models, eliminates the need for dedicated staff to use such models. Being provided with a set of support models, managers can select the analysis support tools that meet their needs. Support tools, being quickly set up and easily used, eliminate the need for technical staff and can effectively be used for providing support to line management activities.

The proposed methodology of designing the support system contributes to the clarification of the decision processes throughout the firm. The design of the support units enables managers to rationalise and to understand their decision environment. Having specified the requirements and knowing how the support unit works, line managers can effectively use the system as a decision support tool.

As described in previous sections, the proposed system, unlike traditional information systems, is modular and can easily be adapted to the changing requirements of the business organisation. The development is therefore continuous and implemented by line managers who will be responsible for developing their support unit.

# 5. APPLICATION FOR AN INTEGRATED OIL PROCESSING AND DISTRIBUTION SYSTEM

## 5.1. Scope of the Application

A typical application of the proposed decision support system is developed for the oil industry where the system is designed for co-ordination of the management process and for providing decision support function for operational managers of a typical oil company which is primarily engaged in oil processing, distribution and marketing operations.

The aim of the application is to demonstrate how the system should be developed according to the proposed methodology. The corporation for which the system is developed is typical and fictitous but the details of the management process are based on research, real life examples and direct communications with experienced managers from the oil industry.

According to the proposed methodology, the system is developed in two stages. The review of the business dynamics, decision environment and the development of the total system according to Phase One of the proposed methodology is presented in Chapter five. The developments of decision units are included within the scope of Chapter Six.

The work has been focused primarily on marketing, production and transportation operations and therefore is not inclusive.

## 5.2. Review of the Business Environment of Oil Processing and Distribution Systems

### 5.2.1. Leading Particulars of the Business Environment and Dynamics

The primary business operations of a typical oil company are complex and the success of a specific business operation also depends on the performance of other business operations. Strategic and operational management of such A corporation is substantial and therefore A review of the business dynamics needs to be carried out at a specific level of abstraction where there is a need for implementing the proposed system. Figure 5.1 indicates the primary business operations of a typical oil company. In summary, crude oil is purchased and transported to processing plants where it is processed in order to obtains semi-finished or finished products. According to the market demand, products are then distributed to the main markets.

The outline business dynamics of state-owned or private oil companies are infact similar: Crude oil is purchased from the main oil producing countries such as the Persian Gulf area or Venezuela, but it may also be purchased from established crude oil trading markets such as Rotterdam.


Figure 5.1 Primalry operations of a typical oil company

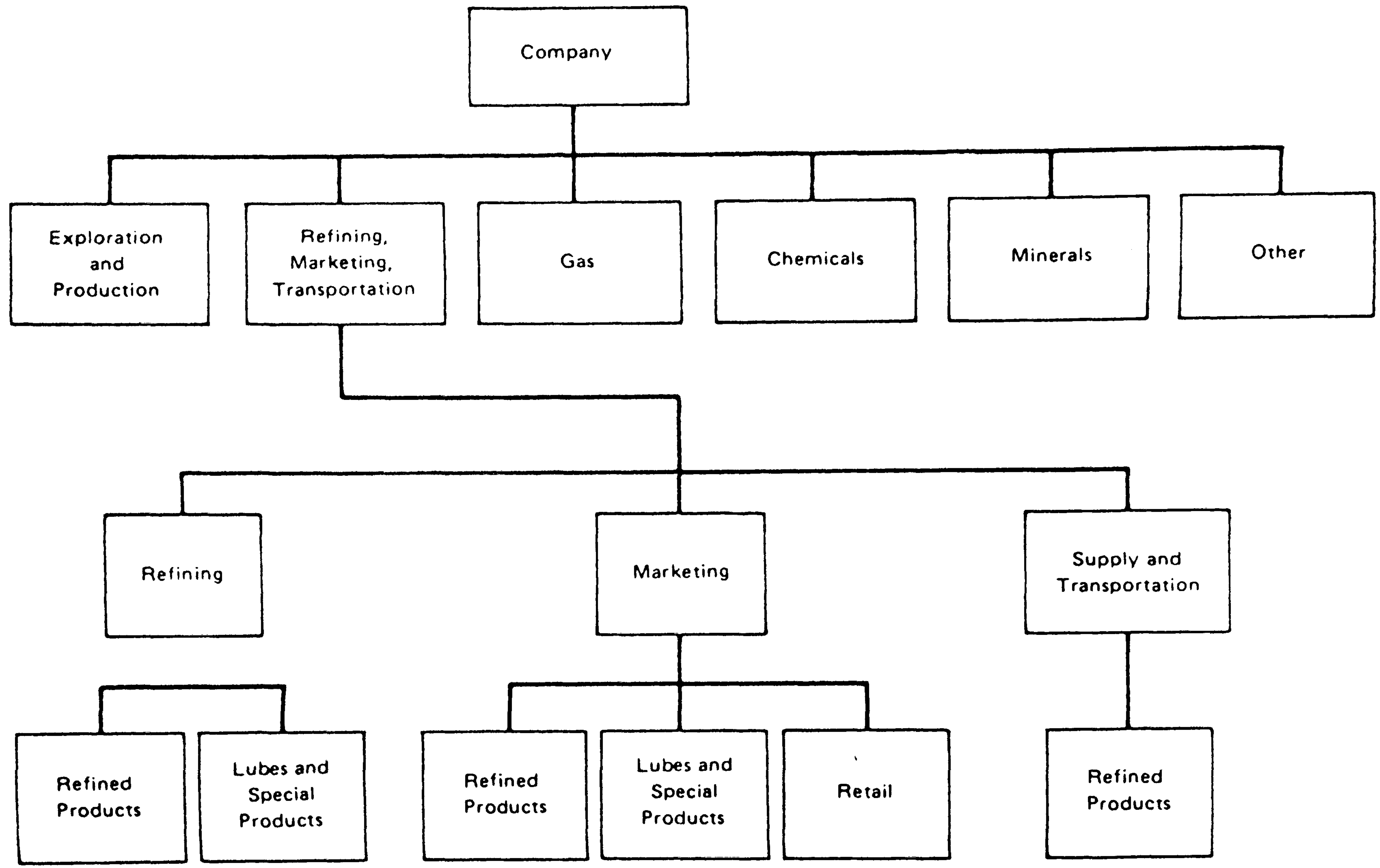



**Figure 5.2 Organisation of a typical oil company (source:I.P.E.)**

Larger oil companies are generally engaged in crude oil exploration and production. Both in state-owned corporations and private companies, as indicated in Figure 5.2, crude production is often delegated to a different group which reports to the parent organisation. As previously defined for the purpose of this study, crude production is not included within the scope of the implementation and the part of the organisation which is engaged in crude production is treated as an outside supplier.

Crude oil prices are determined by supply and demand rates. Although the market price has beeen relatively stable during recent years, a stable environment can deteriorate rapidly according to political events and decisions. As can be observed from Figure 5.3, the demand for crude oil can undergo significant fluctuations. The crude price is not stable and although a base crude price is accepted by OPEC, as indicated in Figure 5.4, prices can vary within days. Because of the quantities involved, fluctuations about the base price result in significant sums [5.1]. An experienced manager emphasises this point:

" The crude base price can easily fluctuate $2 per barrel within a day. Therefore the opportunity cost of a half a day delayed decision for a 200,000 tonne party is $30,000." [5.1]

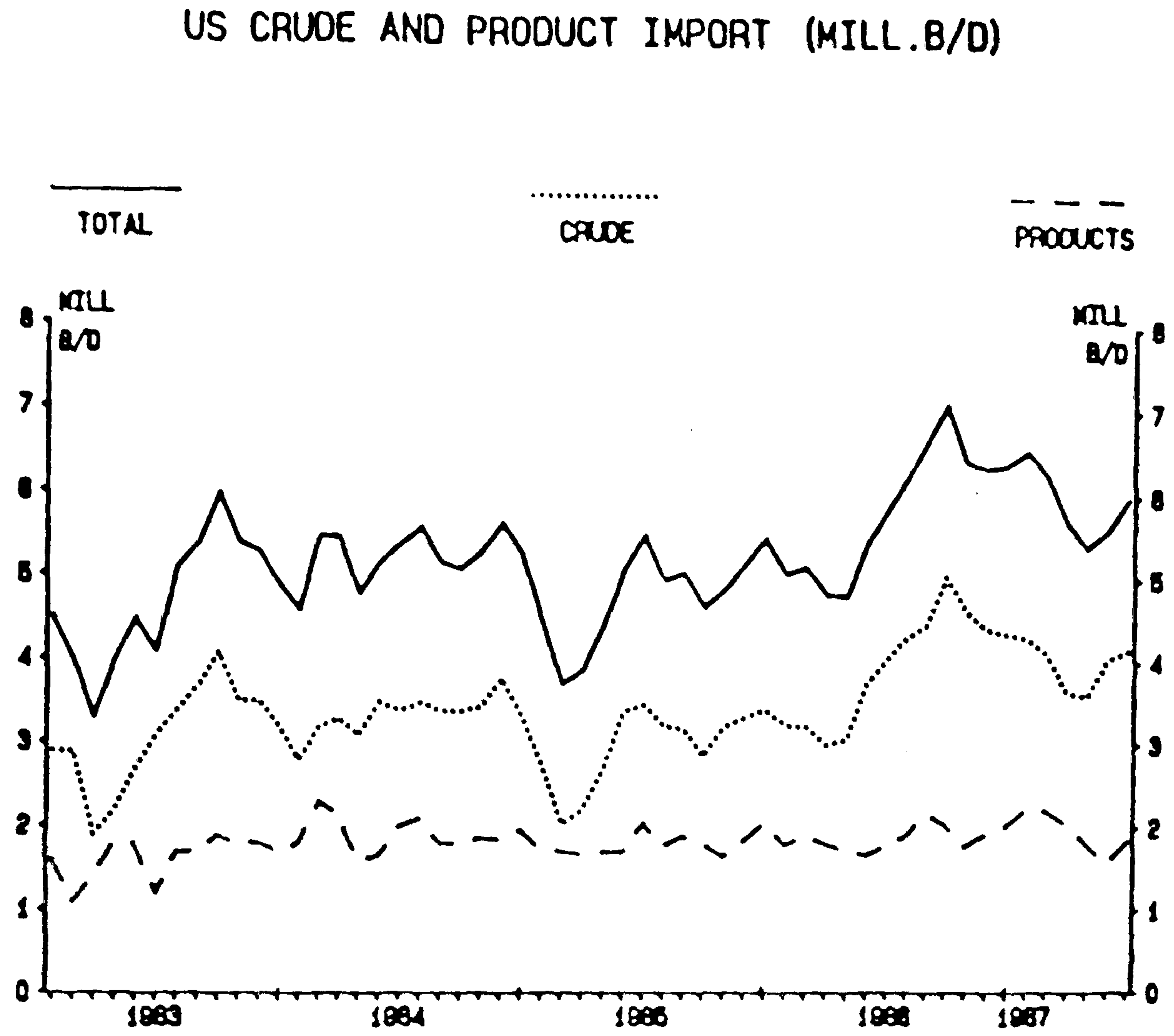



Figure 5.3 U.S. crude import levels (source:Beckstein)

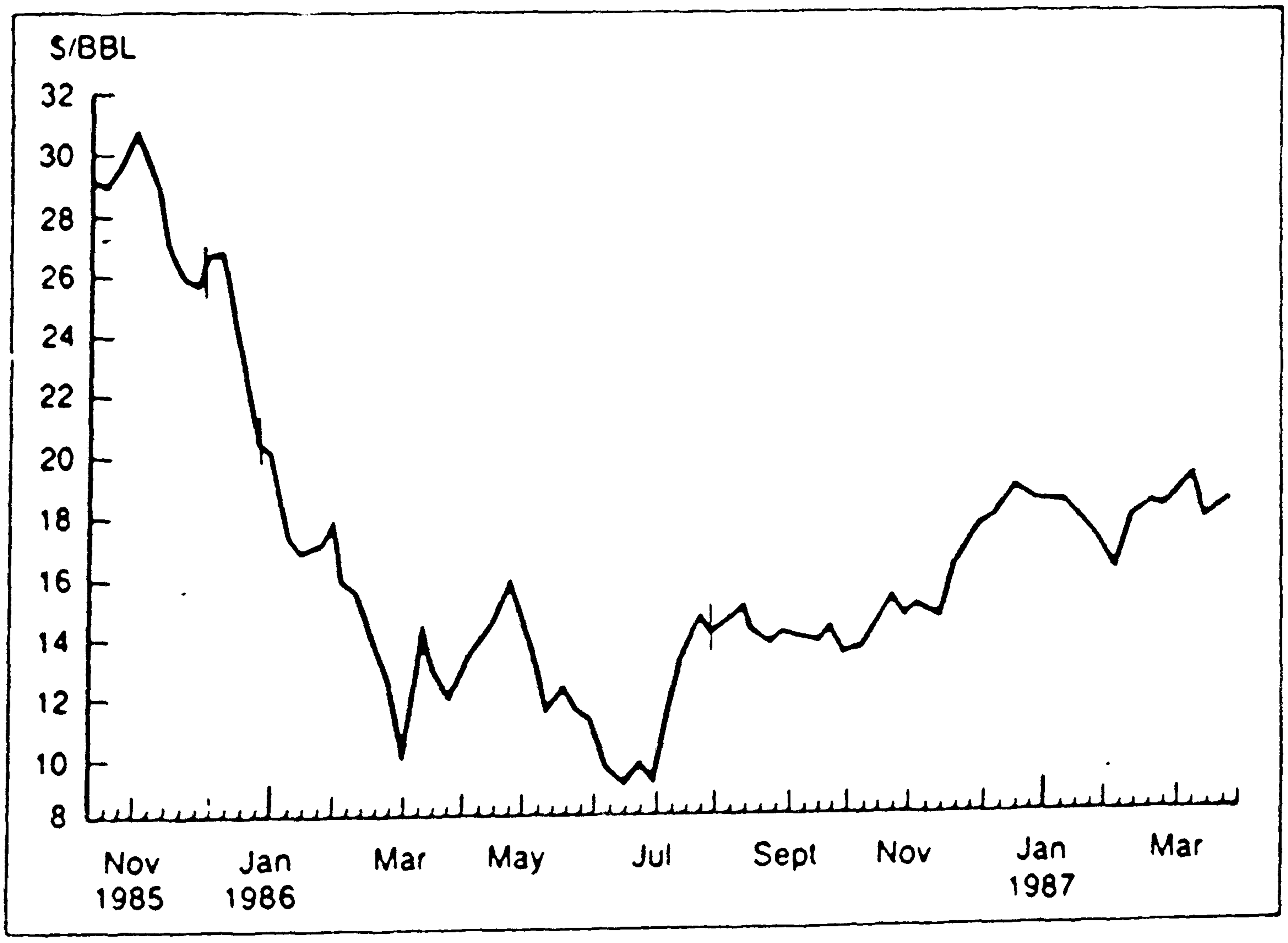



Figure 5.4 Brent blend crude oil spot prices (source:I.P.E.)

Corporations aim to purchase when the price is at its lowest, for a foreseeable future, and to benefit from localised price differentiations between supplier markets. It is therefore essential for the purchasing manager to be provided with information indicating crude price fluctuations at the major supplier markets. Most of the oil companies also operate in direct crude trading, that is, crude sales as well as purchasing [5.1].

Transportation of crude oil to the processing plants is generally through seaborne transportation. In some specific cases pipelines are used as the transportation medium. Maritime crude transportation strategy is primarily influenced by tanker freight rates. A typical oil company owns and operates a number of crude transport tankers which provide only a proportion of the required capacity. The remaining capacity is fulfilled by tanker chartering. Tanker chartering includes two distinct arrangements:

In time chartering, the tanker is usually chartered for an agreed period of time which changes between six months and two and five years. Charter periods in excess of three years are defined as long-term charters and charter periods between six months and three years are defined as short-term charters [5.2]. Tankers which are chartered for more than ten years are regarded as part of the owned fleet. In

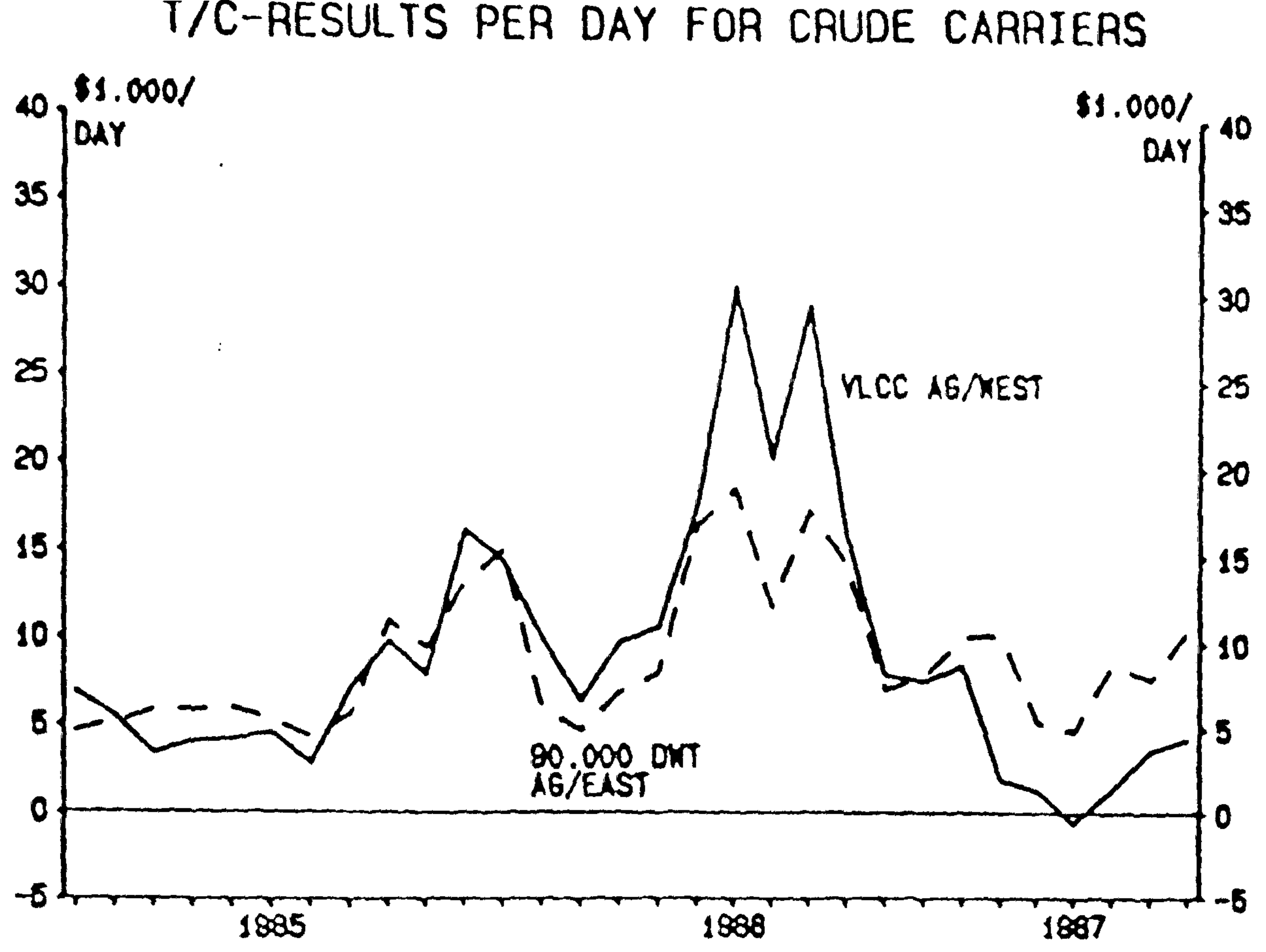



Figure 5.5a Time chartering rates (source:Platou)

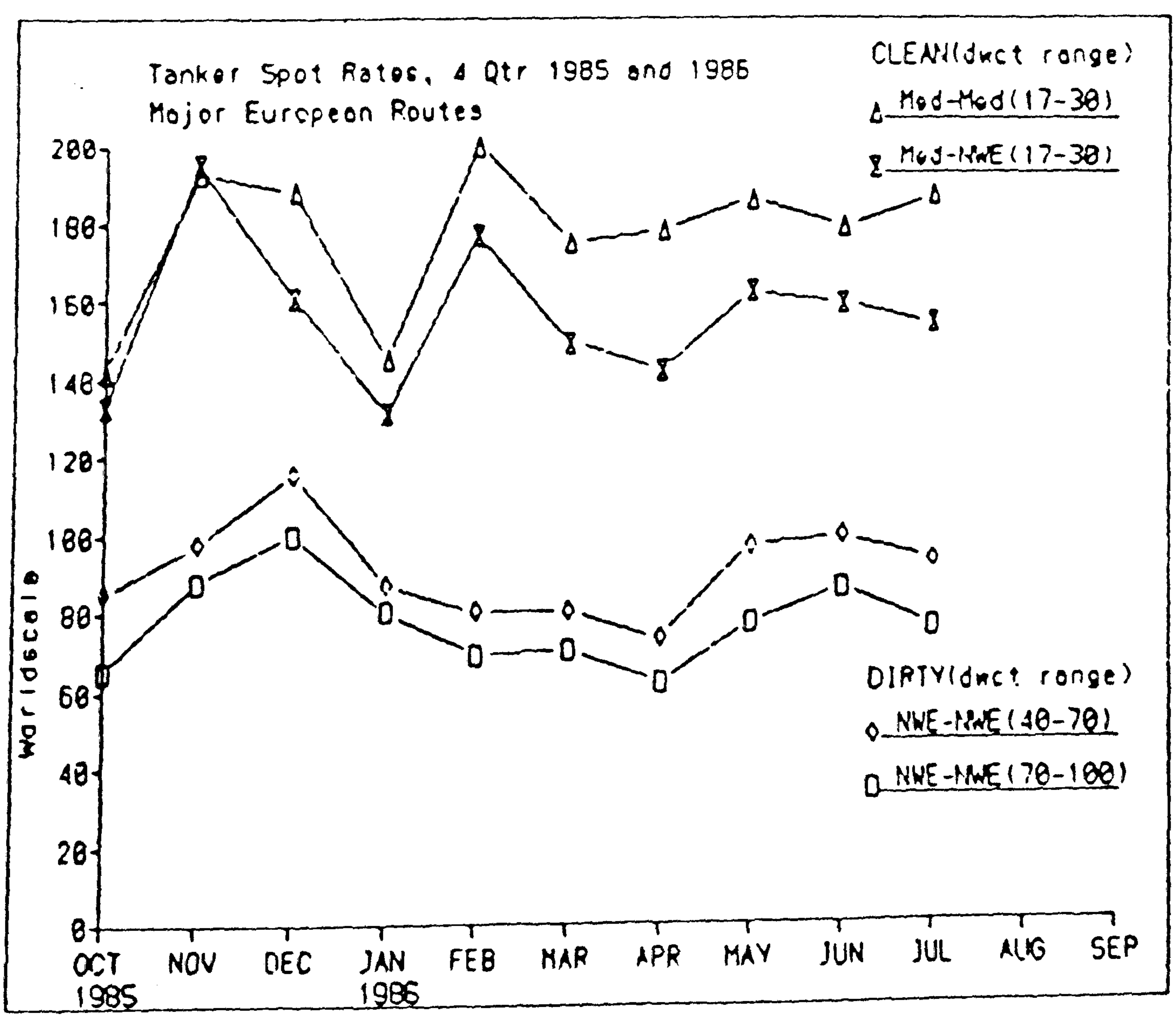


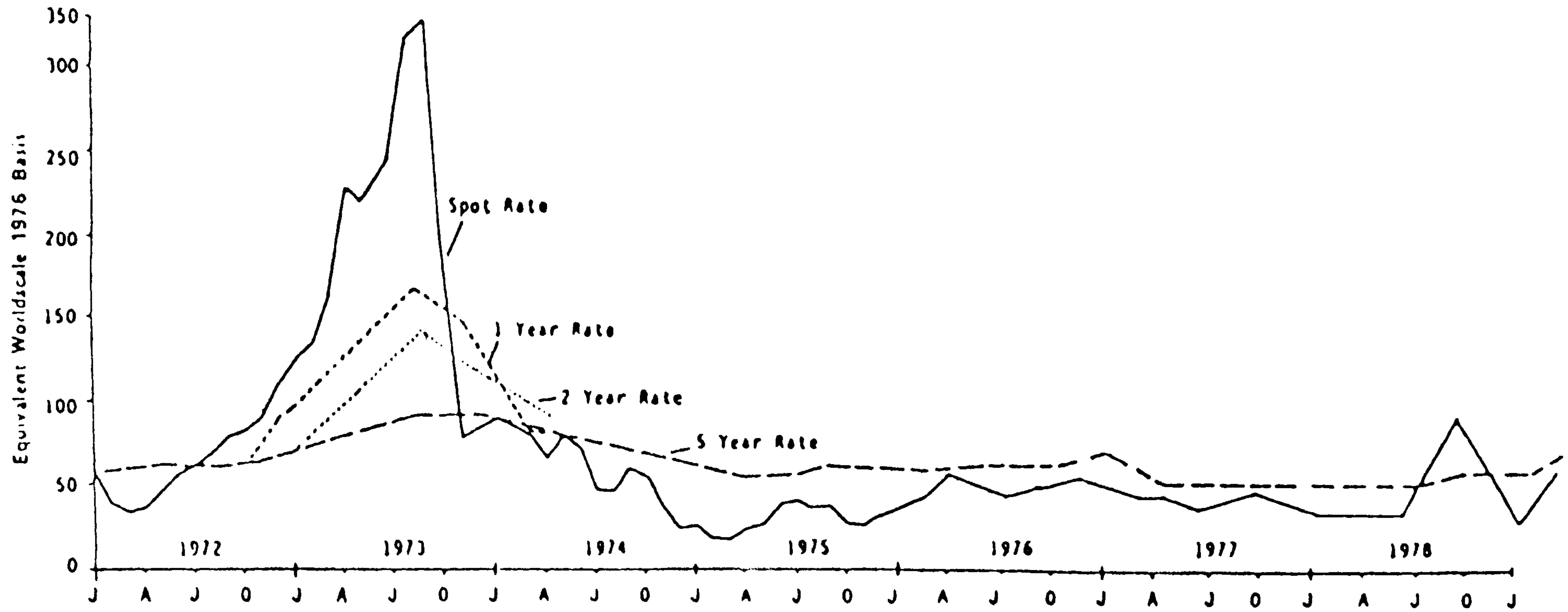

Figure 5.5b Spot chartering rates (source:Energy Shipping)

short-term time chartering, a tanker should be present for service within a month of the chartering arrangement, whereas in distant time chartering a tanker will be present for service at an agreed date in the future.

Time charter rates, although relatively more stable in the short term, can also fluctuate considerably as indicated in Figure 5.5A. Spot chartering prices are very volatile and price range can vary as much as worldscale (WS) five points within a day. On this basis the opportunity cost of a delayed decision in spot chartering a 200,000 tonne crude contract is $60,000 if there is WS 5 points increase during the delayed decision time. As indicated in Figure 5.5B, spot chartering rates vary significantly with tanker types. As can be seen in Figure 5.6, unlike time chartering, spot rates can increase substantially during crisis periods where there is a shortage of tankers. The tanker is chartered for one voyage and generally a spot chartered tanker should be present for loading within twenty four hours of the charter being placed.

Traditional maritime crude transportation strategy is illustrated in Figure.5.7. Owned fleet and time chartered tanker capacity is provided for the constant demand, whereas spot chartering capacity is used to compensate for the fluctuations of the operation. But as the business

COMPARISON OF SPOT MARKET AND TIME CHARTER RATES FOR VLCC'S 1972-1978




Source: J. W. Devanney – Marine Transport Economics, Chapter IV, unpublished manuscript.

Figure 5.6 Comparison of Spot and Time Charter rates (source:Marcus) environment becomes progressively more competitive, companies are forced to adopt a more flexible approach where a dynamic strategy which aims to minimise overall transportation costs is pursued. Such a strategy is only possible where decision makers responsible for the transportation operations have specific information about the various markets and mathematical optimisation tools to evaluate and identify the best combinations resulting in minimum cost solutions.

In order to increase the flexibility of the operation most companies are engaged in external chartering of their available and idle vessels at actual chartering rates, should the conditions be favourable.

In order to minimise distribution costs, process plants are located at various geographical locations. Due to the fact that the major crude supply areas are the same, there is considerable scope for common utilisation of the owned tanker capacity between regional divisions for primary crude transport from suppliers to process plants, and if necessary between process plants. As is illustrated in Figure 5.1,oil companies often sell crude oil back to the crude trading centres such as Rotterdam to benefit from the significant fluctuations in the market.

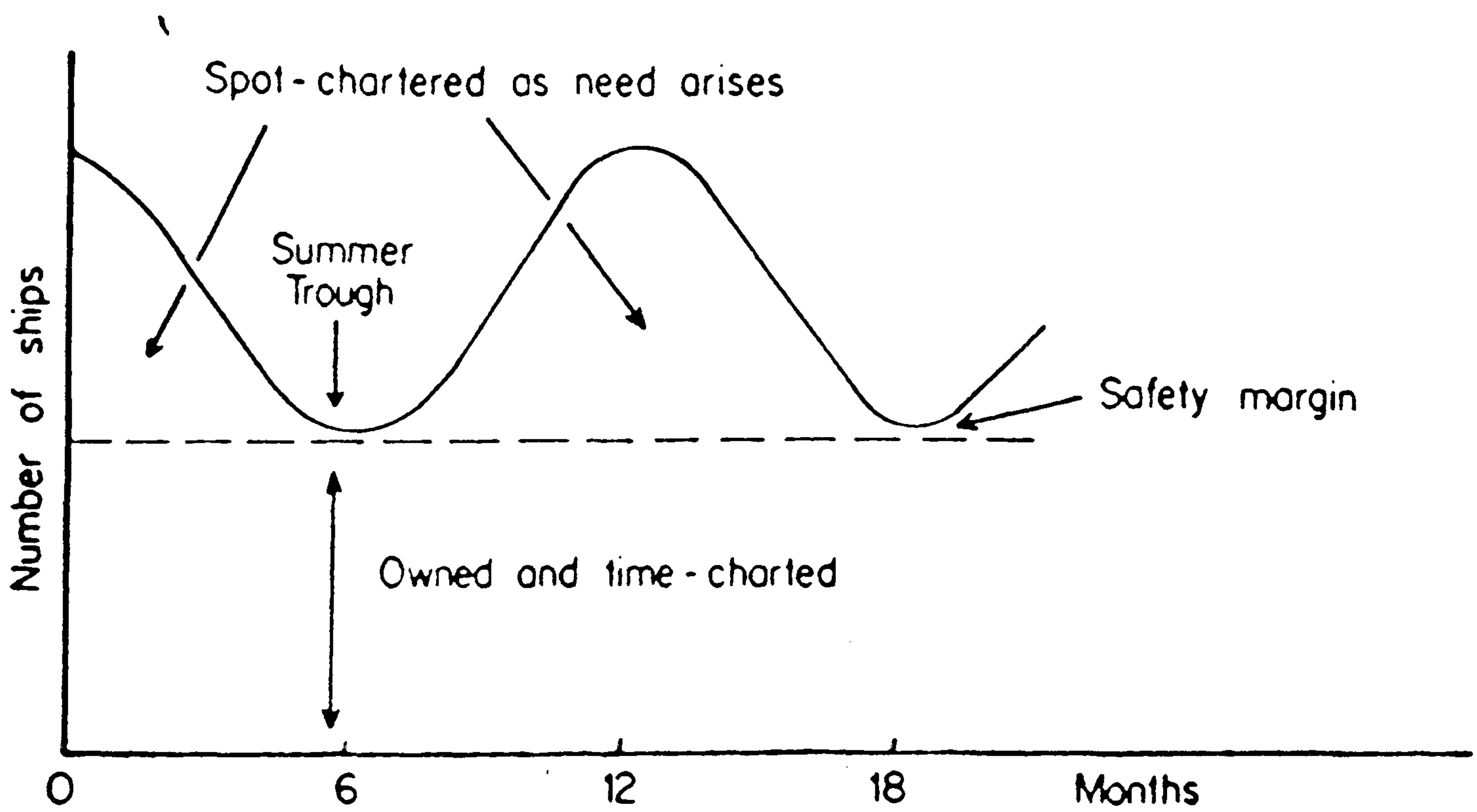



Figure 5.7 Typical maritime transport strategy of an oil company (source:Coyle)

Crude purchasing and supply to the process plants is an extemely complex operation which necessitates close interaction of the Purchasing, Transportation and Crude Stocks management functions. Managers must be promptly provided with information about developments so that the activities are properly co-ordinated. Often operational managers face situations where they have to evaluate the decision environment rapidly prior to arriving at a decision. This evaluation includes the use of quantitative analysis methods such as OR/MS methods. Such cases are further exemplified in the following section.

Crude storage management is responsible for generating purchasing orders according to existing stock levels [5.1]. Crude storage capacity can be a limiting factor for the overall operation. It is not possible for the company to purchase more crude than it can store. Therefore storage facilities of various process plants can be commonly utilised between the process plants. Close co-operation is required between crude storage, purchasing and transportation since, as previously mentioned, these operations are fundamentally interdependent and the opportunity cost of the operations can be significantly reduced with proper co-ordination.

Crude oil is processed at the processing plants in order to obtain products. The processing rates for various products are interrelated. That is, in order to produce a specific product one has to produce other products. Product groups necessitate different storage facilities and tanker types. The demand for the product groups also varies with the dynamics of the particular market environment. Some product markets are much more volatile than the crude market. For instance, as it can be observed in Figure 5.8, according to the international petroleum exchange index, gasoil prices decreased by $40 per metric tonne during January 82 [5.4]. Operational management of the products is even more complex and dynamic than crude purchase and supply operations.

The primary products are liquified gases, gasolines, kerosenes gasoils, diesel-fuels and fuel oils. A typical straight run ratio of these products is respectively 2% for liquefied gas, 23% and 25% for the gasoline and kerosenes group and 55% for the fuel oil group. Since the production of the lighter components is more profitable, process plants are capable of carrying out cracked runs, where the indicated ratios are altered according to the demand. Processing is fully automatic therefore the processing manager who is responsible for the processing operation needs to be informed about the demand levels and the relative costs of alternative processing runs. Storage and distribution present limitations. Unlike crude, certain

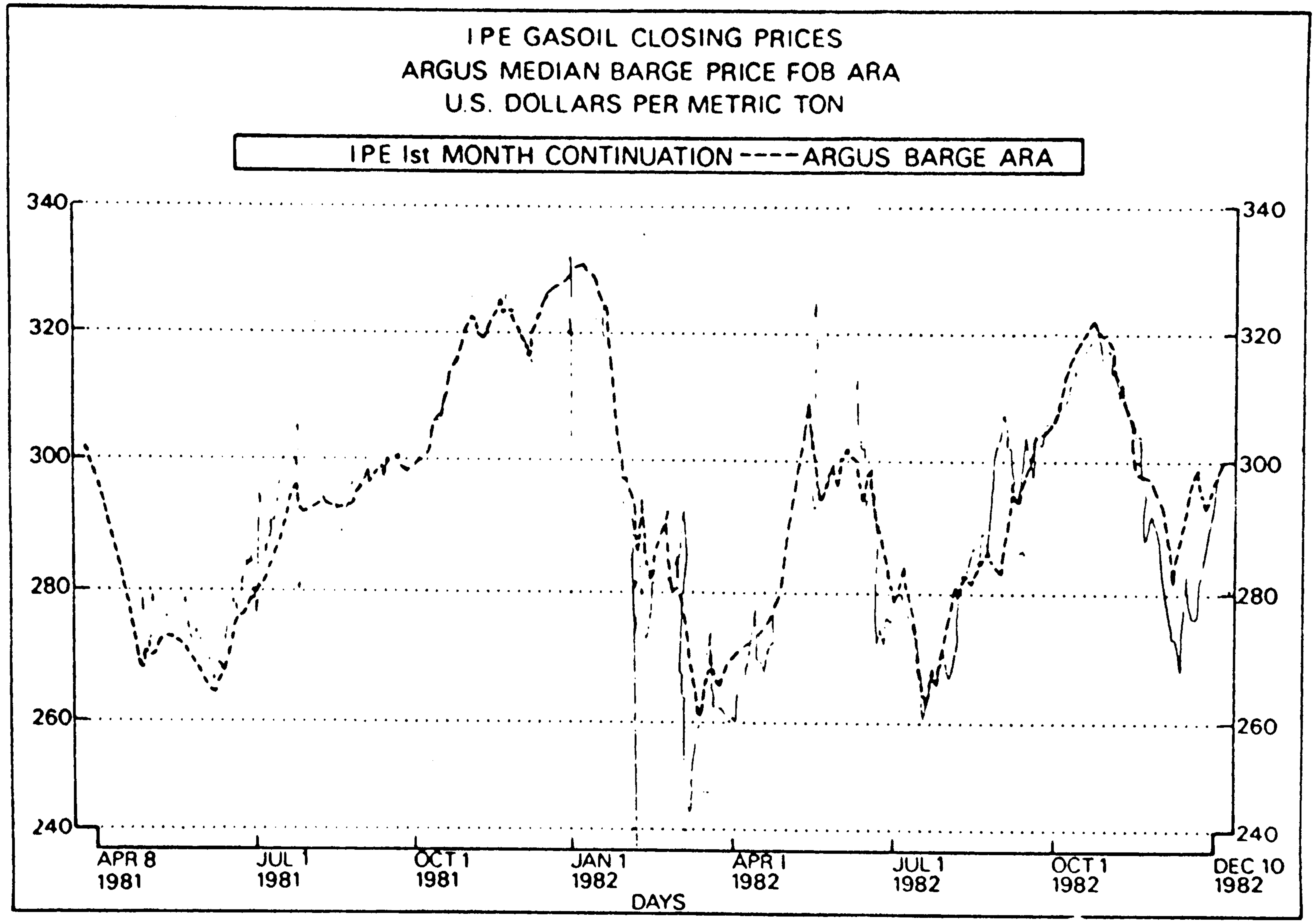



**Figure 5.8 Monthly gasoil closing prices (source:I.P.E.)**

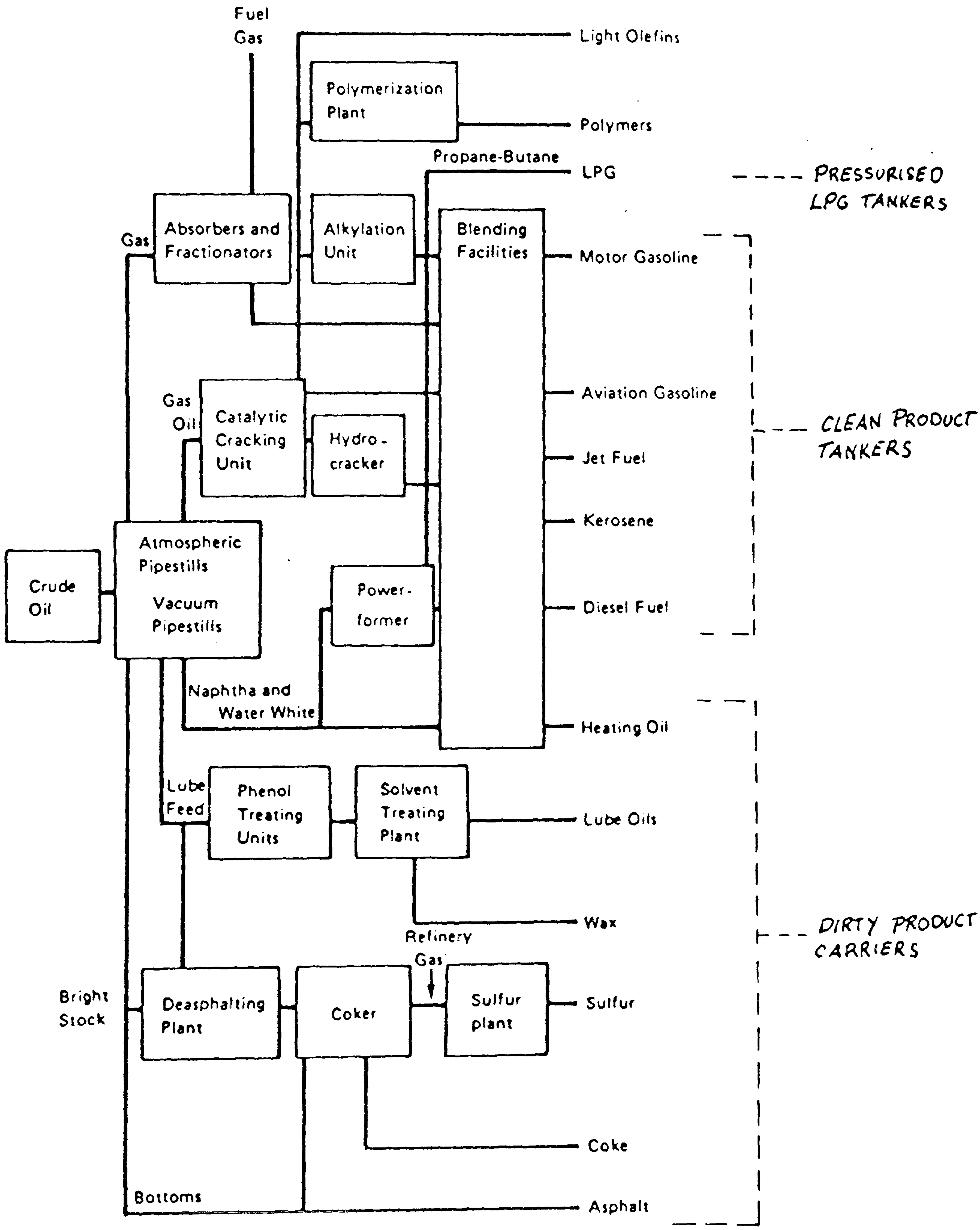



**Figure 5.9 Products of a typical refining plant (source: Green)**

tanker types are suitable for certain products, which further complicates the operation. Figure 5.9 indicates the typical product range with operational management limitations.

Liquefied gas is transported within pressurised tankers of 3,000-75,000 DWT; white products such as gasoil are transported in clean tankers of typically 20,000-30,000 DWT; and heavy products, such as fuel oil are generally transported in dirty tankers of 30,000-40,000 DWT with heating capacity [5.1].

The market dynamics for the products being significantly different and the interrelation of the processing rates increase the need for efficient co-ordination of the distribution strategies between regional divisions. It is essential that distribution managers of a specific product should have information about the product levels at the other regional divisions.

The dynamics of the distribution strategy are similar to the crude supply system. But because the tankers are more specialised, the availability of dedicated vessels is an order of magnitude less than for the crude vessels, thus shifting the emphasis on the owned and time chartered fleet. Product tankers' journey hauls are considerably shorter resulting in more frequent operations and there is therefore significant scope for common utilisation of the product tankers from processing plants to markets and between processing plants.

As previously indicated, the market dynamics of the various product groups can be significantly different. Liquefied gas is primarily used in industry for drying, power production, metallurgical process and chemical feedstock applications. Gasoline and kerosene groups are primarily used in the transport sector. The fuel oil group includes diesel fuels and these are also used in industry.

There are significant differences in product utilisation between regional divisions which are caused by climate, industrial infrastructure, local energy resources etc. This presents scope for exchanging products between the divisions according to the different consumption patterns.

Traditionally, co-ordination of the line management operations which are described above has been carried out through central planning operations where central plans have been prepared at specific time intervals. As the business environment is dynamic, such co-ordination based on central planning is not effective.

Centralised control cannot effectively cope with such a dynamic operational management practice. Control needs to be distributed so that it operates through the feedback loops between various operations. The proposed decision support system will provide a medium for co-ordination of these line management activities at a specific abstraction level.

### 5.2.2. Decision Environment and the Scope of Requirements for Decision Support System

The aim of this section is to emphasise the need for using Decision Support systems in the operational management of typical business operations, and to indicate the scope of the requirements for such systems if they are to be implemented and effectively used. In order to achieve this aim, the decision environment and the dynamics of the decision-making process are reviewed.

Obviously, for the purposes of this work, it is not feasible to cover all possible scenarios. Therefore, a few typical examples, covering various aspects of business operations, are considered.

The main problems and the difficulties of operational managers in oil companies are primarily caused by the complexity of the operations, the degree of interdependence that exists between operations, the uncertanity of the business environment, and the presence of continuous time pressure that is exerted on the managers. Since large sums of capital are tied up with such operations, the effectiveness of the decision process contributes significantly to the overall performance of the company.

A medium-sized oil company may run a number of process plants in different locations, a large fleet of owned, time or spot chartered tankers, and many trading offices operating in a range of products and serving numerous different markets. Most of the operations intersect with each other and there is a common base for various divisions to interact with each other. For typical decision, a number of alternatives and possible scenarios has to be considered [5.1]. Accordingly, the operational environment is complex and dynamic and it requires constant intervention by the operational managers.

" In March 1980, Venture Oil owned or time chartered 16 vessels as shown in exhibit 11.2 (Table 5.1). The Marine Departement moved in the order of 300 thousand barrels per day in its worldwide operations. " [5.2]

Marketing, distribution and storage management operations are interdependent and effective operations requires substantial cooperation of the operational managers.

" For example, if 50,000 tonnes of gasoil sale contract from a specific plant say, Izmit to Hamburg, is delayed for a week due to a transporation failure such as unavailability of the shipment capacity or a mechanical breakdown, and if the gasoil price is depressed say by $10 per metric tonne, the purchaser party will loose $500,000 as a result of this delay and may take legal action to recover its losses. However, in certain conditions this delay may have much larger and more severe consequences : If the clean storage tanks of the plant are full the production rate of gasoil will than have to be reduced. The production rates are interrelated. Therefore, production rates of other products will be reduced and the company will have to breach other contracts." [5.5]

Exhibit 11.2

## VENTURE OIL VESSELS: OWNED AND TIME CHARTERED FLEET

| Owned | Flag | DWT (Summer) | Draft (Summer) | Power Plant* | Year Built | T/C Expiration Date |
|---|---|---|---|---|---|---|
| AMERICAN SPIRIT | Liberian | 271,857 | 69'1" | S | 1973 | |
| CANADIAN LIBERTY | Liberian | 272,426 | 69'2" | S | 1083 | |
| IBERIA | Liberian | 115,851 | 49'9" | D | 1973 | |
| EUROPEAN CHALLENGER | Liberian | 271,685 | 69'1" | S | 1975 | |
| WASHINGTON | Liberian | 270,435 | 69'1" | S | 1976 | |
| NEPTUNE | Liberian | 75,670 | 45'2" | D | 1967 | |
| SEA EXPLORER | Liberian | 71,443 | 41'8" | S | 1964 | |
| LONE STAR | Liberian | 44,328 | 38'0" | S | 1959 | |
| NEW ORLEANS | Liberian | 52,548 | 40'4" | S | 1964 | |
| **Time Chartered** | | | | | | |
| GOOD HOPE | Liberian | 61,928 | 43'3" | D | 1964 | 8/81 |
| SEA GUARDIAN | Liberian | 37,410 | 36'5" | D | 1975 | 2/82 |
| CHAMPAGNE | French | 115,425 | 49'6" | D | 1968 | 10/80 |
| PACIFIC MARU | Japanese | 36,452 | 36'2" | D | 1976 | 2/84 |
| RED SKY | Italian | 20,622 | 31'9" | D | 1959 | 5/81 |
| BEAUFORT | Italian | 20,610 | 31'10" | D | 1958 | 10/80 |
| ODIN 2 | Norwegian | 53,740 | 41'6" | D | 1979 | 12/80 |

* S = Steam Turbine, D = Diesel

Table 5.1 Owned and chartered fleet of a typical medium sized oil company

The business dynamics indicate that primary operations including marketing and maritime transportation, are exposed to volatile external conditions. The uncertain business environment, including crude purchase, spot chartering and product markets, are reflected in Figures 5.4, 5.6 and 5.7. This uncertainty often makes long-term planning very difficult to implement:

" All shipowners are concerned with the future demand of their vessels. In the past, many shipping booms have occurred in conjunction with wars or canal closing --events that are generally impossible to predict. Bulk vessel demand is also affected by worldwide economic conditions (e.g., economic booms, high oil prices, drought), also difficult to foresee with any high degree of accuracy. " [5.2]

The fact that large sums of capital are tied up with the operation, which is subject to uncertain conditions, generates constant pressure on the managers.

" The implications of a decision that you may have to resume in couple of hours are often frightening. For example the capital value of 200,000 tonne of crude is $3.6 million. Based on WS 100, the chartering price of a dirty tanker, say between Bahrain and Izmit is $1.2 million. Therefore the total value of this single shipment is $4.8 million. " [5.5]

Because of these factors it is essential that the managers are continually supplied with the latest information on market developments, the state of events in other operational departments, and tools; for example application programs including forecasting, optimisation and voyage asesessement, which help them to analyse the situation within a limited period of time.

Traditionally, primary operations including Processing, Marketing and Transportation are formally co-ordinated through central co-ordination and planning departments. However, since the environment is complex and dynamic such centralised control in practice is inadequate and often operational managers exchange information through informal communication lines such as telephone conversations [5.1].

This situation is analogous to the main problem of manufacturing systems: How to control a high variety situation ? As is indicated in Chapter Two, traditional production control systems based on centralised mainframe based systems have failed to deliver adequate control functions. Some companies, such as Toyota, have recognised the problem and systems based on centralised operational control are replaced with 'Kanban'systems based on distributed self-organising control enabling regulation to be directly and autonomously executed between production cells.

Traditional 'backward looking' information systems are not suitable as a formal communication medium for such applications.

The decision environment of operational managers is exemplified as below for certain cases:

As previously described, significant line management operations within a regional division involve purchasing supply and crude inventory management as well as production planning, products inventory management, distribution and sales.

There is a close interdependence and information exchange between crude oil purchasing, transportation and inventory control operations. The same interdependence and information exchange exists on a larger scale between products inventory control, distribution and marketing operations because shipments are more frequent and the product range is wider.

However, interaction between production and both crude and inventory control operations, is straightforward and limited because processing, unlike manufacturing, is completely automated and, simplistically, product stock levels dictate processing rate and in turn crude depletion rates.

The following hypothetical but typical case involving two process plants and one regional purchasing and supply services organisation exemplifies the nature of the decision environment:

" Process Plant X has 43,500 cubic meters of crude depletion capacity. At a normal 60% processing rate it depletes 22,000 tonnes of crude oil. The minimum storage requirement at the site is 30,000 tonnes which is sufficient for a week's production at 10% capacity. Process Plant Y having 28,000 cubic meters depletion capacity and at 70% capacity consumes 17,000 tonnes of crude per day. Crude purchasing for both plants is executed from the same sub -organisation providing purchasing and transportation services. At this moment the organisation has 200,000 dwt, 110,000 dwt and 80,000 dwt crude tankers available for operation. It operates 150,000 dwt and 125,000 dwt time charters commited to other jobs. Let us assume Process Plant X ordered the purchase of 120,000 tonnes of a party to be delivered on site in four weeks and the following day process Plant Y ordered the purchase of 150,000 tonnes of crude to be delivered in five weeks. " [5.1]

The primary task of the purchasing manager is to meet the crude oil requirements of Plants X and Y within the requested time period at a minimum cost. Completion of the task is also dependent on the performance of the maritime transportation option.

In this situation, the immediate decisions that have to be made by the purchasing manager are as follows :

i. type of the contract; whether maritime transport is to be provided by contractor or by the organisation itself

ii. potential contractor selection; competitive tender between brokers, direct purchase from producers i.e Gulf, or spot markets i.e Rotterdam or Genoa

iii. purchase strategy; i.e purchase all requirements in one party, or two parties, or if feasible initially supply Plant X from existing stocks in Plant Y

iv. as well as meeting these specific orders, make crude purchase (or sale) if the market conditions are suitable.

Obviously, the purchasing manager needs to be provided with a constant supply of information about the crude prices at various markets:

" There may be substantial differences between different markets. For example it is normal to have base rate + $0.5 per barrel in one market, say Rotterdam, or base rate - $0.75 per barrel in the Gulf." [5.6]

A difference of $1.25 per barrel between two markets is equal to $187 per tonne and the resulting cost offset for a total of 120,000 tonne party would amount to $22 million.

However, the crude price can change substantially within weeks. As can be observed from the Figure 5.3, between December 85 and January 86 it was depressed by $4 per barrel. For instance, if operationally feasible, a delay of 3 days in the purchasing decision would result in a decrease in the purchasing cost of $1.8 million. Alternatively a delay of 3 days during July 86 would increase the cost by $3 million.

Such are the implications of the decisions. It is essential that the purchasing manager is provided with quantitative support tools as well as a continuous supply at his fingertips of external information about crude movements in various markets. For example, he needs to be provided with a forecasting facility which enables him to predict crude oil price fluctuations as well as uncertainty analysis methods. A relational data base on actual and potential suppliers including the progress of contracts is essential for effective operations.

The decision environment may be further complicated by the fluctuations and uncertainties of the maritime transportation market:

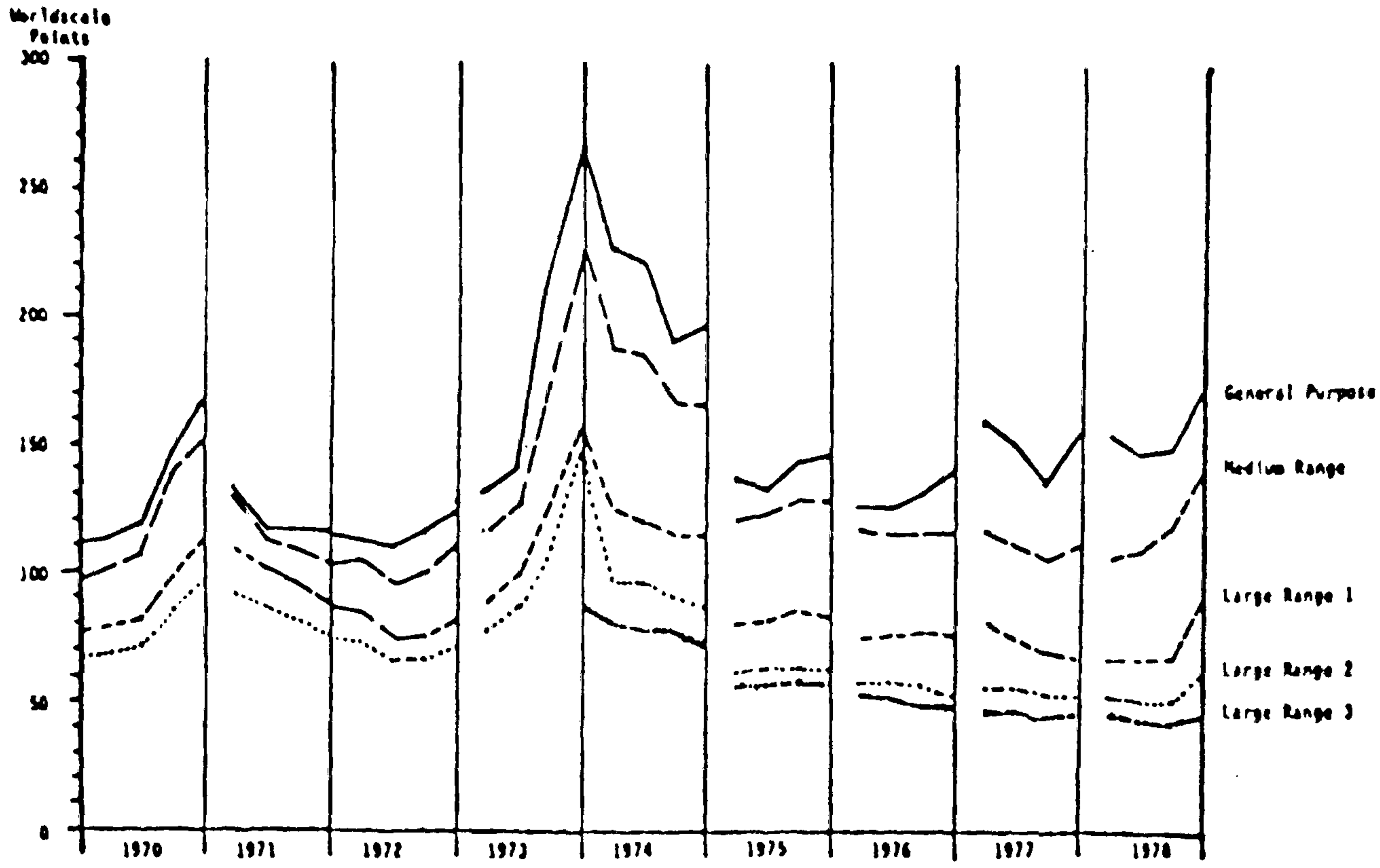
Owned or time chartered tankers may be committed to other jobs. Owned tanker capacity may not be economically feasible for the required assignment. For example if the only available tanker is 110,000 dwt then it would be too small for the assignment. If the time period is feasible then the vessel could fulfil the job in two parties at 50% efficiency.

Spot chartering for the required duty may not be available or the charter rate for the favourable crude market may be higher than the unfavourable market and it may be more profitable to purchase the required party from a more expensive market. Such decisions require the realities of different operations to be jointly considered.

The object of the transportation manager is to meet shipment requirements at a minimum cost. For a medium-sized oil company such as Venture Oil operating a range of owned, time chartered, and spot chartered tankers, as shown in Table 5.1 overall optimisation of the operations for different shipment contracts is a complex task, and often because of the nature of the operational transactions significant opportunity costs are incurred.

As is indicated in Figures 5.4, 5.5, 5.6, in both time and spot chartering, operations are subject to different market dynamics. Market dynamics are different for operational routes such as Gulf/Rotterdam, Genoa/Rotterdam. A further complication is caused by tanker deadweight groups. As indicated in Table 5.2 and Figure 5.10, market dynamics represent significant differentiations for different tanker deadweight groups. A typical marine transportation department of an oil company is indicated in Figure 5.11. In this example, the vessel trading and traffic division is responsible for operational management activities. A typical operational management sub-division of an oil company is as indicated in Figure 5.12.

AVERAGE FREIGHT RATE ASSESSMENTS
WEIGHTED AVERAGE OF ALL PERIOD AND VOYAGE CHARTERS
1970-1978




Source: London Tanker Brokers' Panel.

**Figure 5.10 Chartering rates of varying tanker capacities (source:Marcus)**

LONDON TANKER BROKERS PANEL

Details of Breakdown of AFRA Monthly Assessment
for Vessels of 16,500/549,999 DWT
Covering Period March 16, 1980 to April 15, 1980

| | DWT | Percent | WORLDSCALE Points |
|---|---|---|---|
| General Purpose (16,500-24,999) | | | |
| Company | 1,241,243 | 64.5 | 255.9 |
| Long Term | 347,699 | 18.1 | 239.9 |
| Short Term | 178,377 | 9.3 | 249.0 |
| Single Voyage | 156,425 | 8.1 | 299.5 |
| | 1,923,744 | 100.0 | 255.9 |
| Medium Range (25,000-44,999) | | | |
| Company | 3,826,509 | 52.1 | 198.0 |
| Long Term | 939,298 | 12.8 | 154.4 |
| Short Term | 786,146 | 10.7 | 215.0 |
| Single Voyage | 1,793,940 | 24.4 | 213.3 |
| | 7,345,893 | 100.0 | 198.0 |
| Large Range 1 (45,000-79,999) | | | |
| Company | 6,797,014 | 31.6 | 121.3 |
| Long Term | 4,865,287 | 22.6 | 98.5 |
| Short Term | 2,319,462 | 10.8 | 137.7 |
| Single Voyage | 7,525,203 | 35.0 | 130.9 |
| | 21,506,966 | 100.0 | 121.3 |
| Large Range 2 (80,000-159,999) | | | |
| Company | 12,670,980 | 32.4 | 79.6 |
| Long Term | 10,688,785 | 27.3 | 79.3 |
| Short Term | 3,691,763 | 9.4 | 78.5 |
| Single Voyage | 12,075,067 | 30.9 | 80.2 |
| | 39,126,595 | 100.0 | 79.6 |
| VLCC (160,000-319,999) | | | |
| Company | 49,431,900 | 49.1 | 49.8 |
| Long Term | 34,249,724 | 32.7 | 57.2 |
| Short Term | 3,896,613 | 3.7 | 46.2 |
| Single Voyage | 17,311,547 | 16.5 | 35.9 |
| | 104,889,784 | 100.0 | 49.8 |
| ULCC (320,000-549,999) | | | |
| Company | 7,658,942 | 46.9 | 42.4 |
| Long Term | 4,373,295 | 26.8 | 54.1 |
| Short Term | 1,230,890 | 7.5 | 38.5 |
| Single Voyage | 3,078,187 | 18.8 | 27.4 |
| | 16,341,314 | 100.0 | 42.4 |

**~~Table 5.2 Chartering~~ rates of tankers of varying capacity (source:Marcus**

In a real life situation such a company is responsible for providing maritime transportation capacity for a number of process plants. External vessel leasing operations are engaged in chartering owned vessels to external clients.

The co-ordination of different operations with the purpose of optimising the job allocation between various tankers is a major task and, as indicated previously, is often not fully achieved resulting in substantial loss through opportunity costs.

The decision environment of a simplistic crude transportation operation for the given example is as follows:

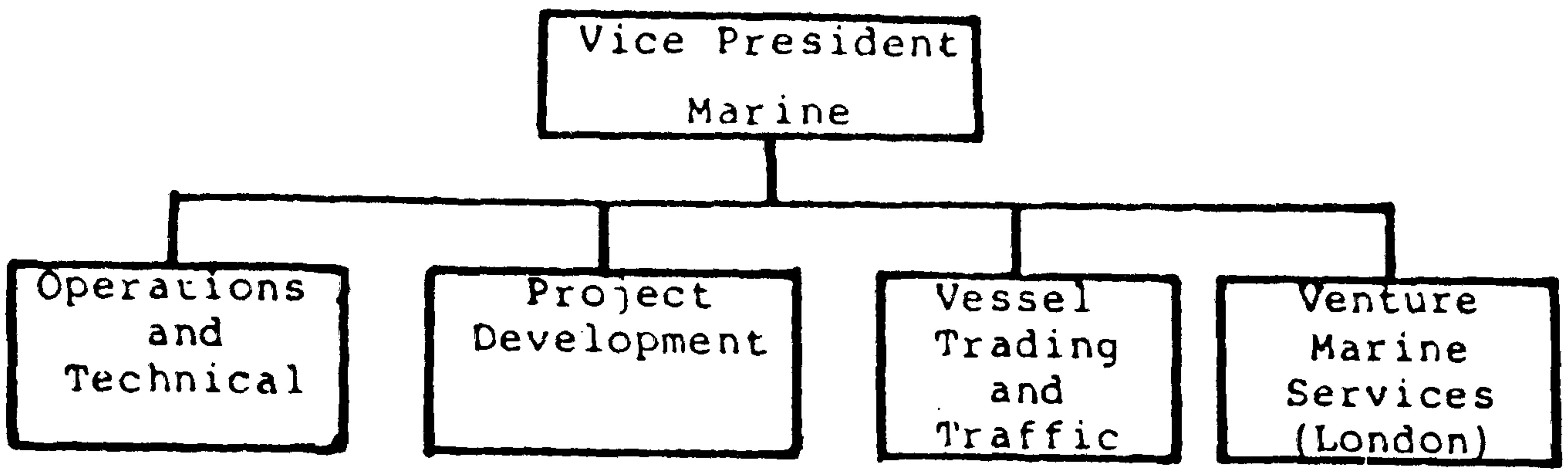
i. allocation of the 120,000 and 150,000 tonne parties between the available owned vessels at a minimum cost considering overall operational costs of these tankers and their geographical location,

ii. switch existing time charters to this assignment and obtain new time charters for the other ongoing job,

iii acquire new time charters; external leasing of the owned tankers can be more profitable,

iv. acquire spot chartered tankers for one-off assignments,

## MARINE ORGANIZATION




**Operations and Technical**

Basic Functions:

a. Operations, personnel, safety, and repair policy for Venture Oil vessels
b. Port information and port limitations
c. Vessel newbuilding
d. Local, national, and international rules and regulations.

**Project Development**

Basic Functions:

a. Capital budget/profit objective
b. Economic analyses

   1. Vessel acquisition
   2. New trade alternatives
   3. Special marine projects.

c. Computer projects.

**Vessel Trading and Traffic**

Basic Functions:

a. Scheduling vessel movements
b. Monitoring daily tanker charter market
c. Chartering term and spot coverage for Venture Oil's marine transportation requirements
d. Ship sales and purchases
e. Trafficking in all-owned, time chartered, and single-voyage chartered vessels in the worldwide trades
f. Contract administration.

**London**

Basic Functions:

a. Supervisor of deck operations and navigation
b. Engineering and related services
c. Safety
d. Manning
e. Training
f. Vessel inspection, ship repair and maintenance
g. Vessel storing.

**Figure 5.11 Organisation and activities of a typical marine transportation departement of an oil company**

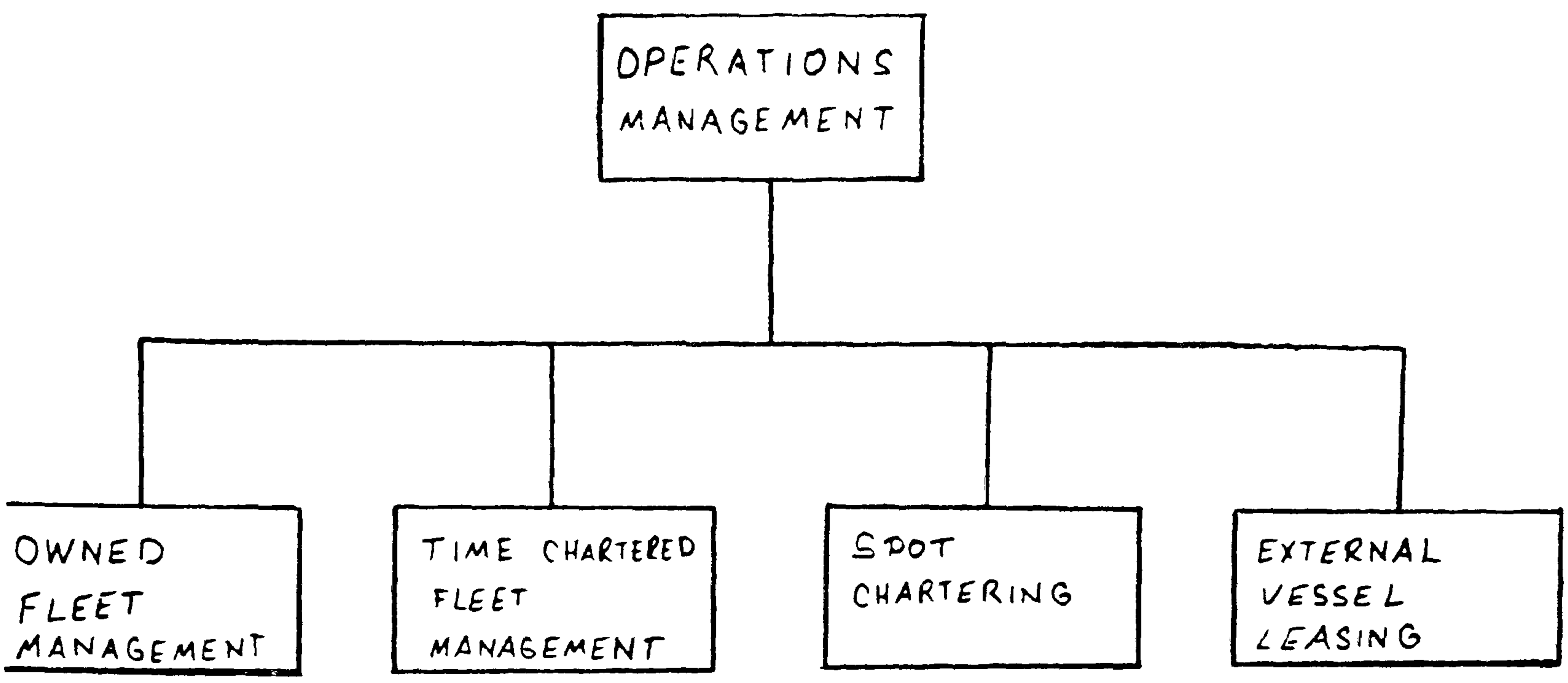



**Figure 5.12 Typical operations departement subdivision of an oil company**

v. acquire new tankers; this option is feasible only if there is an increasing capacity shortage or the speculative market conditions are favourable.

The optimal solution to this problem requires simultaneous consideration of all activity areas. There is substantial scope for using OR/MS methods. In practice such methods are not used because there is no time to collate information from various divisions and to analyse it by computer models. The importance of the time element can be further emphasised by pointing out the fact that, even during the negotiations with a ship owner for a spot chartering deal, there are substantial price fluctuations from the daily rate.

Accordingly, the basis of the operational management decisions is crude, and only ball park comparisons are possible. Mr Cogendez of Cerrahoglu Tanker Trading indicates the following:

" During the course of the operations, the most sophisticated evaluations are done on the back of an envelope. It is just not possible to obtain information from other brokers and to decide accordingly within the available time." [5.6]

However, with the existing technology it is feasible and possible to provide a communication system between the operators where information which is essential for certain decisions is continually exchanged between operators and the operational manager of the crude supply operations can optimise operations by using OR/MS models.

For example Figure 5.13 indicates the use of a linear programming OR model co-ordinating maritime transport operations as a decision support tool. According to the transportation requirements which are supplied to the sub operation managers, various parameters such as available owned tonnage or spot chartering costs are evaluated at each sub-operation and fed back to the operations manager. By using OR models, the operations manager canco-ordinate and optimise assignments more effectively than the traditional practice.

According to the nature of the operation there is substantial scope for using different models at different levels of detail. Mr Bozo of Burko Novi Chartering, Milan, indicates the following:

" We have in-house computer programs for various applications but we cannot use them effectively, because when you are negotiating a chartering agreement over the phone you don't have time to play around with computers. You have to make sure that information is updated all the time." [5.7]

For example a voyage analysis model, including sensitivity

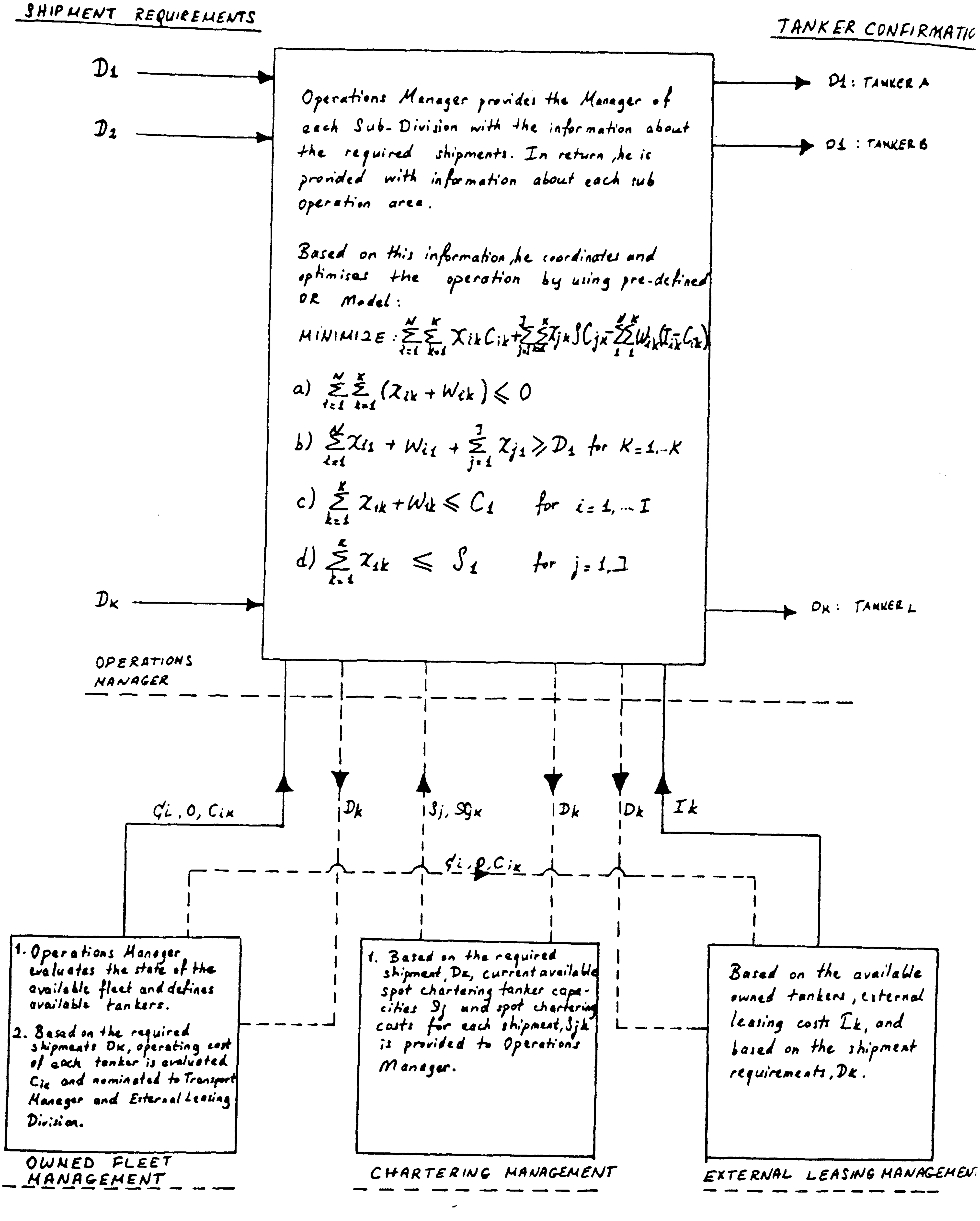



**Figure 5.13 Notional schematic indicating the use of OR as a co-ordination tool**

analysis options such as increasing or decreasing the values of for instance bunkering costs, would be a useful tool. But to be effective, the latest information which is normally used in voyage analysis must be present in the computer.

Evaluation of freight rates or cruising speed often requires complex calculations which must be carried out within a limited time period during the negotiations. Here again there is substantial scope for implementing MS/OR at lower levels of the decision hierarchy.

There is also substantial scope for using such models at higher levels of the hierarchy. They can be used as an investment analysis tool especially when managers are dealing in speculative tanker sales purchasing or chartering operations. A case study has been prepared by Marcus, with the aim of developing a methodology to assist Ogden Marine, Inc (OMI) management in analysing hold/sell decisions for vessels of this company. The entire OMI fleet is then examined in the light of this methodology. However, Marcus, points out that for such high level important decisions, quantitative evaluation through MS models cannot be sufficient and effective, and a methodology must incorporate qualitative considerations:

" It is important to realise that the required charter rate analysis is only a helpful guideline, and that qualitative evaluation based on management's continuous interaction with the shipping market is the key element to successful implementation of OMI's strategy." [5.2]

Table 5.3 indicates the quantitative and qualitative considerations that are included within the scope of this methodology which are provided for such high level decisions. It is also interesting to note that the magnitude of the losses caused by the recent stock market crash has been mainly blamed on the fact that the decision process controlling share sales has been in many significant instances delegated to computers without any qualitative considerations and human judgement [5.8].

The aim of this section has been to indicate that there is substantial scope for using information systems and quantitative analysis tools such as OR/MS at different levels of the decision-making hierarchy provided that the systems conform to the requirements of the users and the business environment.

Table 5.4 indicates a compilation of the OR/MS models which have significant scope for implementation at the various levels of the operational decision-making hierarchy in a typical crude maritime transportation division of an oil company.

Although there is substantial scope for implementation, the use of such methods is not widely accepted in the industry for various reasons:

1. Examine the sale and purchase market and estimate the current charter-free price for each vessel.
2. Subtract the scrap value from the price to determine the present investment in the vessel as an operating entity.
3. Calculate the annual revenue required to recover this investment during half of the vessel's remaining economic life.
4. Add the annual operating cost of the vessel to the required revenue.
5. Basis the vessel's deadweight and estimated operational days/year, derive the required time chartered rate.
6. Compare the required rate with:
    a. That vessel's current rate, if under short-term time charter.
    b. Spot rates.
    c. One, two, and five-year rates*.
    d. Ten-year payout rate based on a newbuilding contract price.
7. As a reference, compare the charter-free market price of each vessel with its book value.

i_ QUANTITATIVE ANALYSIS

1. Future market trends.
2. Age, condition, and technical obsolescence of company vessels.
3. Age and technical profiles of the relevant competition; backlog of newbuilding orders.
4. Impending regulatory changes.
5. Fit of the vessels in the fleet based on the principles of:
    a. Portfolio management.
    b. Admissible risk (i.e., the maximum risk OMI can tolerate on a vessel deal).
    c. Opportunistic nature of shipping.
    d. Principle of speculative acquisition (see Exhibit 7.3 for explanation).
    e. Environmental risk.
6. Book profit or loss that might result from a sale. (While this is not a relevant consideration when evaluating the market, the impact of a sale on earnings-per-share cannot be ignored.)

ii_ QUALITATIVE CONSIDERATIONS

**Table 5.3 Typical analysis requirements in a tanker purchase scenario: Comparaison of Qualitative and Quantitative aspects (source:Marcus)**

Mr Cengizer, operatins manager of DITAS, points to the importance of the operational manager being personally involved with the development of any tools which will be used by managers:

" After a number of unsuccessful projects we finally commissioned Burroughs people for the development. I was personally involved with the development of the system, working very closely with Burroughs analysts. As a result I know the system inside out and I can directly use it when I need it." [5.5]

Mr Erdogan ex-president of TUPRAS -Turkish National Oil Company indicates the following :

" A computer system which will be used in an oil transportation environment must be adaptable. Otherwise, as often happens, it will become obsolete and you need new development projects for replacement. It is a costly, endless circle." [5.9]

Mr Folds of Alter Marine, points to the significance of user-friendliness of computer-based systems :

" You have to be a computer person to understand and operate our systems."[5.10]

There is also significant scope for implementing such systems in other areas of the operations management of a typical oil company. The following is a brief summary of the decision dynamics relating to these areas:

| OPERATION / MODEL TYPE | CRUDE PURCHASING MANAGEMENT | CRUDE TRANSPORTATION MANAGEMENT | CRUDE INVENTORY MANAGEMENT | PRODUCTION MANAGEMENT | PRODUCTS INVENTORY MANAGEMENT | PRODUCTS TRANSPORTATION | PRODUCTS MARKETING |
|---|---|---|---|---|---|---|---|
| **1. OPERATIONS RESEARCH** | | | | | | | |
| 1.1. Linear Programming | | • | | • | | • | |
| 1.2. Investment Analysis/ Engineering Economics | • | • | | | | • | • |
| 1.3. Bayesian Analysis | • | | | | | | • |
| 1.4. Uncertanity Analysis | • | • | | | | • | • |
| 1.5. Forecasting | • | • | • | • | • | • | • |
| 1.6. Simulation | | | | | • | | |
| 1.7. Network Flows | | • | | | | • | |
| 1.8. Resource Allocation | | • | • | | • | • | |
| 1.9. Inventory Planning | | | • | | | • | |
| 1.10. Production Planning | | | | • | | | |
| **2. SYSTEM SCIENCE** | | | | | | | |
| 2.1. System Dynamics | | | • | • | • | | |

**Table 5.4 A compilation of OR / MS models by type of the application**

In processing plants, physical crude processing is fully automatic. Therefore, production rates are limited by the existing plant capacity and alternative cracking proportions. Evaluation of the optimum production rates by defining cracking ratios according to the product stock levels is the primary task of the production manager. His environment, being relatively more structured and less uncertain, allows a large proportion of the optimisation oriented decision strategies to be delegated to the decision support system. It is important to note that most modern processing plants are provided with product supply information and if such a support system should be available, his function will primarily be to monitor the performance of the existing system.

Distribution of products is achieved through interaction between the product distribution and marketing divisions. Figure 5.14 indicates the production distribution system of a typical oil company.

The primary task of the products distribution manager is to provide the required transportation capacity for distributing products to the markets. The decision environment, information needs, and quantitative support needs are therefore similar to the needs of the crude supply manager. However, products maritime transportation is more complex than crude supply because, as indicated in Figure

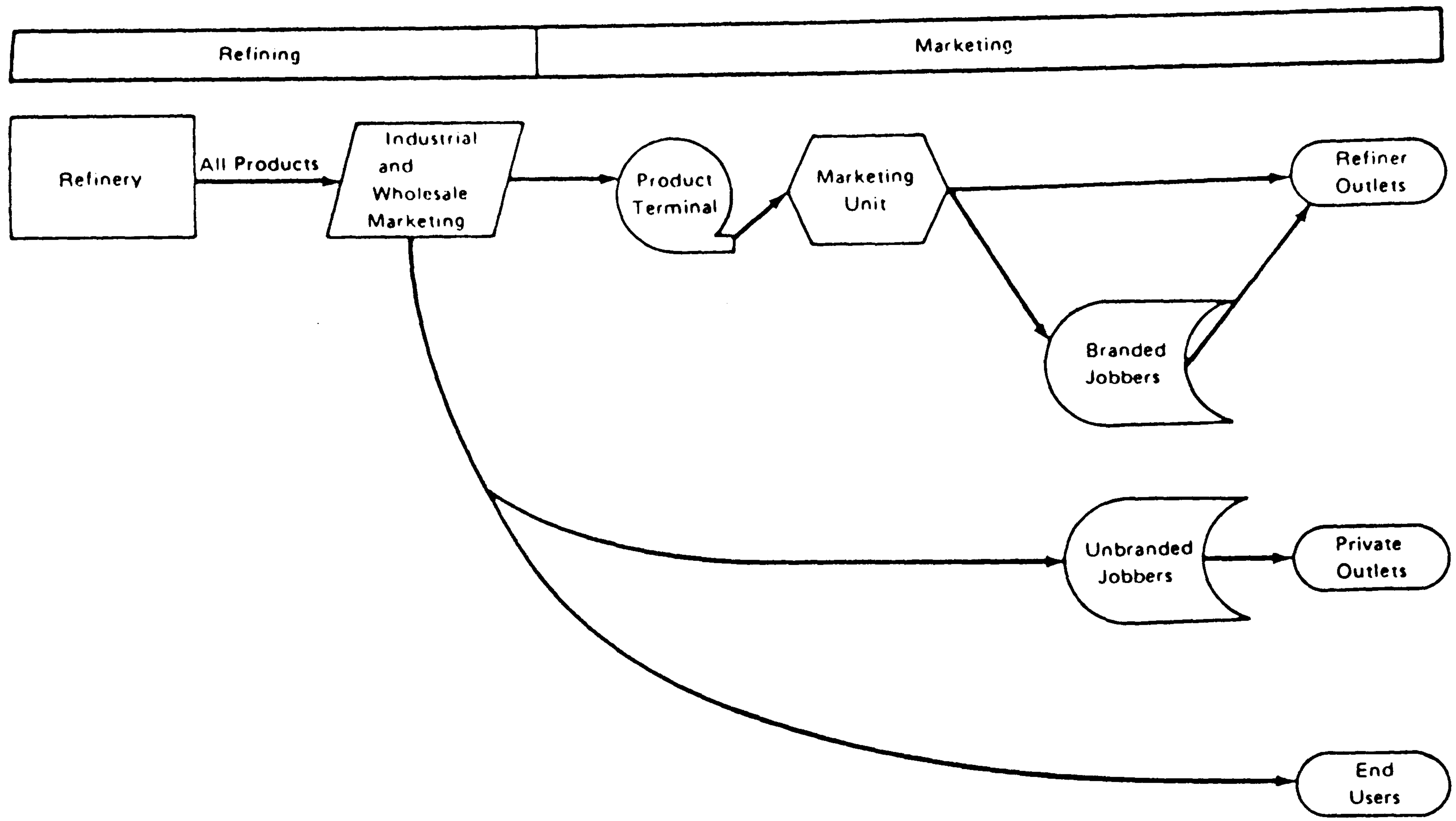



**Figure 5.14 Products distribution system of a typical oil company (source:Coyle)**

5.9, some tankers are only suitable for transporting certain products.

The transportation manager is expected to achieve his objectives while adopting a transportation strategy that allocates work between his owned chartered fleet and the vessels owned by the company. The transportation manager needs to be provided with market information about chartering conditions, interdivisional information about the quantity of products that needs to be transported to the branded and unbranded jobbers, and information about the status of the vessels that are owned or chartered by his department.

In order to optimise transportation operations, the transport manager must be supplied with regular information from managers of other departments and managers of the transportation sub-operations.

Line managers need to be provided with a data base about the state of each vessel, operation research software enabling them to optimise transportation strategies, and on line simulation models enabling them partially to delegate management functions of more trivial operations to the system.

According to the new trends in management practice, the responsibility for strategic decisions is increasingly delegated to the line management. This necessitates integration of the strategic plans with actual operational management providing feedback connections between strategic plans and progress of the operational situation. As a consequence of this, line managers need a tool which enables them to identify operational situations of strategic importance.

Strategic decisions which directly relate to the business operations consist of a product performance evaluation. That is, to evaluate which products are performing relatively better in which regional markets; marketing performance compared with other competitors; the expansion or reduction of the owned fleet for both crude and product transportation; the capacity increase or decrease with regard to processing crude and product in processing plants.

Delegation of the strategic decisions to the line managers is especially beneficial for the transportation function, since the tanker market provides significant opportunities with regard to the purchase of new tankers at prices well below market conditions.

The issues that have been addressed obviously cover only a proportion of the typical operational management's activities in the oil industry. However, they are addressed to point out the large potential for implementing 'forward looking' information systems, OR/MS models according to the needs of the users and the business environment and in order to increase the operational effectiveness of these operations.

## 5.3 Development of the Proposed System

### 5.3.1. Identification of Decision Units and Information Links between them

The aim of this section is to exemplify the development methodology of the proposed decision support system which consists of a 'forward looking' information system interlinking various decision units and a range of OR/MS models provided at each decision unit according to the requirements of the decision environment.

It must be noted that the exemplification is simplistic, and is provided to clarify and to emphasise important points of the proposed methodology. A full-scale implementation requires commitment and the close co-operation of a real life company:

STEP 1. Identification of the business operations and the relationships between them

The aim of this step is to define the scope of the implementation and to identify a range of business operations for which the system is provided. As indicated in Chapter Four a conceptual shift is required : The system should not be developed around the organisation but around the business operation which is a different entity. For example, within the same organisation there are a number of different business operations which have different business dynamics and only intersect with each other at certain points in the business organisation. The same manager may have equally important input to both although, significantly, each has independent business dynamics.

For example, a medium size oil company may have a number of process plants and tankers, dedicated to the needs of this regional division. Figure 5.20 indicates a typical company, where each regional division is provided with a complete independent set of operations. Obviously there is a certain level of interaction, especially between the same operational functions such as transportation. That is, for example, in some situations tankers owned by southern transportation may be used for an east coast transportation.

At a higher level, as indicated in Figure 5.21, some organisations, for example a typical multinational oil company, may have completely independent business operations, with different regional sub-organisations.

Even if the implementation is required only for a regional division such as East Coast Transportation, this step is essential in order to evaluate the functional interactions between other regional divisions.

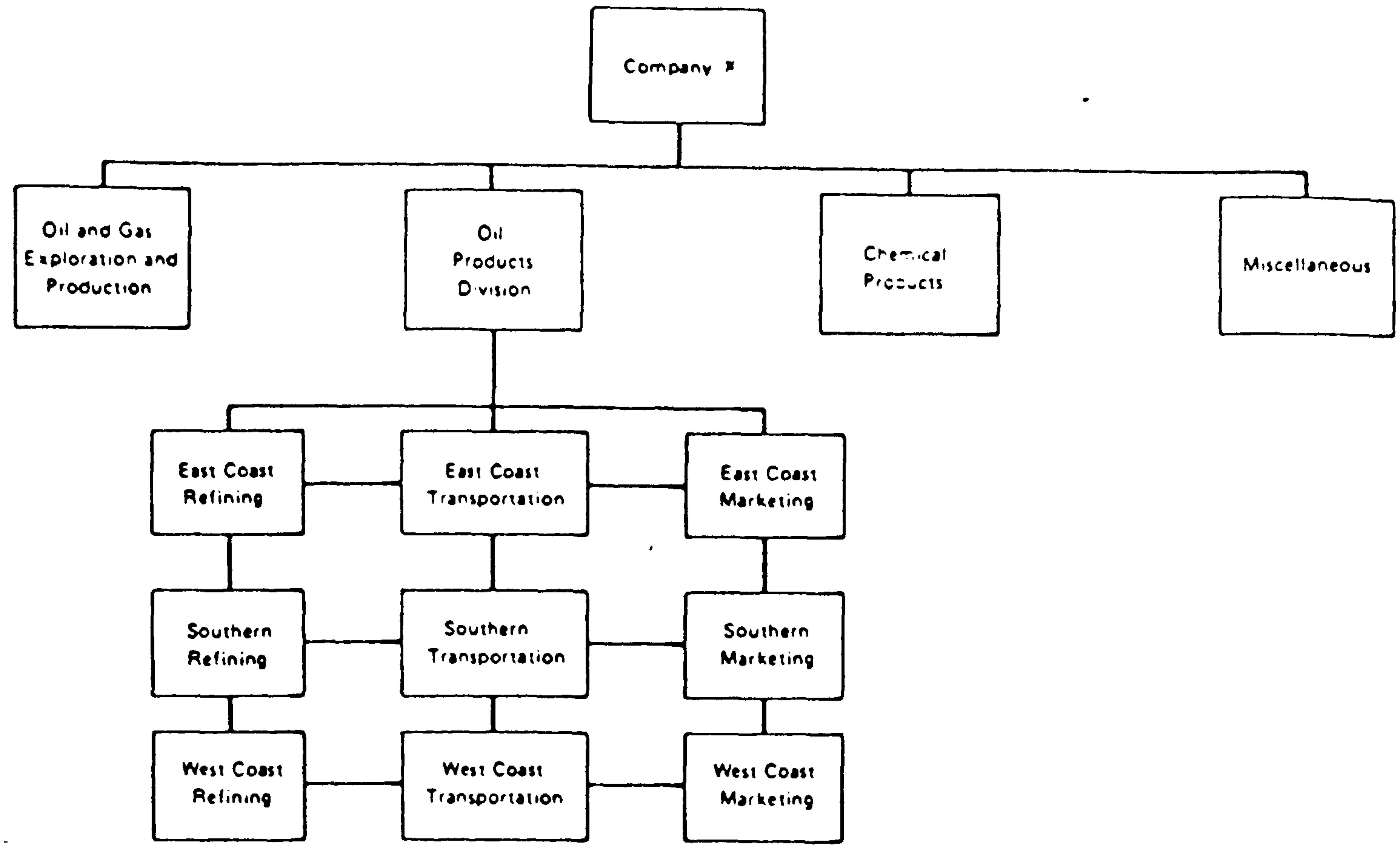



**Figure 5.20 Organisation chart illustrating inter-regional activities of an oil company (source:Beckstein)**

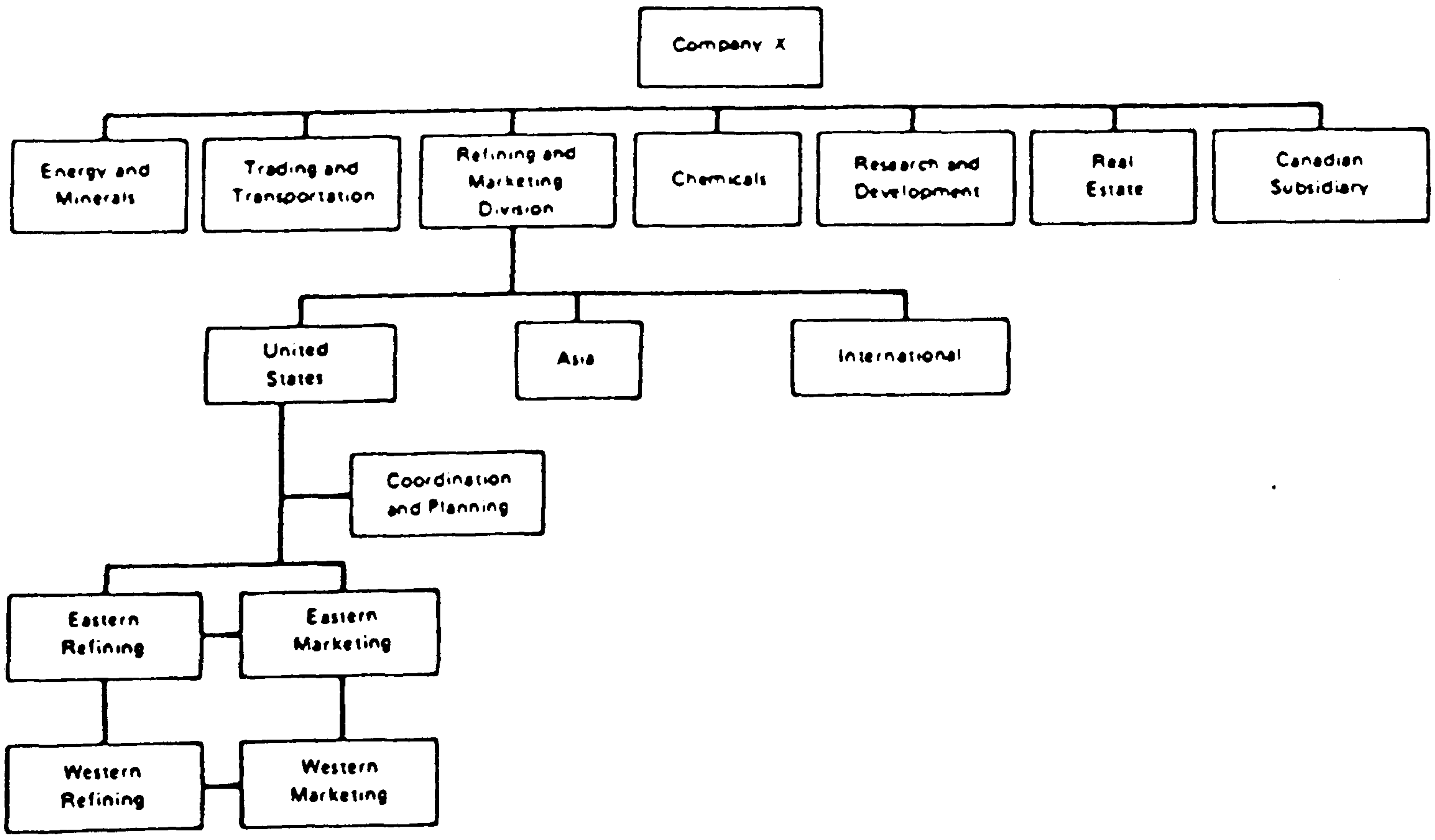



**Figure 5.21 Organisation chart of a typical oil company**

Let us assume that the proposed system is required to be implemented for a national division of a typical company with two regional divisions with independent marketing and transportation, and production operations as illustrated in Figure 5.22.

A company of this size would have a wide range of operations with different levels of importance. The problem is to differentiate independent sets of operations at an appropriate level representing the business dynamics.

As described in Chapter Four there is no point in integrating all various line and staff functions without a specific reason. The functional cohesion method provides a conceptual framework for differentiating business operations.

Operations management is described by Wild, primarily as a capacity management activity :

" Thus operations management can be seen as concerned with the design and planning, operation and control of systems of manufacture, transport, supply and service to satisfy customers' needs and achieve acceptable levels of resource utilisation." [5.11]

For a typical industrial company, a set of operations which directly contribute to the mainstream business activity including purchase of the raw materials, supply of raw materials to the process plants, raw materials inventory

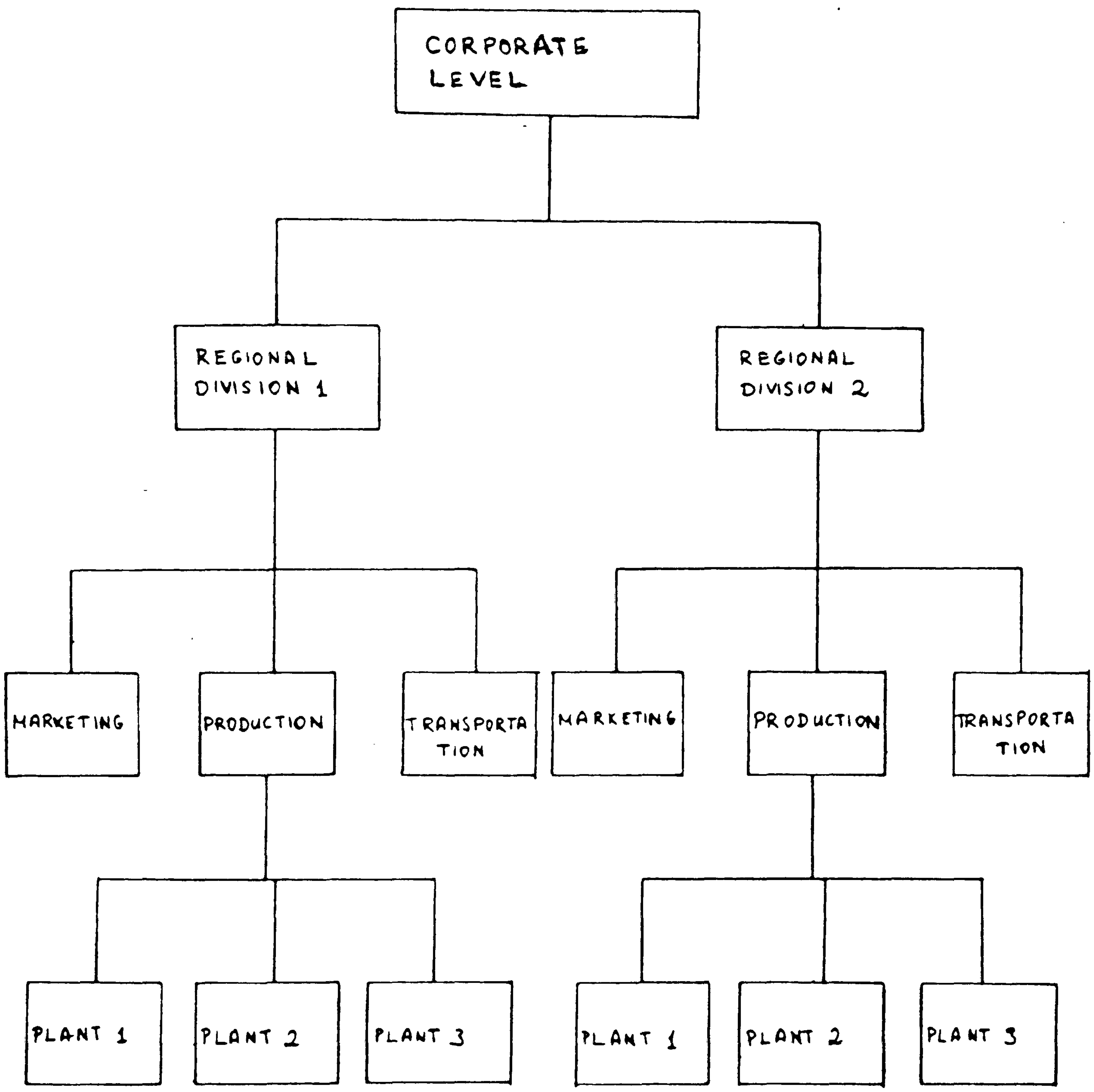



**Figure 5.22 Organisation chart of the exemplified typical company**

management, management of the manufacturing process, finished products inventory management, products distribution management and marketing forms the basis of the operational management.

In this exemplification there are clearly two distinct and independent cycles in each regional division. In a real life implementation, if there is finite differentiation between the operations, it may be more appropriate toefine smaller but more cohesive operations which relate to each other at well-defined points in the process :

For example, the following activities form a highly cohesive sub-group which can be defined as independent operation cycles:

i. Crude purchasing, supply, and stock management,

ii.Crude stock management, processing management, products stock management,

iii. Products stocks management, products distribution and marketing.

According to the scale of the implementation, the last item can be further subdivided into smaller independent storage, distribution and marketing operations for products such as

LPG, gasolines and fuel oils where each group is subject to different market demand and requires different types of tankers and storage facilities.

The main advantage is to break up the problem without artificially breaking it up, as often happens in system analysis applications. If the initial grouping is not entirely correct, it will show up at later stages of the process.

STEP 2 <u>Identification of key operational managers who contribute to each business operation</u>

According to the proposed methodology the second step is to identify a set of decision units in each business operation which was defined at the previous step.

This is achieved by identifying a number of operational managers who are likely to contribute to the particular business operation for which the system is being developed.

In this exemplification, where two business operations are defined for each regional division, the smallest set of key decision makers is obvious: It consists of the line managers of the operations which are essential for the execution of the entire business operation starting from crude purchasing to the sales of the final product.

As has been previously described, primary line management operations of a typical oil processing firm are crude purchasing and supply, processing, products distribution and marketing. Each of these operations fulfill a specific function which contributes to the operational co-ordination.

In a real life implementation, preliminary identification of the decision-making points is unlikely to be correct. However, the methodology is purposely to set up in order to avoid the mistakes that may be caused by misperceptions of the system analyst. It recognises the difficulty of observing a complex and dynamic system. The development, being iterative, if the outcome of the next step is not satisfactory then the initial set of decision units is reviewed and modified.

STEP 3 Identification of the communication patterns and information links between key decision makers in each business operation

The aim of this step is to identify what information is exchanged between decision makers in executing their operational management function.

This step will be achieved by selected line managers themselves. Managers will be requested to record their interactions between other decision makers, which were defined in Step Two, independently for the business operations, which were defined in Step One.

In this exemplification since two business operations are defined in each regional division, there will be no managers contributing to each business cycle in both regional divisions.

The line managers of the decision units will be responsible for defining their decision environment with the purpose of identifying what information is exchanged between them and other decision units.

This will be achieved by requesting line managers to fill in specially prepared worksheets as indicated in Figure 5.23. Managers will be required to fill in these worksheets on a daily basis over a length of time which is sufficient to describe the scope of the operations. For this exemplification a duration of one month is judged to be adequate. Since it is difficult to remember what happened during the day, managers will be requested to fill in the sheets as they go along during the day or record all their conversations during the day. Managers must be requested to do this exercise as a part of their job and therefore a job number must be allocated for this exercise.

At the end of the period these sheets will be collated and analysed to obtain the 'decision process chart' of each business operation. This is covered in the next step.

The outcome of this stage is the definition of the decision environment at each decision unit, the identification of information which needs to be communicated between units and how the units are coupled together. The resulting 'decision process chart' defines what information is normally exchanged between selected operations.

The development of this step is exemplified for the decision units in one business operation in one regional division: Obviously, as explained before, in real life implementation this step will be achieved by managers themselves. This exemplification is simplistic and provided to clarify the implementation of the proposed methodology.

i. Crude purchasing unit

The primary function of the purchasing unit has been defined as the purchase of crude oil that meets the regional requirements with minimum purchasing cost.

Assume the manager of the purchasing unit is requested to buy more crude oil in order to meet the requirements of the processing plants situated within the region.

The purchasing manager needs to be supplied with information about details of crude oil requirements including quantity, expected delivery date, technical specifications and unloading port.

In order to specify whether the purchasing tender is CIF or FOB he needs information about the projected availability of crude transport tankers.

Based on this knowledge, and the time lag associated with the tendering process, the purchasing manager defines specifications for tenders and according to the information about the performance of the suppliers, he identifies which companies ought to be selected for tenders.

In order to minimise costs, the purchasing manager needs to be regularly supplied with price fluctuations of the crude market. If crude prices are expected to increase, often more crude is purchased than the required quantity.

This is practised either for the purpose of speculative trading, or to accumulate extra crude stocks since eventually it will be used in the process plants as raw material. The aim is to maximise revenues when the crude price is increased. He therefore needs to know available storage capacity at the storage tanks. If the prices are expected to fall, the purchasing manager attempts to

| TIME | DECISION UNITS | | | | | EXTRA REGIONAL INFORMATION | | | EXTERNAL INFORMATION | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CRUDE PURCHASING | CRUDE INVENTORY PLANT 1 | CRUDE INVENTORY PLANT 2 | CONTEXT | SOURCE | CONTEXT | SOURCE | ...... ..... | CONTEXT | SOURCE |
| 15.47 | 150 000/6 week P1 / 5 week | | | | | | | | | |
| 15.50 | | | | | | 80 000 DW/4 week | | | | |

Figure 5.23 Illustration of the Worksheet used in Step 3 of the Proposed Methodolog

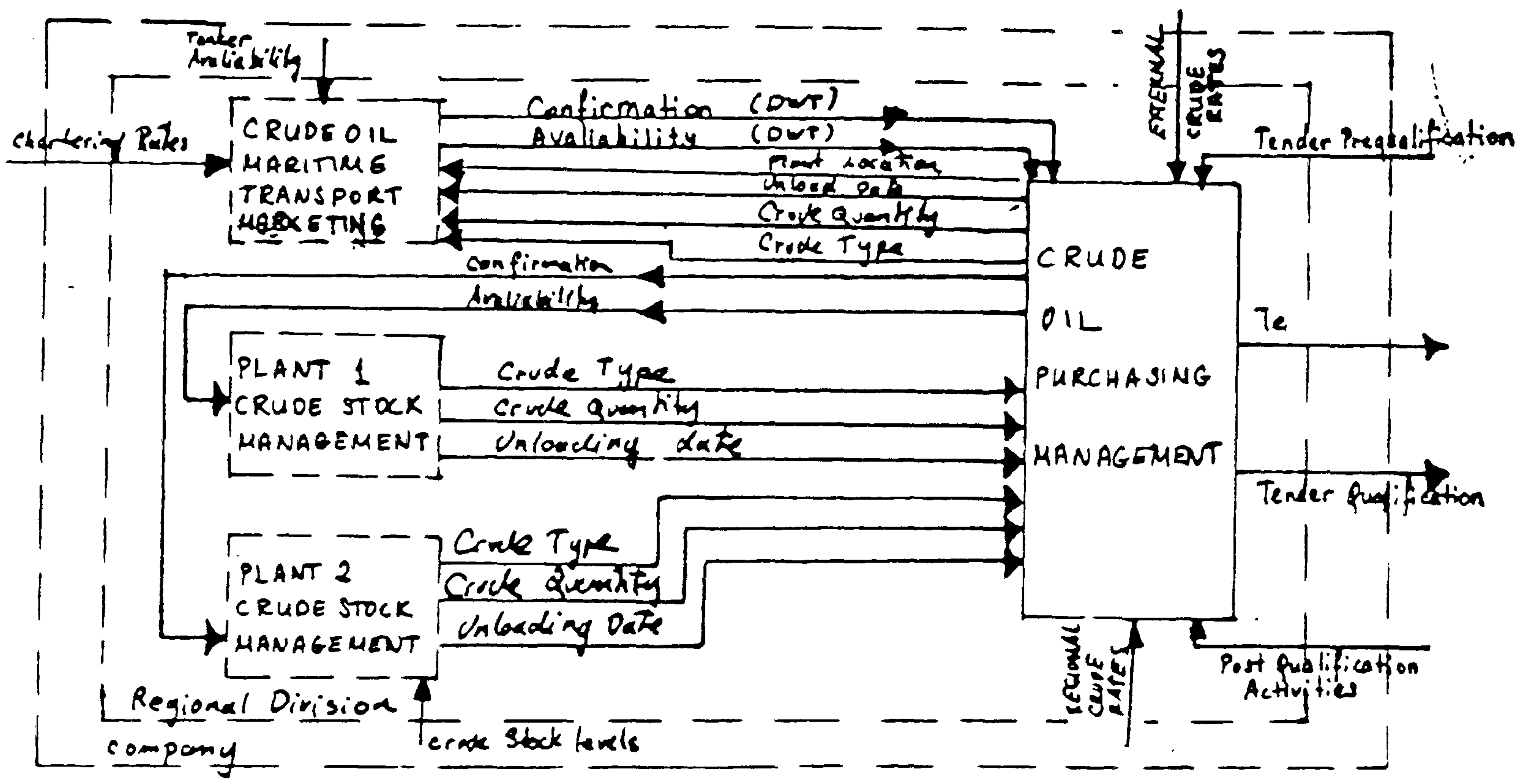



Figure 5.24 Illustration of Step 3 of proposed methodology of communication patterr

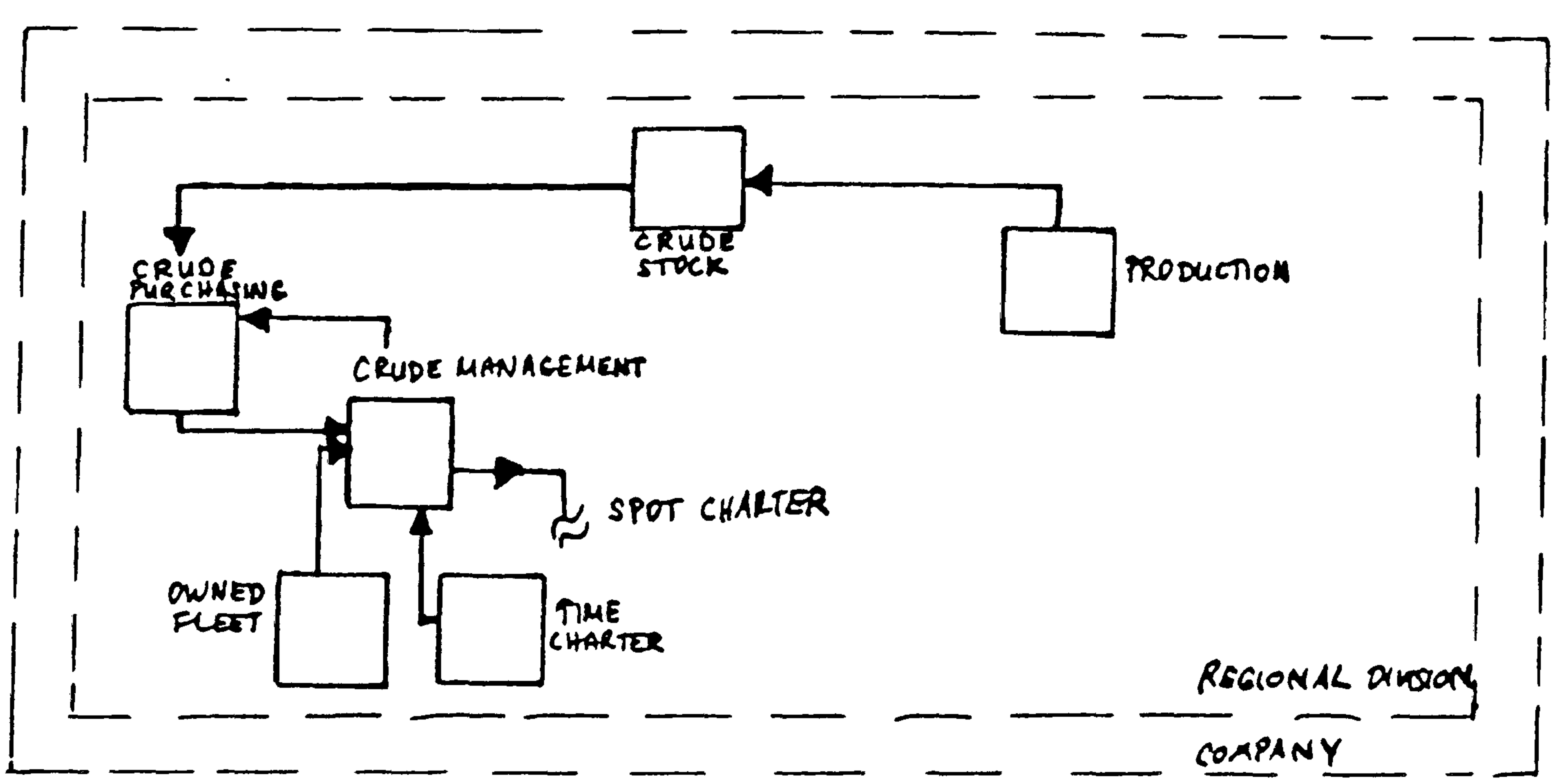



Figure 5.25 Illustration of Step 4 of proposed methodology

minimise the quantity of crude that has to be purchased. He needs to know the availability of crude at various plants within the region and other regions.

The purchasing manager needs to be informed about the progress of the tender since often brokers fail to deliver tender quotations. The finalised crude purchase tenders, either according to the free on board, FOB , or crude sale tenders accordingto the cost insurance and freight, CIF, agreements need to be communicated directly to the decision support unit of the crude oil transportation manager.

The interrelations and the patterns of information exchange of the crude purchasing decision-making unit are illustrated in Figure 5.24.

ii. Maritime crude transportation unit

The primary activity of the crude oil transportation operation is to provide transportation capacity which meets the requirements of the corporation with a strategy that minimises the transportation costs and maximises the revenues obtained from external chartering of the tankers owned by the corporation.

The input information about the quantity of crude which needs transporting and expected journey length must be provided to the transportation manager. According to the state of the owned and chartered fleet, the transportation manager attempts to allocate the tankers according to a strategy that minimises overall transportation costs. According to the size of the transportation operation, during the next step it may be necessary to define more decision units describing crude transportation operations: For example, management of each of the owned, time chartered and spot chartered fleets incorporates significant and dedicated decision making-activities.

In this exemplification, definition of crude transportation management as the decision unit would show up to be insufficient at the next step, because information exchange between, for instance, the owned fleet manager or chartering manager would be obvious. Therefore, the decision units of the business operation will have to be redefined, incorporating new additions.

The line managers who are responsible for time and spot chartering operations need to be provided with information about current world scale chartering rates and vessel availablities.

The line manager who is responsible for managing the owned fleet needs to be informed about the market conditions which correspond to the purchasing, sales or scrapping, and external chartering market conditions, that is, time or spot chartering of the owned tankers which are idle and non productive. Indirectly, he also needs to be informed about the market-dominated transportation costs.

Managers of the other or 'second order decision units' need to be informed about the state of the operations for which they are responsible. The owned fleet manager needs to be provided with information about the position, availability, technical specifications, and operational efficiency of the tankers included within the owned fleet.

The chartered fleet management needs to be continually informed about the position and availability of the chartered tankers.

The crude supply manager is responsible for co-ordinating the transportation activities and needs to be provided with the second order managers' information that enables him to co-ordinate and to optimise the performance of the transport system as a whole.

The transportation capacity and the state of the crude assignments is continually communicated with purchasing unit and crude storage management units at the process plants.

Delegation of the strategic decisions to the line managers of the crude supply system is especially important since tanker sales and purchases present dynamic and speculative market conditions, which often present significant opportunities. Such opportunities, however, necessitate rapid response by the managers. Therefore, it is advantageous to delegate the responsibility of the strategic decisions to line managers.

iii. Crude stock management

The aim of crude stock management is to meet the raw material requirements of the process plants at a minimum inventory carrying cost. It may be necessary to subdivide the crude stock management unit into the sub components, because each process plant normally has its own crude stock management operation.

The information needs of the unit are automatically defined by the crude depletion rates and existing crude levels. The crude stock manager identifies the strategy and informs the purchasing division about the required quantities of crude oil. Strategic decisions address the increase or decrease of the storage or processing capacity.

iv. Production management

Production in process industries is generally automated and unlike in the manufacturing industry there is not a significant need for a support system for managing the details of the production process, because it is automatically controlled.For this application operational management is doing no more than executing the control function in line with predetermined standards.

v. Products inventory management

The primary aim of products inventory management is to meet regional market requirements at a minimum inventory carrying cost and to identify delivery patterns which conform to the availability of the transportation capacity.

The information needs of the unit are about the product demands including the type, quantity, and expected delivery time of the assignment, availability of the products at the process plants and information about the availability transport facilities. Normally, the processing rates are adjusted according to the product levels but should it be necessary, in order to compensate for significant surges in the demand, the necessary information can be rapidly communicated to the production control and crude purchasing operations.

vi. Products maritime transportation unit

The aim of the products transportation manager is to provide a distribution capacity which meets the regional products transportation demands. Although the dynamics of the operation are similar to the crude supply operation, there are significant differences. Unlike crude oil, products necessitate different tanker types and there is less scope for spot chartering of the more specialised product types. Therefore, traditionally, products are transported by vessels owned by the corporation. Information communication patterns are also similar to the crude supply operation. Transport requirements are initially specified by the marketing operation where quantity, type and required delivery date of the cost insurance and freight contracts are communicated to the product transportation manager. The nomination of the loading port for the contracts is specified by the products inventory manager on the basis of the information presented to him by managers of the owned and chartered fleet.

vii. Marketing Unit

Sales information is provided to the marketing operation and according to the market demand development, the requirements are communicated to the finished products inventory and products transportation management. They include the required delivery date, the quantity, delivery port and the technical specifications of the contract. For CIF sales these requirements should also be communicated to the products distribution management. The aim of the marketing operation is to maximise the revenues obtained from sales. Direct trading is practised in some corporations and therefore the marketing manager who is responsible for direct trading needs to be informed about purchasing prices. The manager of the marketing unit should be provided with strategically important information about the market development of the new products as well as existing ones.

STEP 4 Analysis of of the communication patterns between decision units

The communication patterns that have emanated from the previous step are collated from the selected decision units and compared and analysed. Analysis is carried out by system consultants. Progressively, an abstract indicating the communication patterns between the decision units is obtained.

In this exercise, the number of decision units being limited, construction of the communication chart is relatively easy. But in large-scale implementations, where a multitude of decision units are present in the system, the identification of the decision units and the communication patterns is a difficult exercise. Provision of computer-based automated worksheets can be used so that preliminary screening can be done automatically.

The resulting sheets should be compared and if the communication patterns that emanate from the chart are not compatible or the chart is incomplete, either the definition of the business dynamics is not correct or the preliminary identification of the decision units is incomplete or faulty. According to the state of the chart, the development must iterate either by returning to the Step 1 or Step 2.

For example, Figure 5.25 indicates that the description of the business operations has been correct but definition of the decision units has been insufficient: Crude and product transportation management requires more decision units such as owned fleet management and chartering management.

The exercise is than repeated until a satisfactory representation of the communication and information exchange patterns between decision units are obtained. Figure 5.27 indicates such a complete chart. At this stage it is essential that operational managers are consulted and requested to confirm that the obtained chart represents true information exchange patterns within the corporation.

The chart should clearly identify the following:

i. The communication patterns including the frequency and the context of the information that is transmitted between decision units,

ii. The context of the information flow from environmental conditions to decision units,

iii. Identification and flow of the information which contributes to the strategical decision making.

The remaining steps of the methodology are exemplified in the next section: Information exchange patterns between decision units are rationalised in the light of the theories offerèd by Cybernetics.

### 5.3.2. Co-ordination and Rationalisation of the Obtained Model

The aim of rationalising communication patterns from the obtained model is to streamline the information flow within the system and to provide a framework which results in the continuity of the decision process which is compatible with the business dynamics throughout the organisation.

As described in the previous chapter, the basis for the rationalisation is to identify natural operational business dynamics, at an appropriate level. In a complex environment, identification of the basic operational business dynamics which consists of the dynamic interactions between various operations is a difficult task.

In the oil industry, the identification of the crude purchasing or product sales or time charter rates for term contracts the exemplifies self-organising characteristics of business dynamics.

" Assessement of the product sales tender formula, especially for term contracts, is complex and requires a complex evaluation procedure. This is because the important events are interrelated and a change in one event has immediate implications for other events : For example, say the demand for a particular product, fuel oil, is increased because of a cold winter. As result of this event, the fuel oil product stocks will be depleted and when the demand rate exceeds supply rate, fuel oil prices will escalate. In order to compensate for reduced fuel oil levels and to increase gross revenues, the yield ratio producing fuel oil is increased and if this is not sufficient, the total plant throughput ratio is also increased. As a result of this, the demand for crude type with a favourable yield ratio and the demand for dirty product tankers increase. This in turn results in an increase in chartering rates for product rates. Eventually, as the fuel oil supply rate exceeds the demand rate, fuel prices decrease with a reversal in dynamics. However, modified yield ratios resulting in a depression in other product supply rates also result in a shortage of the particular product type, say gasolines and kerosenes, which in turn increases the demand. Similarly, the shipment of fuel oil from process plants at southern parts generates a demand and increases prices at other regional divisions. The whole thing is dynamically balanced and continually changing. In order to keep up, the operation must be as close as possible to the market so that the time lag is minimised. " [5.30]

Athough the identification of the complex business dynamics is difficult, it is achievable because it is not a function of the particular company: therefore, in time, the analyst can develop an understanding of the particular business environment.

Rationalisation is carried out in the light of the cybernetic principles which correspond to the regulation and co-ordination of systems. The fact that the primary aim of the proposed system is to enhance the autonomy of the decision process, it is essential to ensure that the existing communication patterns do not present restrictions to the continuity and flow of the decision process.

However, any changes which are introduced into the existing system will be validated and the implications of the rationalisation will be explained to the operational managers. The exercise will only be complete once the changes are confirmed by the managers.

In order to minimise additional work, a rationalisation and co-ordination exercise should be carried out according to the proposed methodology.

The first step is to establish the business dynamics and the feedback connections between various operations. The result of this step is an abstract chart indicating the dynamic relationships between operations. Figure 5.26 exemplifies such a chart.

The second step is the rationalisation of the communication patterns between decision support systems so that they match the general pattern of this chart.

In the oil industry, as can be observed from the obtained chart, the relationships and the information exchange between decision units are complex. In real life situations, the managers continually interact with each other to compensate for the deficiency of the formal communications, which cannot keep up with the dynamic decision environment [5.12].

The main problem of the decision process at this level is analogous to the problems of the design process where the decisions in different disciplines are interdependent and therefore maximisation of the information exchange between disciplines is essential. As has been exemplified in Chapter


Figure 5.26 Illustration of Business Dynamics in oil Industry

Four, the main advantage of using computer-aided design systems during the design process is the fact that they enhance the information exchange between various departments. Engineers working within a specific department can implicitly account in their decisions, for the requirements of other disciplines; provided that they are aware of the requirements.

In an operational management decision, this problem is much more significant, since the time period for the decision is limited. This often results in the loss of significant opportunity costs.

The main issues which correspond to the rationalisation of the relationships between first order decision units are about the effective co-ordination of the various operations. The problem must be addressed respectively for both immediate operational and strategic management activities.

In terms of immediate operational management, the relationships between the decision units must enhance the interaction between units and must not prevent the continuity of the decision process. This is especially important for the implementation of the new management practices where the emphasis is focusing on the autonomy of the operational activities.

Operational managers will be provided with a constant influx of a market information which is fundemental for the operations. The flow of significant information between decision units provided to line managers will be automated without necessitating managerial intervention.

The decision units will be connected to each other so that the information between two units continually flows in a circular pattern at previously defined intervals. Market requirements for the products influence the line management operations, and information flows backwards through the feedback connections which are provided between decision units. As a result, operational management responds, and material flows forward through the physical process. Figure 5.27 exemplifies rationalised communication patterns.

A feedback loop between the decision units is provided to the regional marketing and products inventory managers. Information flow between these units is according to the following pattern. Marketing requirements are communicated to the products inventory manager. According to the product levels, production rates, and yield ratios of the plants situated at other regional divisions, the inventory manager provisionally confirms the achievability of the assignment. Ifemand cannot be met, marketing may choose to compensate through direct trading or reflect the delay to the customers. A feedback loop is also provided


Figure 5.27 Typical illustration of the information system as a result of the Phase 1 of the proposed methodology

between marketing and transport operations where information requiring in-house shipping is supplied to the transportation manager who, in turn, nominates vessels. Obviously, the transport availability influences the type of sales contracts.

Finished products inventory provides information on the requirement and the likely loading ports for the transportation manager. The transportation manager, in turn, provides the products inventory manager with information on suitable vessels and their expected transportation costs, enabling the inventory manager to evaluate an allocation strategy. The products stock manager, in turn, confirms the loading port, and the transport manager nominates vessels whether they are owned or chartered. As a result the transport manager is provided with the required capacity.

Delegation of the interdepartmental communications to the system improves the continuity of the decision process between departments and that in turn leads to better and more effective co-ordination of the different operations.

The processing rate at the process plants is governed by the existing product levels. The continuous supply of information about product levels enables the production manager to evaluate required yield ratios independently from the process control computer. Similarly, the information flow between processing and crude oil inventories is significant for strategic planning aspects.

The communication patterns between crude stock, crude supply and crude purchasing are rationalised as follows:

Feedback connections between crude stocks, maritime transportation, and crude purchasing units enable a continuous flow of significant decision-making information between these units.

Corresponding first or second order decision support systems in each regional division must communicate with each other exchanging relevant information about their activity areas.

Feedback connections between the respective purchasing, transportation, and inventory management operations of various regional divisions are provided with the aim of increasing the scope for interaction between regional divisions. For example, providing the crude stock manager with information on crude levels in other regions will enable him implicitly to consider meeting his own crude requirements from other plants as well as generating requirements for the purchasing division.

In a different scenario, should the situation be favourable, it may be beneficial to import a surplus product from the other regional division instead of producing the same product within the region. Similarly, the transportation capacity of the other regions can be used, should the conditions and costs be favourable.

This facility obviously promotes the common utilisation of the corporate resources, increasing the stability and the synergy of the business operations; as a result of such a co-ordination, operations in different regional divisions will compensate for each other.

As a result of the rationalisation, the flow of information within the regional division is as follows:

Crude requirements are provided to purchasing and to crude supply units. The purchasing unit nominates likely loading ports to the transportation unit. According to the availability of the crude tankers, the transport manager nominates tankers back to the purchasing unit. According to the availability of the in-house transportation capacity, the transport manager defines the contract type as CIF or FOB.

Regular supply of environmental information is essential for the operational efficiency in keeping up with the market developments. Such information is traditionally obtained from publications such as Lloyds list, informal communication links between operational managers in other firms where the acquisition of such information requires dedication of time and effort. Regular supply of essential information about crude and products rates can be formalised by integrating the issues of the marketing services such as from 'Platts Market Scan' to the information system. Tanker chartering rates can be extracted from the integration of the informal telex communications with the brokerage companies. Figures 5.28 and 5.29 illustrate a typical Platts information sheet and a typical informal telex sheet.

Strategic decisions require a projected knowledge of the decision environment. Unlike the operational decision environment, the information which is communicated to operational managers should present an overall view of the environment over a time period enabling them to anticipate, since essentially strategic decisions are more important for future performance.

Therefore, as well as the immediate requirements, projections about the business environment must be communicated between operational managers so that the current activities are regularly checked against the business plan, introducing feedback connections between strategic plans and operational realities. This enables strategic plans continually to adapt and evolve in line with

++ PLEASE READ EDITORIAL GASOIL NOTE ++

MOGAS: TRADE AGAIN THIN ON CARGOES NORTH AND SOUTH BUT LEVELS SOFTENING AMID DIMINISHING U.S. SUPPORT AND LOWER INDICATIONS FROM SELLERS. PREMIUM .15 BARGES TRADED DOWN NEAR 178 FOB R+DAM.

NAPHTHA: PAPER MARKETS TOOK A FURTHER DIVE ON BEARISH API+S. DEC TRADED MAINLY BETWEEN 149-150, ALTHOUGH LOWER NUMBERS WERE TALKED. RELAXED PHYSICAL BUYERS QUOTED DOWN TO THE MID-HIGH 140+S BUT SELLERS WERE GENERALLY RELUCTANT TO DO OVER-AGGRESSIVE NUMBERS. MED ALSO WEAK IN THIN PHYSICAL TRADE. BARGES INDICATED AROUND 147-149 FOB R+DAM.

GASOIL: PRICES FELL IN NWE AS PROMPT SELLERS OF NON-EEC CARGOES OFFERED 156.75. DEC TRADED IN A WIDE 155.85-158 CIF RANGE. JAN STILL DISCOUNTED FROM DEC BY 25-50 CTS. ON EEC GASOIL SELLERS TALKED TALKED NEAR 165-166 AND F.O.D. OFFERED AROUND 162-163 AS PROMPT BUYERS RPTD SCARCE. IN THE MED EEC CARGOES QUOTED BETWEEN 161-162 AND NON-EEC TALKED NEAR 159-160 IN A DAY OF THIN TRADE. EEC BARGES OPENED WITH TRADE AT 157 BUT WEAKENED THROUGH THE DAY WITH NUMBERS QUOTED AS LOW AS 155 FOB ARA.

FUEL OIL: BEARISH FUNDAMENTALS PUSHED HIGH AND LOW SULPHUR NUMBERS DOWN DRAMATICALLY KEEPING MOST PHYSICAL INTEREST RELAXED IN BOTH NWE AND THE MED. BUNKER C PAPER TALK ENDED THE DAY FIVE DOLLARS WEAKER AROUND 80 ALTHOUGH TRADE WAS CONCLUDED BELOW THAT DURING THE DAY: 1 PCT FLEXI TALKED DOWN TO 96-98 WITH ACTIVITY LIMITED TO THIN PHYSICAL TRADE AT A SLIGHT DISCOUNT TO FORWARD INDICATIONS. THE MED REMAINED MORIBUND WITH BUYING INTEREST LIGHT AND PRESSURE FROM BOTH SPANISH MED HIGH SULPHURS AND THE FALLING SOUR CRUDE MARKET. BUNKER C BARGES DROPPED TO 78-79 WHILE LOW SULPHUR NUMBERS SLIPPED ALTHOUGH ACTIVITY WAS LIMITED BY THE GERMAN HOLIDAY.

DEALS:
NAPHTHA: DEC PAPER AT 149.50 (X2).
GASOIL: NON-EEC DEC CARGOES RPTD AT 158, 156.25, 157.50, 155.85. JAN RPTD SOLD AT 156.25 AND 157.
FUEL OIL: 1ST HALF DEC BUNKER C RPTD DONE AT 78.50, 79, 2ND HALF DEC AT 79.75, 80, 1ST HALF JAN AT 79.35, 79.75 (X3), 79.75, 79.85, 80, 80.25 (X2), 80.40, 80.80, 81, 81.50 AND 83 CIF NWE.

CRUDE NOTE: HEAVY MORNING TRADE SAW 15 DAY BRENT CONTINUE THE DOWNWARD SLIDE FALLING A FURTHER 25 CTS FROM CLOSE IN NEW YORK LAST NIGHT, BOTTOMING OUT AT 17.40 BEFORE LUNCH. RELATIVELY QUIET P.M. TRADE SAW FIRMER LEVELS ON SHORT COVERS, BUT FUNDAMENTALS LOOKED SET TO REGAIN UPPER HAND LATE IN THE DAY. NEWS OF WET TRADE SCARCE, DATED DUBAI RTPD AT 16.22, AS JAN DUBAI MOVED AT 16.41. AS HIGH SULPHUR FUEL OIL COLLAPSED IN THE MED, BEST BUYER OF SOUR BBLS RPTD FROM U.S. AT WTI LESS USD 3 CIF FOR RAS BUDRAN, MED BUYERS DIFFICULT TO FIND BEING RELUCTANT TO MAKE COMMITTMENT ON FALLING MKT. SALES RPTD INCLUDE: DEC BRENT AT 17.28. JAN BRENT AT 17.48, 42(X2), 40(X2), .44(X3), 43, 425, 46, 45(X4), 47(X3), 46, 50, 45(X3), 46, 55, 58, 60. DEC/JAN BRENT SPREAD AT 16, 17 CTS FAVOR OF JAN, JAN/FEB BRENT SPREADS AT 6, 6.5 CTS FAVOR OF FEB. NOV 25-27 BRENT AT 17.15. YSTDY: NOV NINIAN AT JAN LESS 40 CTS.

TRADER NOTES: A) EFF IMMEDIATELY INTERNATIONAL TANKTERMINAL OPERATORS HAVE SET UP A LONDON OFFICE AT HAMMOND HOUSE, 117 PICCADILLY, UNDER THE SUPERVISION OF RUUD VAN STRALEN. TEL 629 2484. TLX 291015. B) EFF IMMEDIATELY WILLEM VREULS FROM EPSILON CONSULTANTS B.V. WILL ACT IN AN ADVISORY CAPACITY ONLY TO DUTCH ENERGY CONSULTANTS C.V. TEL 010 4052113. C) DAVID REES, FORMERLY OF STRAITS PETROLEUM, HAS JOINED BELGIAN REFINING CORPORATION N.V. AS SUPPLY AND TRADING MANAGER, EFF NOV 16. TEL GENEVA 4122 31 02 91.

EDITORIAL GASOIL NOTE: DUE TO THE RESPONSE FROM THE MARKET, PLATTS HAS DECIDED TO REVISE THE PROPOSED GASOIL QUOTATIONS. THIS REVISION WILL BE PUBLISHED ON 30 NOVEMBER 1987. THE NEW QUOTATIONS WILL BE PUBLISHED TOGETHER WITH THE MAIN QUOTATIONS. THE PROPOSED QUOTATIONS WILL BE PUBLISHED THROUGH DECEMBER. PLATTS WILL QUOTE THE DAILY NUMBERS IN THE PROPOSED FORMAT, SO SUBSCRIBERS CAN UNDERSTAND HOW THE PROPOSED QUOTATIONS WILL WORK. IF THERE ARE NO MAJOR PROBLEMS, THE PROPOSED QUOTATIONS WILL REPLACE THE MAIN QUOTATIONS ON JANUARY 1, 1988. IF YOU HAVE ANY COMMENTS, PLEASE SEND TO: THERESE STANTON, PLATTS, LONDON, TELEX: 892191 --

| | | CARGOES FOB MED BASIS ITALY | | | CARGOES CIF MED BASIS GENOVA/LAVERA | |
|---|---|---|---|---|---|---|
| PREM 0.4 | -1 | 164-166 | | -1 | 170-172 | |
| REG 0.4 | -1 | 154-156 | | | | |
| NAPHTHA | -2 | 141-142 | -2 | -2 | 150-151 | -2 |
| JET | -2 | 180-181 | -3 | | | |
| GASOIL | | 157-158 | | -2 | 159-162 | -1 |
| 1 PCT | -2 | 91-92 | -2 | | | |
| 3.5 PCT | -4 | 77-79 | -3 | -3 | 82-84 | -3 |

| | | CARGOES CIF NWE BASIS ARA | | | BARGES FOB ROTTERDAM | | | CARGOES FOB NWE | |
|---|---|---|---|---|---|---|---|---|---|
| PREM 0.15 | -1 | 181-182 | -1 | -2 | 178-179 | -2 | -1 | 176-178 | -1 |
| PREM 0.4 | -1 | 176-177 | -1 | | | | | | |
| REG UNL | | | | -1 | 170-171 | -1 | | | |

**Figure 5.28 Typical Platts European marketscan**

888512 FWCHAR G
888512 FWCHAR G
8812927CLTNKA G

CLK TTA003/TNK 8612310858 TLX091 8612310858 .TNK AC200

TT 2878 HF/VAA 31.12.86

CLEAN TANKER REPORT

A.G.
---

KPC - 20 CLN (7 DDD + 13 GO) KUWAIT/BEIRA 5-7 JAN

KANEMATSU - 30 GO JUBAIL/SPORE-JAPAN RGE 25 JAN

PVT CHRTRS - 50 UNL AG/JAPAN 10/20 JAN

R.SEA
---

GOLDEN GATE - 50 UNL MOGAS YANBU/E-W 10-20 JAN

MOBIL - 30 YANBU/OPS 1-10 JAN - POSS HAVE 3 CARGOES

F.EAST
---

CHEVRON - 35 JET + DO SPORE/H.KONG 4-9 JAN

SHELL SPORE - 20/25 SPORE/CHITTAGONG OR BANGKOK 10-14 JAN

KANEMATSU - 25/27 JET SPORE/JAPAN 16-18 JAN

MED/BL.SEA
---

PVT GERMANS - 25/33 DDD BL.SEA/UKC-USAC 5-10 JAN

STINNES - 20/30 DDD BL.SEA/OPTS 2-8 JAN

PETRACO - 25/30 GO CZA/UKCM-USAC 5-7 JAN

LOYALTY - 30 GO LAVERA/USAC 1/10 JAN

COPECHIM - 30 GO BL.SEA/UKCM-USAC 4-6 JAN

MABANAFT - 25 GO BL.SEA/UKCM-CANARIES 8/10 JAN

UKC
--

ELF - 20 GO RDAM/DUNKIRK OR HAVRE PPT

SCANOIL - 22 GO ARA/UKC 5-10 JAN - FXD ON SUBS

VITOL - 30 UNL UKC/USAC 1-10 JAN

M+G - 15 GO ARA/UKC PPT 18TH

COASTAL - 18/22 GO RDAM/UKC 5TH JAN

SITCO - 25/30 UKC/OPTS 5-10 JAN

COASTAL - 33 CONT/USAC 3-10 JAN

TOTAL - 30 GO GHENT/DUNKIRK 3-5 JAN

AIC - 20 GO ANTWERP/UKC 3-7 JAN

LOYALTY - 16 GO RDAM/N.FRANCE PPT/7TH AND 13 GO GHENT/FR.ATL PPT ONW

PVT CHTRS - POSS 25/32 CLN DIESEL SWEDEN/MONTREAL PPT ONW

USWC
---

PVT CHTRS - 20 UNL USWC/HAWAII END DEC/ELY JAN

CARIBS
---

NONE

REGARDS
CLARTANK LDN

++

NNNN

W.AFR
-----
PVT CHTRS - 1 M BBLS NIGERIA/OPTS PPT ON

TOTAL FRANCE - 125 NIGERIA/FRANCE 7/10 - FXD SKAUBO P/T

FINA - 45/80 WAF/OPTS 14/16 - MAX 100 DWT LOADS MUANDA 90 DEG F

ATTOCK - 125/135 FORCADOS/UKC-MED-STATES 7/9 - W.D.W.O.F.

PVT CHTRS - 236 WAF/WEST MID JAN

MED
---
AGIP - 80 S KERIR/VENCIE PPT

SHELL - VLCC CEYHAN/ROTT 5 JAN FXD AS ABV

BP - 125 ARZEW /RDAM 12 JAN

ISAOIL - 50 BEJAIA/VADO 8 JAN

SOPONATA - 30 FO LA CORUNNA/PORTUGAL 26/30 ALSO
20 FO HEAT 70 DEG C 1/1/1 VOY MED/PORTUGAL 26/31 W.D.W.C

TUPRAS - 100 LA SKHIRRA/TURKEY 30 DEC - FXD AS ABV

ESSO ITALY - 25/30 ELEUSIS/AUGUSTA 2/6 F/B 45 DTY ELEUSIS/AUGUSTA

CARIBS/MISC
---
SHELL - 120 DCS BOCAS/ANGLESEY 9/11

ELF - 28 CARIBS/EUROPE 5/9 - HTD CRUDE

SHELL - 30 P. MIRANDA/TRANMERE 1/3 - 145 DEG F

PERIOD
------
NITC - 350 DWT PLUS STORAGE AT HORMUZ PPT TO 20 JAN
ALSO 150/300 DWT SHUTTLE KHARG/HORMUZ PPT TO END JAN
BOTH 6 MONTHS T/C - PLS OFFER

REGARDS CLARTANK LDN

+++

NNNN

8812927CLTNKA G

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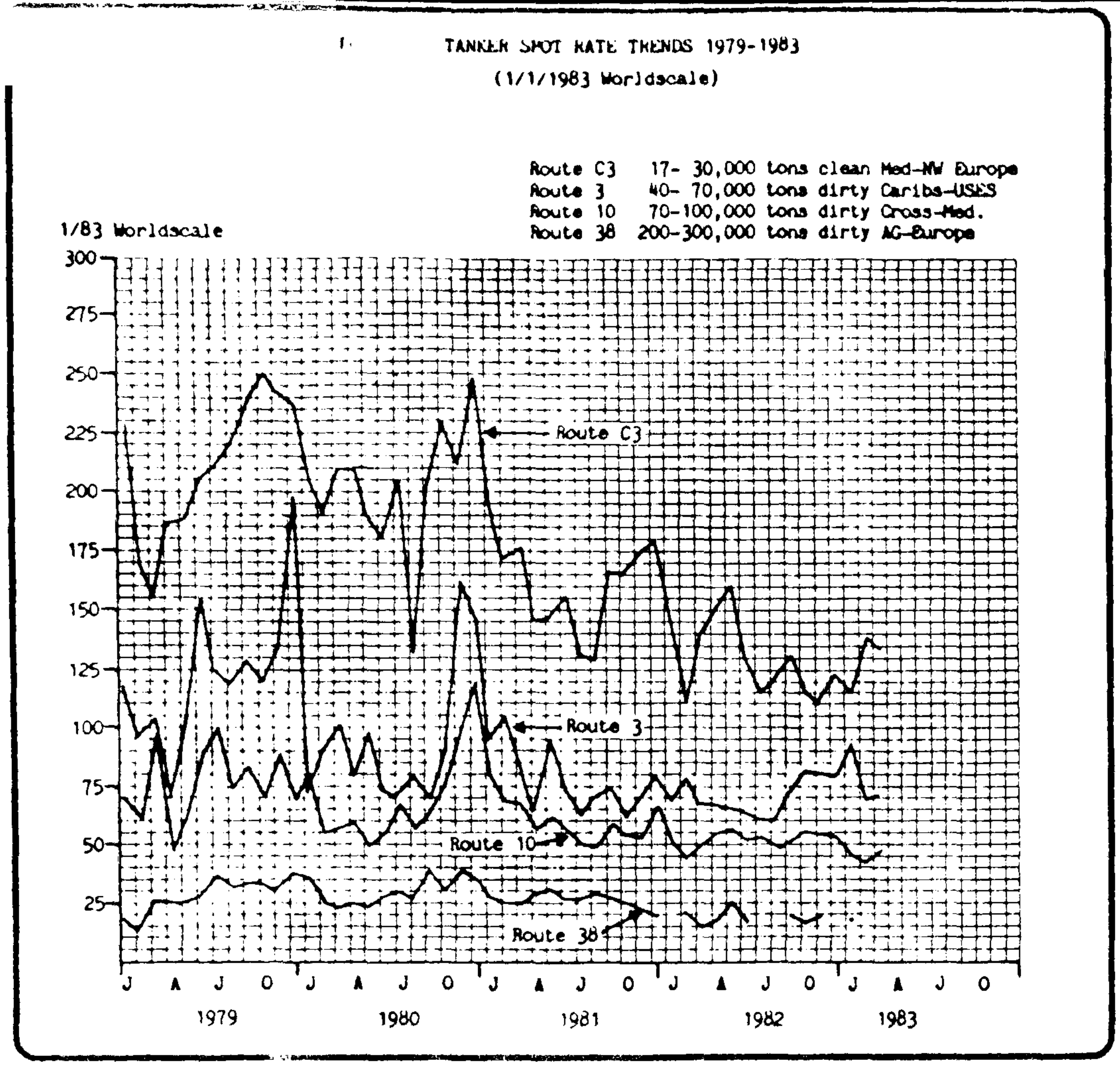
**Figure 5.29 Typical information exchange between companies**

the operational realities. However, such projections, unlike traditional forecasting methods, should only cover a foreseeable future. This period by definition cannot be fixed and varies according to the perception of the specific line manager. According to the predicted conditions, each manager in turn evaluates his own decision environment. For example, as well as the existing conditions, the maritime transport manager passes his estimates on expected charter rates to the crude purchasing manager. Using this information the purchasing manager defines distant purchasing formulas for term contracts.

Rationalisation of the information links with regard to strategic decisions must be progressively carried out within the previous states. It will continually and automatically provide strategic information about the market conditions and will enable the managers to evaluate and tackle the strategic problems. For example, Figure 5.30 and Table 5.5 indicate the development of yearly averaged chartering trends which is typically strategic information, directly emanating from the operation.

As indicated in the proposed methodology, communication patterns between operational decision makers of the same function such as time, spot, external chartering and owned fleet management of the maritime transport operations will also be rationalised. Such rationalisation generally



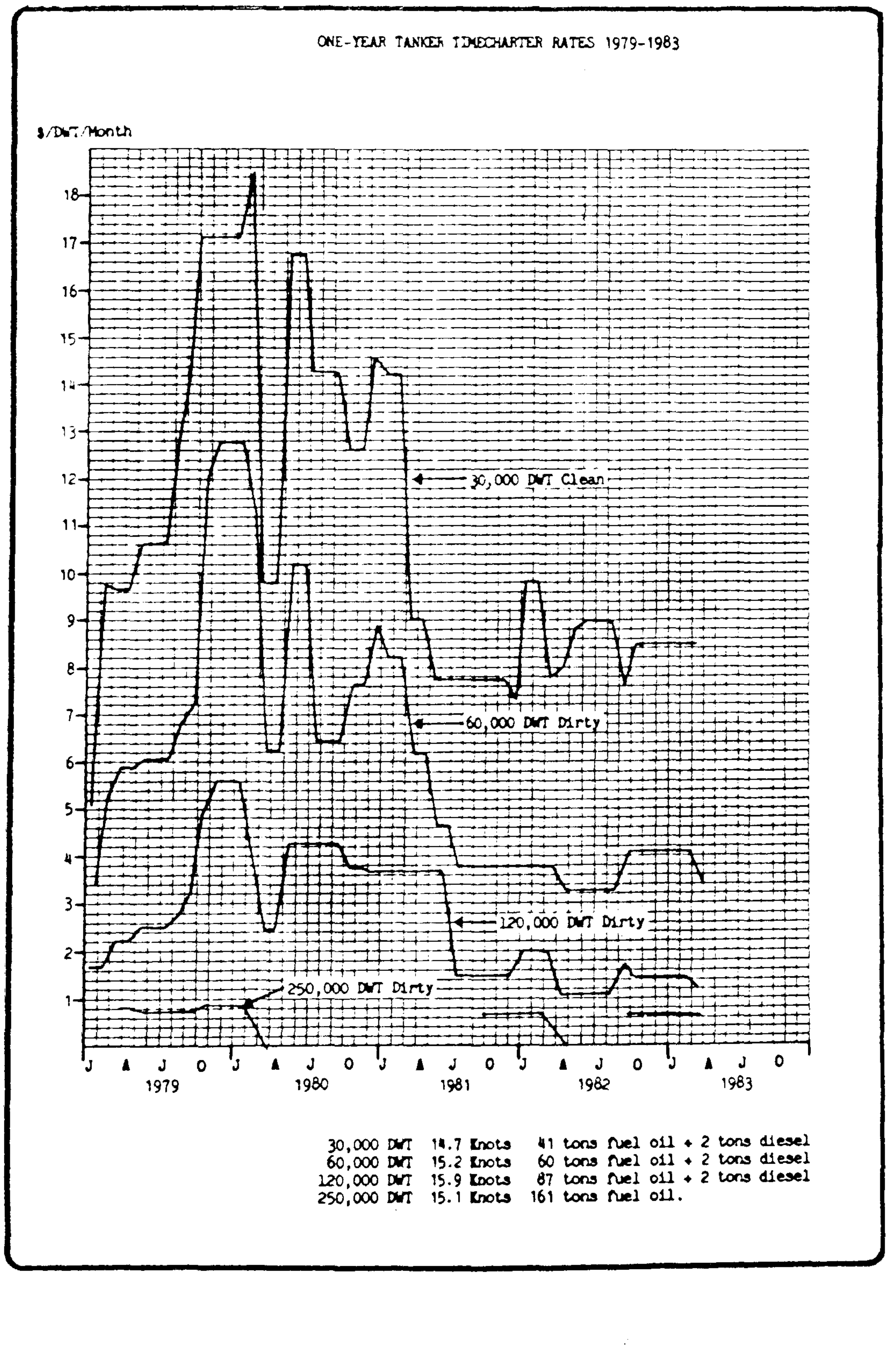




**Figure 5.30 Averaged Spot and Time Chartering trends**

Table 3. DIRTY SPOT CHARTERING TRENDS (M. DWCT)

| LOAD | DISCHARGE | 1982 MAR | 1982 APR | 1982 NOV | 1982 DEC | 1983 JAN | 1983 FEB | 1983 MAR |
|---|---|---|---|---|---|---|---|---|
| AG/RS | EUROPE | 2,697 | 3,591 | 5,483 | 2,283 | 2,737 | 2,058 | 1,515 |
| | CAR/USES | 1,159 | 680 | 219 | 631 | 241 | - | 245 |
| | FAR EAST | 3,195 | 1,565 | 2,221 | 1,830 | 2,192 | 1,462 | 937 |
| | S.E. ASIA | 656 | 355 | 80 | 677 | 563 | 578 | 419 |
| | OTHERS | 3,098 | 5,482 | 3,554 | 2,382 | 2,176 | 1,314 | 1,439 |
| | TOTAL AG/RS | 10,805 | 11,673 | 11,557 | 7,803 | 7,909 | 5,412 | 4,555 |
| CAR | USES | 1,570 | 1,394 | 2,275 | 2,454 | 1,171 | 1,080 | 1,786 |
| | EUR | 1,640 | 687 | 457 | 1,088 | 895 | 1,002 | 1,228 |
| | OTHERS | 888 | 651 | 800 | 807 | 1,004 | 479 | 943 |
| | TOTAL CAR | 4,098 | 2,732 | 3,532 | 4,349 | 3,070 | 2,561 | 3,957 |
| ECM | USES | 276 | 833 | 913 | 746 | 327 | 124 | 873 |
| | OTHERS | 493 | 452 | 428 | 782 | 584 | 435 | 1,039 |
| | TOTAL ECM | 769 | 1,285 | 1,341 | 1,528 | 911 | 559 | 1,912 |
| MED | CAR/USES | 235 | 869 | 700 | 562 | 241 | 311 | 250 |
| | MED | 1,552 | 1,519 | 2,197 | 2,983 | 1,495 | 1,239 | 1,741 |
| | OTHERS | 1,162 | 2,762 | 2,612 | 3,165 | 2,685 | 2,030 | 3,194 |
| | TOTAL MED | 2,949 | 5,150 | 5,509 | 6,710 | 4,421 | 3,580 | 5,185 |
| INDO | FAR EAST | 352 | 150 | 181 | 351 | 141 | 234 | 534 |
| | OTHERS | 1,051 | 429 | 1,200 | 890 | 115 | 314 | 517 |
| | TOTAL INDO | 1,403 | 579 | 1,381 | 1,241 | 256 | 548 | 1,051 |
| WA | CAR/USES | 742 | 1,090 | 862 | 548 | 127 | 187 | 861 |
| | EUR | 750 | 330 | 782 | 1,438 | 836 | 540 | 776 |
| | OTHERS | 455 | 72 | 424 | 510 | 463 | 83 | 337 |
| | TOTAL WA | 1,929 | 1,492 | 2,068 | 2,496 | 1,426 | 810 | 1,974 |
| NWE | CAR/USES | 906 | 1,084 | 1,787 | 1,415 | 345 | 293 | 1,424 |
| | NWE | 2,275 | 1,796 | 1,729 | 2,158 | 2,158 | 1,778 | 1,648 |
| | OTHERS | 512 | 422 | 164 | 506 | 281 | 325 | 520 |
| | TOTAL NWE | 3,693 | 3,302 | 3,680 | 4,079 | 3,144 | 2,396 | 3,592 |
| OTHERS | | 1,566 | 1,106 | 1,196 | 1,454 | 1,360 | 636 | 1,614 |
| TOTAL | | 27,212 | 27,319 | 30,264 | 29,660 | 22,497 | 16,502 | 23,840 |

DIRTY SINGLE VOYAGE CHARTERING BY COMPANY, MARCH 1982-MARCH 1983 (M. DWCT)(a)

| CHARTERER | 1982 | | | | | | | | | | 1983 | | | TOTAL 12 MONTHS(b) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | |
| BP | 574 | 518 | 634 | 1,306 | 1,721 | 460 | 873 | 1,630 | 1,447 | 2,380 | 1,430 | 1,532 | 1,340 | 15,271 |
| Exxon | 1,934 | 969 | 745 | 1,074 | 1,357 | 300 | 468 | 557 | 560 | 1,384 | 807 | 464 | 1,008 | 9,693 |
| Gulf | 772 | 254 | 1,146 | 360 | 1,036 | 681 | 1,685 | 933 | 489 | 420 | 233 | 314 | 447 | 7,998 |
| Mobil | 736 | 699 | 997 | 1,109 | 1,186 | 162 | 469 | 665 | 484 | 767 | 912 | 307 | 366 | 8,123 |
| Royal Dutch/Shell | 440 | 938 | 589 | 1,131 | 1,044 | 1,009 | 803 | 1,462 | 977 | 1,143 | 1,254 | 902 | 659 | 11,911 |
| Socal | 789 | 761 | 422 | 951 | 556 | 520 | 395 | 1,355 | 995 | 1,330 | 260 | 135 | 224 | 7,904 |
| Texaco | 1,107 | 947 | 1,323 | 1,397 | 1,068 | 758 | 346 | 1,353 | 772 | 975 | 716 | 357 | 873 | 10,885 |
| TOTAL MAJORS | 6,361 | 5,086 | 5,856 | 7,328 | 7,968 | 3,890 | 5,039 | 7,955 | 5,724 | 8,399 | 5,612 | 4,011 | 4,917 | 71,785 |
| Agip | 911 | 160 | 383 | 441 | 350 | 596 | 958 | 615 | 519 | 1,253 | 288 | 210 | 355 | 6,128 |
| Amoco | 163 | 551 | 285 | 1,007 | 505 | 833 | 662 | 437 | 184 | 810 | 241 | 171 | 595 | 6,281 |
| Atlantic Richfield | 141 | 515 | 457 | 635 | 970 | 608 | 170 | - | 245 | - | - | - | 130 | 3,730 |
| Burmah | 630 | 463 | 537 | 994 | 53 | 137 | 71 | 134 | 134 | - | - | 40 | 70 | 2,633 |
| Charter Oil | 251 | 384 | 73 | 751 | 175 | 123 | 555 | 110 | 344 | 50 | 388 | 295 | 246 | 3,494 |
| Chinese Petroleum | 926 | 413 | 601 | 205 | 756 | 338 | 483 | 690 | 174 | 364 | 616 | 365 | 287 | 5,292 |
| Coastal | 150 | 1,043 | 405 | 621 | 908 | 546 | 319 | 1,115 | 637 | 213 | 173 | 205 | 614 | 6,799 |
| Conoco | 115 | 69 | 249 | 234 | 203 | 67 | 65 | 364 | 370 | 94 | 377 | 65 | 115 | 2,272 |
| Ostoil | 27 | 360 | 837 | 760 | 510 | - | 1,540 | 500 | 530 | 720 | 600 | - | 285 | 6,642 |
| Ness | - | 248 | 855 | 801 | 854 | 312 | 620 | 405 | 315 | 348 | 92 | - | 100 | 4,950 |
| Iprem | - | 235 | 482 | 299 | 568 | 220 | 902 | 660 | 418 | 456 | 290 | 400 | - | 4,930 |
| Marathon | 160 | 323 | 358 | 476 | 402 | 451 | 435 | 938 | 440 | 145 | - | 100 | 200 | 4,268 |
| MITC | 963 | 792 | 1,026 | 1,175 | 955 | 1,005 | 75 | 964 | 527 | 575 | 450 | 243 | 287 | 8,074 |
| Petrofina | 840 | 508 | 714 | 250 | 373 | 896 | 338 | 474 | 467 | 59 | 70 | 380 | 461 | 4,990 |
| Maro Rich | 55 | 173 | 165 | - | 465 | 255 | - | 380 | 79 | 465 | 118 | - | 98 | 2,198 |
| Somedporte | 924 | 699 | 1,534 | 602 | 1,045 | 1,627 | 2,743 | 1,957 | 1,563 | 640 | 725 | 600 | 503 | 14,238 |
| Shell Oil | 359 | 214 | 747 | 330 | 464 | 719 | 175 | 384 | 723 | 670 | 56 | 183 | 162 | 4,827 |
| Sohio | - | 172 | 130 | 395 | 311 | 191 | 313 | 413 | 242 | 190 | - | 110 | 130 | 2,597 |
| Somerelf | 603 | 230 | 487 | 330 | 378 | 633 | 323 | 788 | 248 | 687 | 395 | 208 | 106 | 4,813 |
| TWO | 95 | 800 | 50 | - | 200 | 181 | 680 | 560 | 1,000 | - | 373 | 80 | 55 | 3,979 |
| Total | 495 | 972 | 1,117 | 888 | 970 | 598 | 704 | 1,126 | 1,037 | 1,517 | 678 | 467 | 636 | 10,710 |
| Others | 13,043 | 12,909 | 8,395 | 12,107 | 11,837 | 10,198 | 12,894 | 11,256 | 14,344 | 12,005 | 10,955 | 8,349 | 13,488 | 138,737 |
| TOTAL NON-MAJORS | 20,851 | 22,253 | 19,887 | 23,301 | 23,252 | 20,534 | 25,025 | 24,270 | 25,540 | 21,261 | 16,885 | 12,471 | 18,923 | 252,582 |
| TOTAL | 27,212 | 27,319 | 25,743 | 30,629 | 31,220 | 24,424 | 30,064 | 32,225 | 30,264 | 29,660 | 22,497 | 16,482 | 23,840 | 324,367 |

(a) Includes combined carriers fixed for trading in oil.
(b) Excludes March 1982.

**Table 5.5 Development of Spot Chartering trends**

includes effective co-ordination of the sub operations.

Allocation of the work between time, spot, external chartering and owned fleet management operations requires complex interactions and information exchange patterns between managers.

Since the operational costs of owned, time and spot chartered tankers are progressively higher, general practice is to use owned and time chartered fleets for base load and to compensate for the peaks through spot chartering. Owned but inactive tankers are used for external chartering operations.

The decision environment has the potential of generating large amounts of variety, which may rapidly escalate and therefore reduce the effectiveness of the decision-making operations. The communication patterns which would be obtained as a result of the rationalisation will implicitly and continually reduce such variety.

Provision of feedback connections between the crude or products maritime transportation management and sub operations managers, including owned, time, spot and external chartering, is essential.

Information flow through the feedback connections would be as follows:

The crude transportation requirements, including information on quantities, expected delivery date and unloading ports, are communicated to sub operation managers. Depending on the details of the requirement, at each sub operation unit, the information about tankers which can be allocated to the job and chartering rates or transport costs are communicated back to the maritime transportation manager. Based on this information, the operations manager evaluates the optimal transportation strategy which meets the shipment requirements.

Once the general strategy is defined by the transportation manager, the target actions are communicated back to sub operations. The managers of the sub operations including spot, time external chartering and owned fleet management, aim to achieve the targets set by the operations manager.

However, due to the uncertainties of the business environment such as tanker availability or fluctuations in chartering costs, the achieved results are fed back to the operations manager. Such regular flow enables the operations manager to monitor and alter the previously defined allocation strategy as appropriate. Regulation of the transport sub operations will therefore be achieved through the autonomous and self-organising feedback loops.

Introduction of the independent feedback connections between sub operations is essential in cases where a specific operation compensates for others. Traditionally, if a suitable owned tanker or time charter is not available, then the shipment is delivered by spot charters, regardless of the chartering cost.

It is therefore essential that a feedback connection is provided between owned, time chartering operations and spot chartering operations so that in the case of a failure, the requirement is automatically met by spot chartering without the intervention of the operations manager. Similarly, a feedback connection needs to be provided between the owned fleet and external chartering operations, so that information about the idle vessels is continually and automatically provided to the external chartering operation through the system.

# 6 DETAILS OF THE SYSTEM

## 6.1. Development of the Decision Units

This section exemplifies the implementation of the second phase of the proposed methodology.

According to the proposed methodology, the development of the analysis support models succeeds the completion of the information system. As a result of the first phase, information exchange patterns between operational managers which are provided with a decision unit are established. In the second phase the main bulk of the work includes the development of systems including OR/MS models at each decision unit.

Although the systems would be independent, and would be developed according to the specific requirements of each manager, the continuity of system would be maintained by the information system.

The structure of this chapter is as follows:

In Section 6.2, identification of the decision-making scenarios, and analysis of the decision process, are exemplified.

Development of quantitative analysis models and definition of organisational and technical requirements are briefly exemplified in Section 6.3

Model development and user trials are briefly exemplified in Section 6.4

It is important to re-emphasise that the object of this chapter is only to exemplify a typical implementation, with the purpose of clarifying the principles of the proposed system and of the proposed development methodology. It is not an attempt to develop the proposed system at a pilot scale. As previously indicated, such an exercise necessitates the full commitment of a commercial company. However, the basic design of the system is implicitly suitable for the development of a pilot scheme involving one business operation and a few decision makers.

Therefore, the details of each step are not a thorough description of the work, but a simplistic exemplification of indicative cases.

## 6.2. Identification and Analysis of the Decision-Making Scenarios

### 6.2.1. Identification of the Decision-Making Scenarios

The aim of this step is to identify a range of scenarios which are frequently encountered by the operational decision makers.

According to the proposed methodology, dedicated analysis support models will be developed for frequently occurring scenarios. General purpose models will also be provided for less frequent scenarios. The development, therefore, will implicitly focus on relatively more frequent problems which may require analysis.

This is in line with the general progressive implementation principle of the proposed methodology : For example, chartering operation occurs more frequently than speculative tanker purchasing and therefore implementation for the speculative purchasing scenario can be carried out when the development for the chartering scenario is completed.

Identification of the scenarios is based on the work which has been initiated at the third step of the first phase of the proposed methodology : A range of scenarios already is identified in this step with the purpose of defining the information requirements of the operational decision-making unit.

For example, internal and external information requirements for a crude purchasing scenario have already been defined at this step. The object of this exercise is not to repeat this step but to focus on the scenarios which are more likely to necessitate the use of quantitative analysis support models.

As indicated before, the aim of this section is only to exemplify the proposed methodology. Therefore, scenarios which are considered below are not inclusive. The dynamics of the decision process in some decision units are similar: For example, although the dynamics of the business environment are different, the decision environments of the maritime crude transportation and products distribution operations are similar. Therefore, exemplification is carried out for some decision units only. Identification of the decision-making scenarios is carried out by the manager himself. Operational managers will be supplied with worksheets or if the computers are already available in the department they will be given spreadsheets. They will be required to fill in these sheets daily for a substantial period of time, say for example, a month. Figure 6.1 indicates a typical master sheet provided to all decision-making units. Such sheets can be based on

| TIME | DESCRIPTION OF THE SCENARIO | CLIENT DECISION UNIT | DESCRIPTION OF REQUIREMENT | ESTIMATED VALUE | INFORMATION REQUIREMENTS | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | . . . . . |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Figure 6.1 Illustration of the typical worksheet for identification of decision scenarios

| DECISION SCENARIO: | | |
|---|---|---|
| IDENTIFICATION OF INTERMEDIATE DECISIONS : | | |
| INTERMEDIATE DECISION NO 1. | DESCRIPTION OF INFORMATION NEEDS : | |
| | DESCRIPTION OF PROCESSING NEEDS | |
| | GENERATION OF POSSIBLE OUTCOMES | |
| | IDENTIFICATION OF ALTERNATIVE COURSES OF ACTION | |
| | EVALUATION OF BEST ALTERNATIVE | |
| INTERMEDIATE DECISION NO 2. | | |

Figure 6.2 Illustration of a typical guidesheet for development of Information Processing Model of decision scenarios

spreadsheets. As managers progress with their operational decision-making work, they will be expected to define the activity that they are engaged in.

Such spreadsheets are particularly useful in identifying the scenarios and their occurrence probability. Spreadsheets can be designed in such a way that they automatically analyse the occurrence of specific scenarios.

A real life implementation is not carried out; therefore, the typical decision-making scenarios for operational decision units are obviously not obtained through this system:

The primary decision-making scenarios of typical crude purchasing operations are described by Mr Eraydin as follows:

" Main purchasing work includes a tender preparation, management and qualification for the usual requirements of our refineries. We also deal with spot purchase parties when the crude costs are favourable. " [6.1]

A significant proportion of the marketing operations is similar to crude purchasing operations. They consist of tender management for products marketing. However, although less unlikely, if the prices are favourable and the stock level of a product is particularly low, products can be purchased from the open market.

The primary decision-making scenarios in a typical maritime products transportation unit is described by Mr Serpen as follows:

" The operational management in a products transportation department is complex. The main concern of the general manager is to meet shipment requirements at a minimum cost. This involves thinking about the effectiveness of the existing strategy : How do you achieve the required shipment, do we need more time charters, more LPG tankers? Why are clean product tankers continually underemployed, do we need to scale down our owned and time chartered fleet capacity? Decisions with capital investement implications are ultimately the general manager's reponsibility: What should the age and capacity of the tanker be? etc. " [6.2]

The primary decision environment for specialised operational managers are described by Mr Serpen as follows:

" Main decisions concerning chartering managers are related to the chartering rate evaluations, voyage analysis, charter selection and management. Charter selection involves evaluation of the alternatives and qualification of the most profitable scenario. " [6.2]

The decision environment about the operations of the owned fleet is described as follows:

" The usual issues in the operational management of the tanker fleet owned by the company are : i. allocation of the shipment requirements between available tankers, ii. continual capacity reviews for expansion or reduction in the fleet capacity, iii. routine fleet maintenance decisions such as dry docking, repairing or scrapping older tankers." [6.2]

The operational decisions regarding crude stock management, refining and product storage are closely interrelated. Although an operating plan is used as a guide for production-related decisions, as described before, such plans cannot cope with the dynamism and the variety of the operational environment. According to the actual product levels, refining ratios are continually reviewed by the plant manager. Changing production ratios cause changing demand on the crude stock levels and the crude quality.

The operational decisions about product stock maintenance are often about the confirmation of the product supply requirements for branded or unbranded jobbers.

Unlike operations management, in manufacturing industries, production management is relatively straightforward, because the production process is fully automated: the primary operational decisions are related to reviewing and refining the ratios and rates according to the immediate fluctuations in the product stock levels. This also includes a continual review of the processing rates:

If the refinery operates under capacity, than the plant manager seeks to subcontract processing work from other rafineries. Or, alternatively, if the product stock requirement exceeds refining capacity, then the required amount can be subcontracted to other refineries. A less frequent decision-making task is to decide on the capacity expansion or reduction requirements for the next operating plan as a feedback for strategic management.

The operational decision-making scenarios of crude stock management are rather limited. They are essentially to review the crude stock levels and to generate purchasing requirements for the crude purchasing division.

It must be re-emphasised that the scenarios which are described above are generalised and simplistic and referred only to exemplify the implementation of the proposed methodology. A real life implementation would involve a much larger set of decision-making scenarios.

### 6.2.2 Analysis of the Decision Scenarios.

The aim of this section is to exemplify the seventh step of the proposed methodology : It is to obtain a detailed account of the decision process for the essential operational decision scenarios which have been identified during the previous step.

As previously explained in Chapter Four, the end product of this step is an information processing model of the particular decision scenario.

The information processing model will be based on the guide sheets which will be filled in by the operational managers at least once a day and on the verbal protocols obtained from the operational managers during the act of decision making.

The information processing model will be obtained by the evaluation of both the guide sheets and the protocols jointly by the manager and the analyst. Figure 6.2 indicates a typical guidesheet.

The resulting model will indicate the information inputs to the decision process, operational objectives, possible courses of action, alternating sequence of quantitative and qualitative analysis, evaluation criteria and post-decision actions.

It is important to note that the basis of the differentiation between quantitative and qualitative analysis will emanate from assessing the context of the analysis requirements of the operational managers. Initially such requirements will be described by the managers. The quantitative and qualitative analysis requirements will be defined according to the context of the description, availability of the quantitative information, and the involvement of the value judgements with the decision.

Indication of the time available for the analysis will be provided as a guide for the development which will be carried out during the subsequent step of the proposed methodology.

The following is a simplified exemplification of this step for certain scenarios:

The decision scenarios which have been identified within the scope of the crude purchasing operations can be classified into two groups:

The tender preparation, management and qualification are the intermediate steps of normal crude acquisition operations in meeting the process plant demand. Since the analysis must be carried out jointly between the manager and the analyst it is analyst responsibility to point out this fact.

However, the speculative crude purchase is a fundamentally different operational activity and must be analysed separately.

The tender preparation, qualification and management form a sequence of decisions, which are necessary for completing the purchase of crude oil. In this sequence, the completion of one decision generates the requirement for the next decision.

As previously described in Chapter Four, the basic decision process conforms to the following pattern:

i. information collection,
ii. problem recognition and formulation,
iii. generation of the alternative courses of action,
iv. analysis,
v. implementation of an evaluation criterion and choice,
vi post-decision monitoring

This pattern applies to each sub decision which is defined within the above sequence.

The essential set of information describing each requirement is crude quantity, unloading date at the plant, technical specifications and unloading port. This set is sufficient for execution of the purchasing operation. Other information is superfluous and need not to be included in the system. Although the information exchange between the decision units is established at the first phase, if more information is required as a result of more detailed consideration, it can easily be provided due to the modular structure of the proposed system.

The tender scheduling is based on the unloading date, availability of the crude according to specifications and shipping considerations.

According to Mr Eraydin:

" Scheduling is traditionally done by the manager himself who relies on his experience. He knows the general properties of the crude provided by main supply areas, how long it takes to transport crude to the plants and the actual tanker market. A misjudgement in scheduling often results in costly spot chartered shipments." [6.1]

Although such scheduling is typically evaluated by the manager, there is substantial scope for using quantitative analysis models: A model which relates unloading dates, shipment duration costs and availablity is feasible; because the information would be available. The time duration that can be allocated to the scheduling exercise is in the order of one to two hours.

The tender preparation requires the determination of the supplier companies and the type of the tender contract: Whether it is free on board, shipping provided by the company or cost insurance and freight CIF, shipping supplied by the supplier. Since a reliable information on the performance of the suppliers is more difficult to obtain, there is no point in providing a detailed model: because the information fed into the model would likely be inaccurate.

The tender qualification is an important decision with significant implications. According to Mr Eraydin:

" Qualifying the purchasing tender is always a stressful decision. It is not a simple case of selecting the lowest quotation. The technical specifications which are within the required band may vary. For example, quotation A may be cheaper than B, but its yield ratio may be more favourable. You can improve the quality of the decision by using technical methods instead of ball park comparisons, provided that technical methods fit in with your way of thinking. " [6.1]

There is substantial scope for using a quantitative analysis model as well as qualitative considerations where the model relates the crude purchasing costs to yield ratios and evaluates the real value of the tender. Such a model can be used to generate alternative courses of action as well as analysis of these alternatives.

Such a model will be especially useful in the evaluation of firm tenders, where a fixed quantity of crude is purchased at an agreed price for an extended period of time. The effectiveness of the choice will depend on the demand and price fluctuations involving products and the crude. For this application, the model needs to be provided with prediction capabilities.

After the tender qualification, the operational manager monitors the progress of the tender: the supplier may fail to deliver the required quantity, the shipment may be delayed on delivery, testing results may represent different crude specifications. Such things generate substantial decision requirements within a very limited time period. Mr Eraydin explains the following:

" For example, you have a quotation for $150 tonne, if the supplier delays the delivery for a week and in the meantime conjuncture results in depression of $15 tonne, you have a number of options: if you have time, you can reject the tender because it is late and you try to purchase the requirement from the spot market however you must check the availability of suitable tankers or current spot charter rates. It may be more advantageous to negotiate with the supplier. You have very limited time to evaluate your options." [6.1]

Such decisions primarily require the provision of tanker availabilities and spot chartering rates from the tanker chartering division.

Speculative crude purchasing involves risky decisions: The operational manager must have confidence in the market conditions. A wrong decision may result in substantial losses.

The decision requirements in products marketing are similar. The main issue is the determination of the term sale price for branded jobbers as well as the determination of tender quotations for unbranded jobbers. The speculative product purchasing and sales are often practised and require careful analysis of the market conditions: Mr Serpen quotes the following:

" Back in 1985 Mr von Siegner, operations manager of Global Energy Ltd. purchased 30,000 tonnes of colonial type unleaded gasoline for $175 per tonne. By the time the shipment reached its market, which took approximately a month, the gasoline prices had crashed down to $120 : as a result of this deal Global Energy went bankrupt." [6.2]

There is a need for quantitative analysis models in estimating the market movements and assessing the implications of the decision for range of possible outcomes.

However, such models are not sufficient for the evaluation and conclusion of a decision. There are other aspects such as political or psychological ones which cannot be quantified, but nevertheless must be taken into account. Therefore, the model can be used to generate the possible outcomes with the purpose of testing possible actions subject to changing conditions.

Such use will focus the attention of the manager on a reduced number of outcomes which can be further evaluated qualitatively. It will also help the operational manager to grasp the dynamics of the environment. In some industries such practice is already in progress: Rockart et al address the importance of this trend:

" At Nothwest Industries, the senior managers have chosen the contents of the data bases available to them and have learned to do some programming themselves. Instead of merely having access to the data, they are able to do creative analyses of their own. " [6.3]

However, the operational manager must always use his judgement prior to deducing his final decision.

Simplified exemplification of the analysis of decision scenarios for crude and products transportation operations is as follows:

The information input consists of the description of the shipment requirements: <u>Product type</u>, <u>quantity</u>, <u>loading port</u> <u>delivery port</u> and <u>collection date</u> and the required <u>unloading date</u>. If any of this information which is exchanged between the purchasing and transportation units has been missed and not included in the system, the information system is not complete and must be updated.

The operations manager evaluates the information provided to him by his subordinates:

The owned fleet provides information about the available tankers including their current operating cost and location.

The current availability and the rates of time, spot and external chartering operations are also provided to the operations manager.

Continual assessment is based on the comparative analysis of the alternative strategies. There is substantial scope in using a mathematical model in the evaluation of possible alternatives and the optimisation of the general transportation strategy. It is essential that the information is quickly loaded to the model.

The second important decision scenario is speculative tanker trading. Tanker sale or purchase prices are relatively more stable than crude or product prices; therefore, direct speculative trading is not just to buy and to sell tankers. It is explained by Marcus et al as follows:

" The speculative tanker trading is essentially taking advantage of the depressed markets to purchase selectively quality tonnage, and then taking advantage of the strong markets to obtain period charters from first class companies. This separation of the act of obtaining a vessel from chartering that vessel, permits the owner to obtain a market rate, not a present financial rate. Therefore, a careful market analysis must be done, prior to a speculative purchase or contract, because the date of the time charter is fixed later." [6.4]

Figure 6.3 illustrates the typical traditional sample calculation procedures. Such ball park calculation methods result in a rough assessment. The quality of the assessement can be substantially increased by more sophisticated models provided that they can be easily operable.

Such decisions are especially critical for chartering operations, because the time available for the analysis and the evaluation of the decision is much shorter. The typical firm durations for the time charters are usually half a day to a day, for the spot charters less than a few hours. Brokers who are involved in chartering operations need on line analysis models, so that they can assess and evaluate conditions while they negotiate with the chartering party over the telephone or telex.

For time chartering arrangements, the forecasting models, and statistical capital investment analysis models are particularly useful.

The decision scenarios, involving the operational management of the owned fleet involve maintenance-oriented decisions such as voyage analysis, optimum speed determination, or sale or scrap value determination.

The typical development of these models is exemplified in the next section.

SAMPLE INVESTMENT CALCULATION

OGDEN NELSON

1. Examine the sale and purchase market and estimate the current charter-free price for the vessel.

   -- A 1973-built 330,000 DWT tanker just sold for $23 million, about $70 per ton. The OGDEN NELSON would therefore be worth about: $70 x 266,000 = $18.6 million. Adjust this down for her extra year of age but up for inert gas equipment, therefore assume <u>$18.0 million</u>.

2. Subtract the scrap value from that price to determine the present investment in the vessel as an operating entity.

   -- Current scrap value for the OGDEN NELSON is $4.05 million, therefore, $18.0 - $4.05 = $13.95 million.

3. Calculate the annual revenue required to recover this investment during half the vessel's remaining economic life.

   -- The OGDEN NELSON is 8 years old and should have 17 years of remaining economic life. To recover $13.95 million in 8.5 years using a discount rate of 11.5%, annual payments must equal $2,658,000.

4. Add the annual operating cost of the vessel to the required revenue.

   -- The OGDEN NELSON's annual operating cost is $1,550,000. Assuming that future escalation flows through to the charterer, the required annual revenue is $2,658,000 + $1,550,000 = $4,208,000.

5. Basis the vessel's deadweight and estimated operational days/year, derive the required time chartered rate.

   The OGDEN NELSON's deadweight is 266,120 tons and she routinely operates about 11 1/2 months of the year. Therefore, the required time charter is:

$$\frac{\$4{,}208{,}000}{266{,}120 \times 11.5} = \$1.38/\text{DWT/month}$$

<u>Time Charter Advantage if Bunker Prices Double</u>
New Vessel vs. existing 41,600 DWT vessel:

| | Existing Vessel | New Vessel |
|---|---|---|
| Vessel Cost | $122,740 | $ 93,860 |
| Bunkers | 193,568 | 90,124 |
| Port Charges | 16,500 | 16,500 |
| | $332,808 | $200,484 |
| Tons | 39,752 | 41,382 |
| Per Ton | $8.37 | $4.84 |

<u>Advantage of New Vessel Per Voyage</u>:
41,382 x (8.37-4.84) = $146,078

<u>Advantage Per Day</u>:
$146,078 / 14.44 days = $ 10,116

<u>Time Charter Equivalent Advantage</u>:

$$\frac{\$10{,}116 \times 30.4}{42{,}355} = \$1.26/\text{DWT/month}$$

**Figure 6.3 Illustration of the traditional Time Charter calculations**

## 6.3 Requirements for Quantitative Models

The aim of this section is to exemplify the eighth step of the proposed development methodology.

The outcome of the previous section is the Information Processing Model of the particular scenarios, where the boundaries of the required quantitative analysis model are clearly defined within the decision process. As a result of the previous step the object of the model as well as its boundary is defined and clarified.

For example, the object of the transportation model is not to automate the decisions about the establishment of the operational strategy, but to focus the operational manager's attention on a range of feasible and effective strategies. However, the aim of the production management models is to maximise the automation of the decision process, since the decision environment is well structured and the decision requirement is frequent.

The purpose of this step, as defined in Chapter 4, is to define the most effective and suitable model structure conforming to the requirements:

In order to achieve this, a range of standard and non-standard models will be investigated by the analyst. For example, the transport co-ordination problem can be solved as a typical resource allocation model, as a linear programming model or a stochastic simulation model. For some scenarios it may be necessary to use composite models, where in order to achieve the required result, a number of different OR/MS methods are integrated into the same model. For example, evaluation of the speculative tanker purchasing for time charters can be tackled by using a forecasting and an engineering economics model for capital investment analysis.

The forecasting model can be a simple or multiple regression, an exponential smoothing, or a more complex systems dynamics model.

It is essential that the complexity of the model should justify its functional requirement. Although, it is difficult, the financial gains due to the usage of the model, the development costs and the resulting payback period must be calculated. Financial gains can be estimated by evaluating the concluded operational situations in order to assess the implications of using the proposed model under the same circumstances. Selection of the model is also defined by the quality of the input information.

Following are brief summaries of the proposed models for the sample scenarios:

The tender scheduling problem is relatively unstructured, and substantial uncertainty is involved with the input data. Standard OR/MS models for operations scheduling are suitable for well-structured problems. Since the object is not to obtain a concrete schedule, but just to assign priorities to the purchasing requirements, a cheap and purpose-built model can be provided for this task. Figure 6.5 illustrates the basic principles of this model.

The two files are continually updated by the estimates of the operational managers. The first file defines the probability of purchasing crude from different supplier markets. The second file defines the mean and the standard deviations of the voyage durations between process plants and suppliers. Given the technical specification of the required crude, the program identifies the most likely supplier port. Given the location of the process plant, the mean and standard deviation of the voyage duration is obtained from the second file.

The definition of the evaluation criteria is difficult, because two different issues are simultaneously considered; larger quantities are more important but the requirements must be provided by the required unloading date. The adopted criterion combines tyhe two different issues. The financial contract value is dominant if the time available is larger than the voyage time, the available time becames dominant for the opposite condition.

Evaluation criteria must be updated in line with the feedback obtained from actual usage.

As described in the previous section, determination of the tender type and the determination of the prequalification list are two main decisions of the tender preparation scenario.

Prequalification list is based on qualitative considerations. However, determination of the tender type especially for time charters requires use of quantitative models : Present worth value of CIF type and FOB type contracts needs to be calculated. Although it is easier to calculate monthly costs of the in-house tankers, external charters require additional forecasting models.
It is essential that such models must be rapidly set up and used, since there may be a high number of contracts. The time allocated to a specific contract is limited. The model, will only be used when market conditions are stable.

In the tender qualification scenario, traditionally the minimum cost quotation is selected. However determination of the real minimum cost scenario is complex. The requirements for analysis support models are as follows:

For one-off purchases, the real cost of the contract can be calculated through a simple formula which accounts for the yield ratios and current product sale rates.

However, whatever the model indicates the decision maker may prefer to choose the minimum cost quotation simply because it is safer for him to do so. For example, if the operational manager has had a bad experience with a particular supplier indicated by the model, he may choose a different option. This exemplifies a situation where a model will be undermined by manager for psychological reasons.

A manager who is dealing in speculative purchasing is subject to a different psychology : He has to choose the correct course of action. In this case more sophisticated models are justifiable because the implications of the decision are significant and there are no apparent reasons which influence the manager in undermining the support model. In this example the model can be used as a guide so that the operational manager is not adversly affected by the market fluctuations.

The decision maker needs more sophisticated models for evaluating the decision environment in a speculative purchasing scenario. Standard models are not suitable for his requirements which include, facilities for the following:

i. crude and product rates forecasting,

ii. the evaluation of the adjusted present worth value of the crude in light of the product rate profiles,

iii risk analysis of the alternative scenarios

He must be able to input his own judgements into the model as input data.

A crude maritime transport manager needs relatively straightforward models for maintenance operations which are described in the previous chapter.

However, speculative tanker purchase or time chartering have serious implications and a more complex model which is similar to the previous case is justifiable.

Co-ordination of various activities in the department, can be achieved through a linear programming based model which is notionally illustrated in Figure 5.13. Solution of this model over a time period requires the incorporation of statistical methods.

These are just a few examples, in a real life situation even at a modest scale, each decision unit would have a wide range of models of varying complexity.

## 6.4 Model Development

This section exemplifies Step 11 and Step 12 of the proposed methodology including model development and user trial aspects.

Model development is exemplified for three scenarios including tender scheduling, speculative crude purchasing and coordination of the crude transportation operations.

Model must be constructed from small and stand-alone units, which are uniform and homogeneous in terms of their complexity. Models must not be too sensitive to the quality of input data.

Figures 6.4, 6.5, 6.6 illustrate notional flowcharts for model development.

It is essential that models are continually validated with actual conditions. Such continual validation enables the manager to develop an experience and it also provides feedback which improves the performance of the model.

Information processing system of all scenarios must be kept for further reference so that when a modification is needed it can be easily carried out.

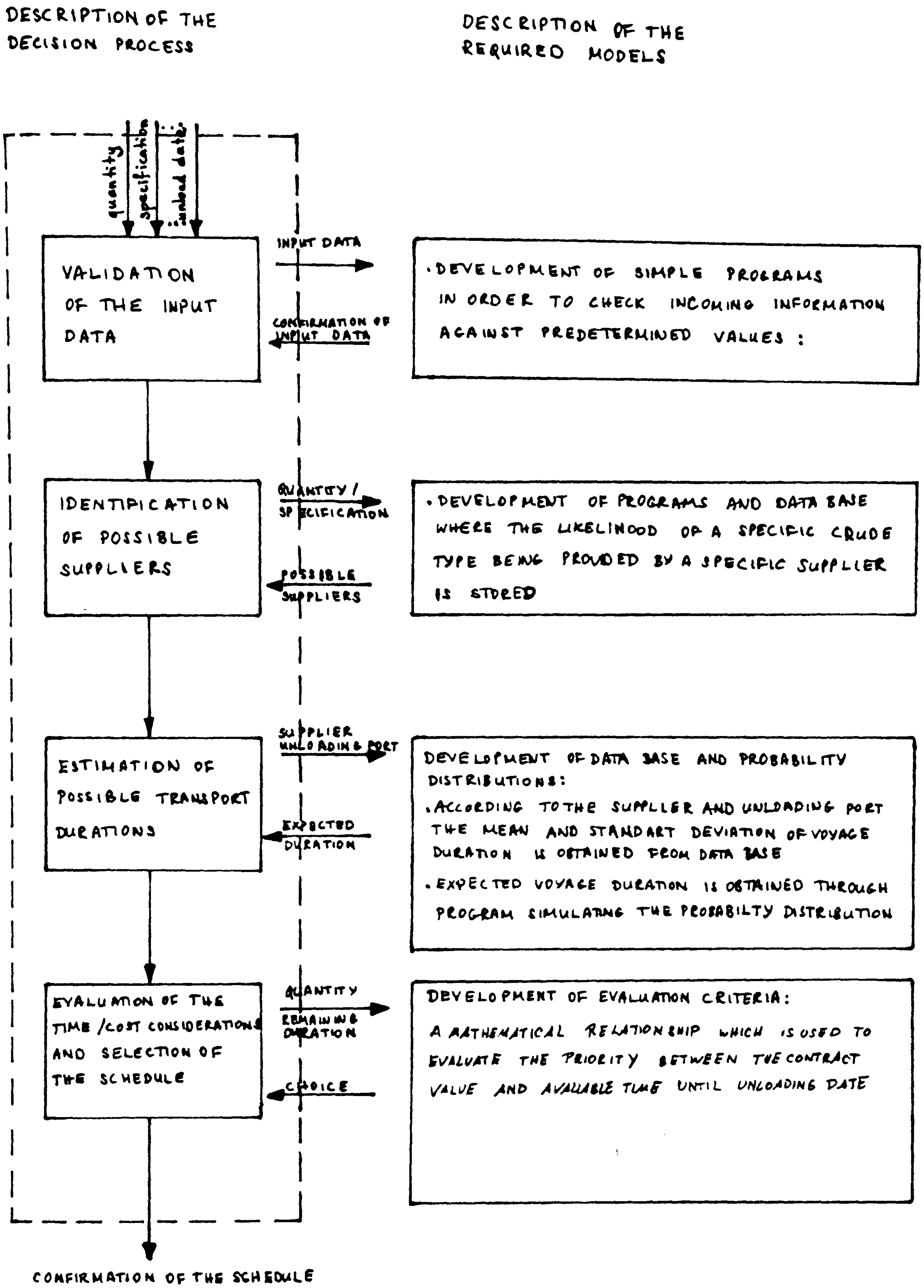
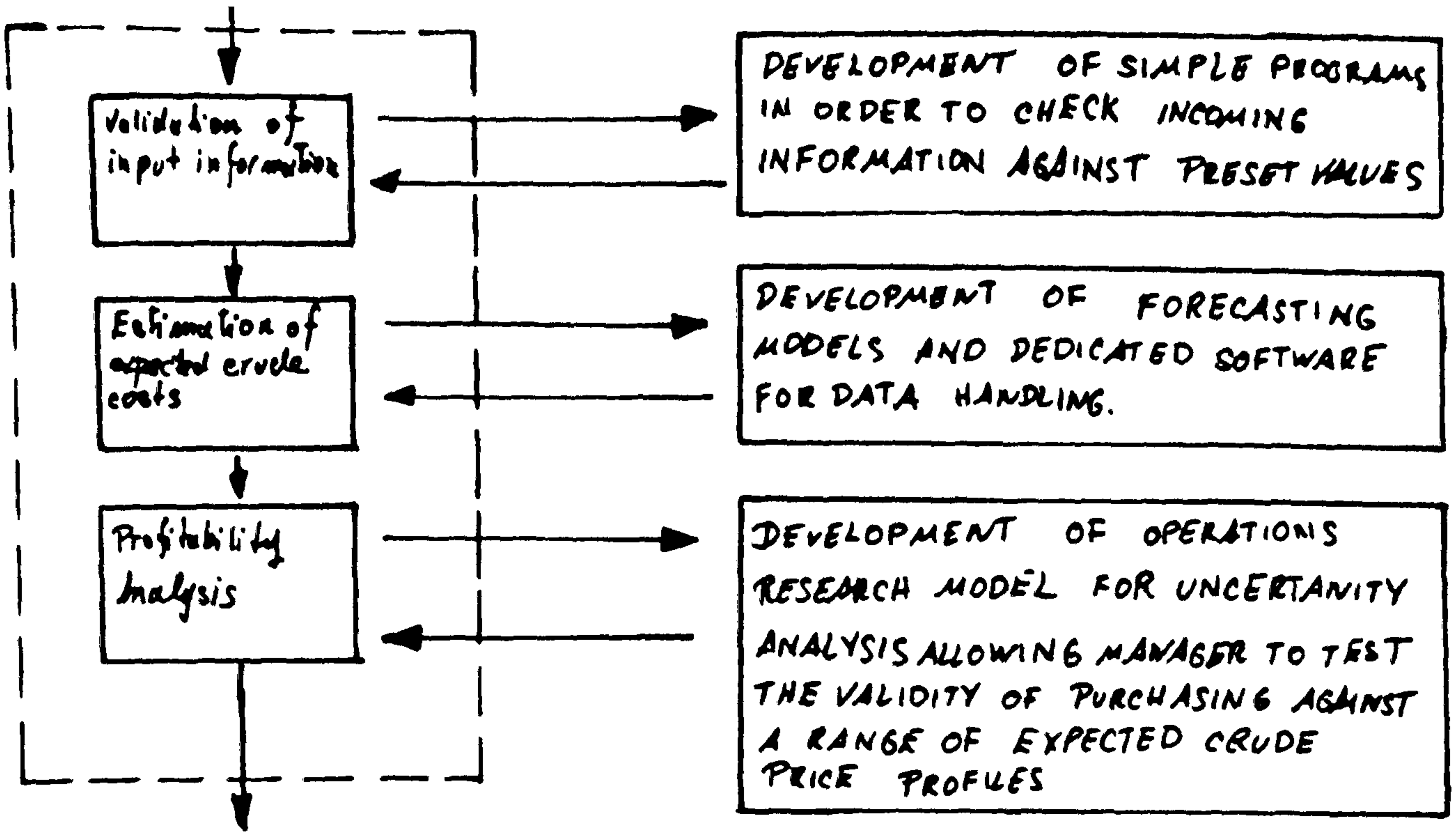
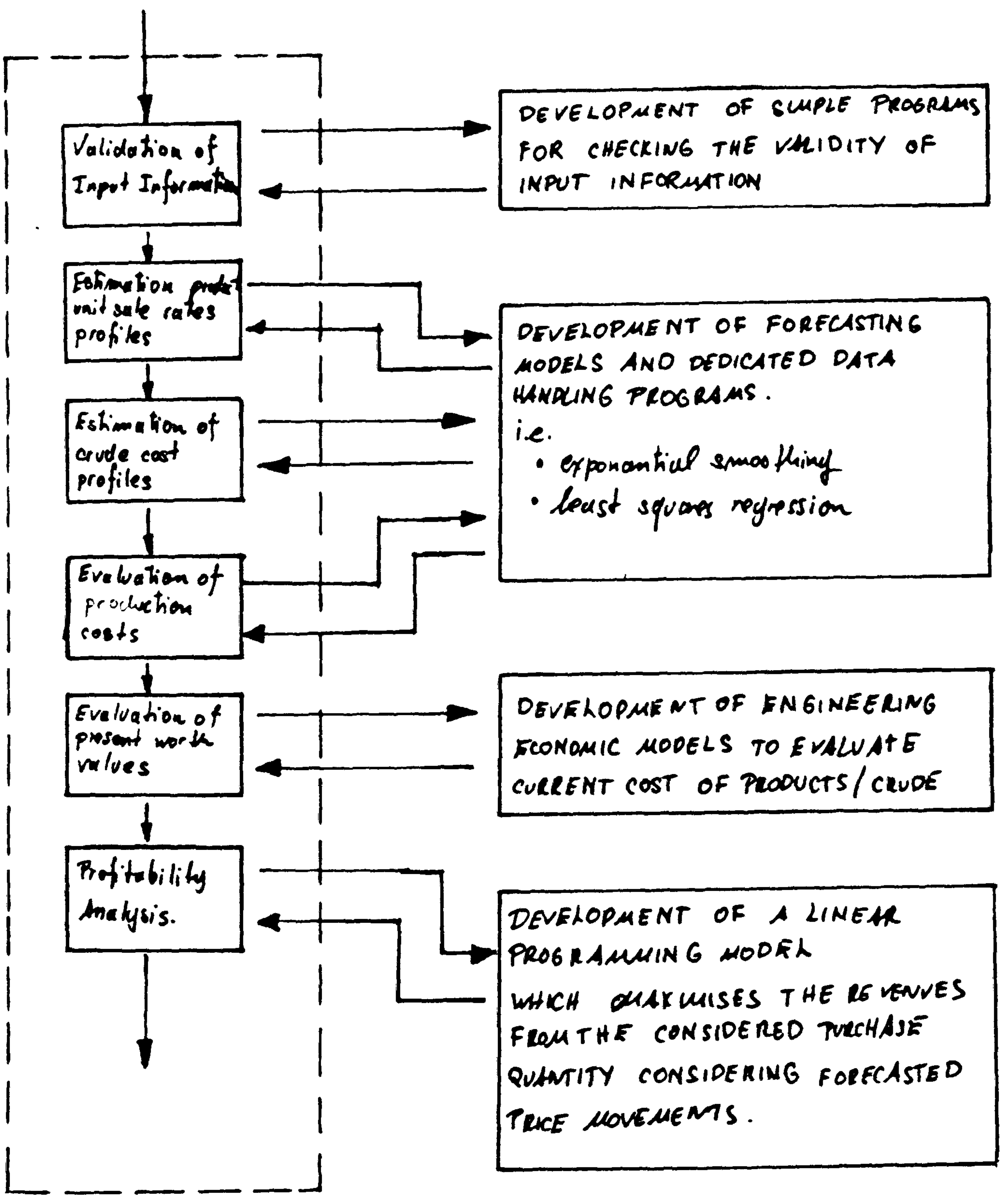



**Figure 6.4 Notional illustration of quantitative model development for 'Tender Scheduling' scenario**




i- Decision Process Based on Estimation of Crude Prices




ii- Decision Process Based n Estimation Crude and Product Prices.

**Figure 6.5 Notional illustration of quantitative model development for 'Speculative Crude Purchasing' scenario**

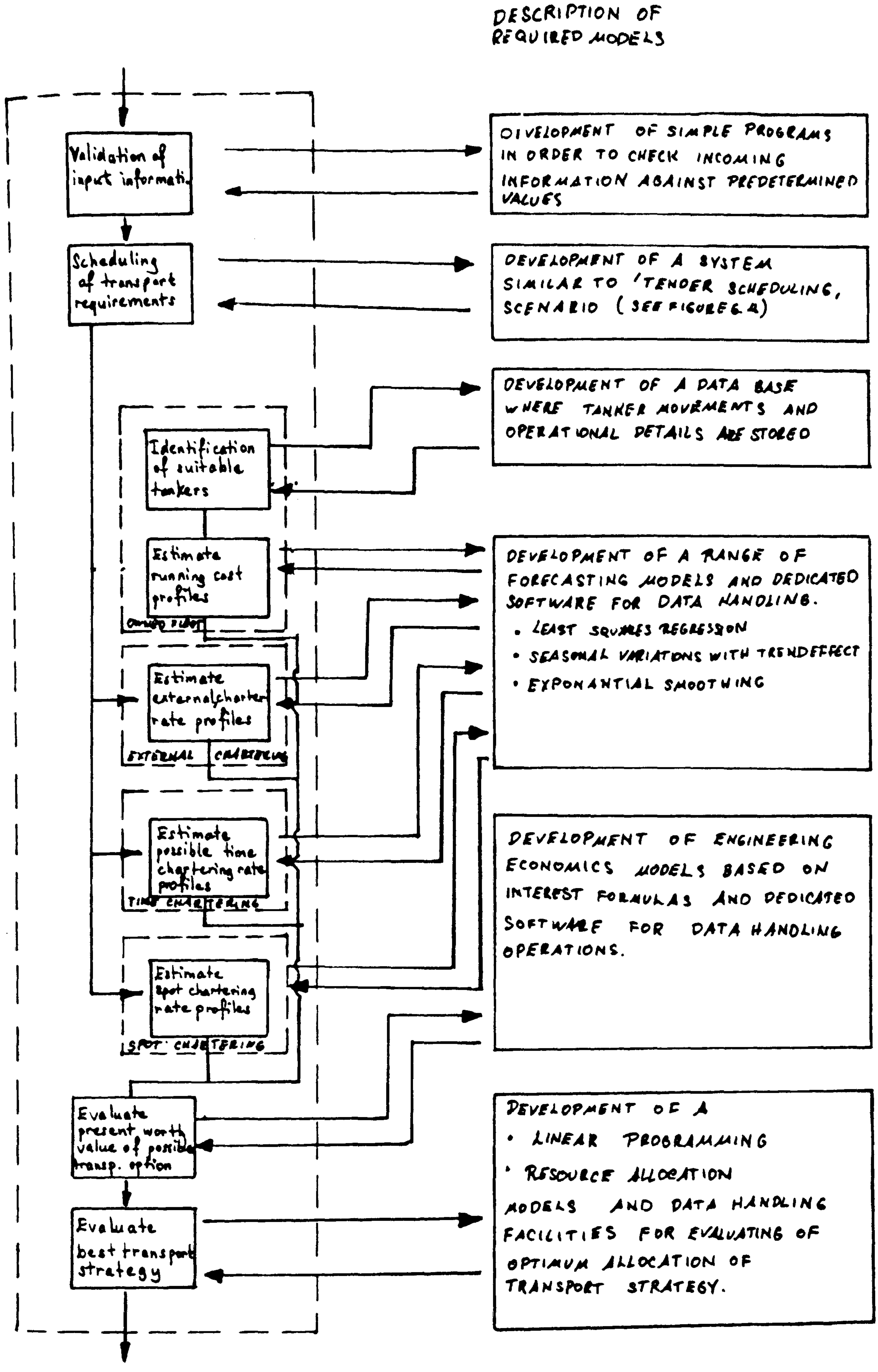



**Figure 6.6 Notional illustration of quantitative model development for 'Maritime Transport Coordination' scenario**

# 7. DISCUSSION

## 7.1 Contributions to the Design of Support Systems for Operational Management of Industrial Corporations

The executive line management of oil processing and distribution companies operates in a complex and dynamic business environment. Operational management is sensitive to market fluctuations and this necessitates continual interaction of the line managers within a specific department or between various departaments. The overall efficiency and performance of the corporation is significantly dependent on the successful co-ordination of the executive managerial activities, since business operations are interdependent. Corporate resources are often not fully utilised due to lack of information exchange capacity between regional divisions. Managers are continually confronted with complex situations which require analysis and evaluation, often within very limited time periods. The working environment is frequently chaotic and managers being regularly pressurised by the pace of the operational requirements, cannot give time to evaluate the strategic performance of their departments.

However, strategical plans are prepared by the corporate staff who are not directly involved with strategical management activities. Besides, the plans are based on long term forecasts where there is little contact between the actual business environment and the corporate strategical plans.

Such characteristics are not exclusive to the oil industry but are also common to typical consumer-oriented decentralised manufacturing companies or retailing groups.

Increasing international competition has been pressurising companies to be more competitive and to adopt effective management practices. Especially progress in information technology and the increasing use of information processing equipment as a management support tool is influencing management practice, and thus the effectiveness of managerial activities and business operations.

The management support needs of corporations are primarily provided by corporate management information systems as a medium for information exchange and communications. The Management science techniques including operations research and systems simulation are primarily implemented by specialist staff.

As previously stated in Chapter Two, although the traditional management support facilitites are useful for some applications, they fail to provide effective 'on line' support function to the managers with regard to operational management activities especially in decentralised companies where the overall performance significantly relies on the co-ordination of the business activities throughout the organisation.

The literature survey conducted as part of the research reported here has indicated that separate information processing departments are increasingly unpopular in industry because they are not effective in meeting the information processing needs of the line managers. The systems which have been used until recently have evolved from computer-based automated data processing applications where the emphasis is on the detailed measurement of past events instead of providing a support function enabling managers to innovate for the future. The use of management science methods is not widely accepted and practised by line managers since the application of these methods is usually delegated to specialist staff. Because the time period for evaluating operational decision problems is limited, there is not enough time to communicate with management science specialists and to solve complex models which necessitate substantial data preparation times.

Traditional applications of information systems for direct decision support have also resulted in undesirable side effects which affect the performance of the management as well as being financially consuming systems.

Unlike most systems analysis applications, the decision process throughout the business organisation is complex and often ill defined. It is potentially dangerous to delegate the development work to the systems analysts since they can misinterpret the nature of the process. The decision process involves a team of managers therefore it is complex and dynamic. A major drawback of corporate information systems is caused by maintenance problems. The development time of such complex systems is long and therefore cannot keep up with the continually changing decision environment. A chronic problem which is often encountered in production control applications in the manufacturing industry is the fact that the rigidity of the information support and control system influences the flow of the actual production control practice and the entire production control process is dominated by the system. This is fundamentally dangerous for direct decision support applications because the operational management process is much more dynamic. As the operational management process changes, the traditional information system will become progressively incompatible and either the system will influence the management process or it will not be used and will become redundant. Management information systems, being integral and complex, tend to be completely recommissioned at significant costs and additional stress for the employees due to the new training and habituation periods. Management practice and the decision process being dynamic, and operational managers being limited in the time that they can allocate to training, makes this problem serious. On the other hand, although a number of products labelled as management support systems are increasingly available as finished products, they cannot deliver such decision support function. This is because the management process which needs it is a function of the specific business dynamics, organisational structure, and subjective decision process of the operational managers.

The literature survey has indicated that the recent trend in management practice is increasingly favouring decentralisation of operational management control and therefore decision-making activities. This trend indicates a substantial increase in the dynamism of management operations. The just-in-time approach to production control in the manufacturing industry underlines this trend.[160]. The object of this approach is to reduce inventory levels and thus the entire business operation is more susceptible to problems. Managers have more responsibilities in coping with the problems and they increasingly rely on having adequate information and communication capacity. The scope for interaction between managers horizontally and vertically through the organisation and with the external environment is increased.

This trend points out that managers will increasingly require a dedicated information system with local information processing capacity which will significantly contribute to the co-ordination of the operational management process throughout the organisation.

The other significant trend which is progressively developing is to involve line managers with stratgeic decision-making activities and increasingly delegate the responsibility for strategic decisions to the line managers. Line managers are mainly occupied with operational management problems and therefore have limited time which can be allocated to the evaluation of strategic management activities.

There is a requirement in the oil industry and, as previously explained in Section 4.3.1 in other industries with similar characteristics, for a multifunction decision support system to co-ordinate the operational management processes throughout the organisation and to provide an on-line direct decision support function for the managers who significantly contribute to the operational management process. The existing approach in implementing management information systems and management science methodologies is not satisfactory.

This problem incorporates fundamentally important managerial issues and therefore a radical approach has been adopted for evaluation and development of a solution.

The resulting system has to conform to the requirements of these issues. As a tool for co-ordinating the decision making activities of managers at the various departments and at the various levels of the hierarchical structure, the system should be compatible with the theories which relate to the co-ordination and regulation of organised systems. As a tool for evaluating the decision environment, for providing solutions to managerial problems, and for automating the decision making work, the system should conform to the requirements of effective interactive man and machine problem solving systems. The object of the system is to provide decision support functions, so it should be adaptable in order to accommodate the continually changing needs of the business environment and evolving corporations.

The details of the system that corresponds to the provision of information processing facilities, quantitative analysis support facilities etc. are in fact dominated by these issues. The emphasis therefore is to provide a total system which successfully conforms to the requirements associated with these issues and delivers effective and adequate decision support functions.

A methodology has been developed for designing such decision support systems which conform to these requirements. The system is to be developed in two phases: The first phase includes identification of the significant information that is exchanged between managers during the operational and strategic decision process and which is delegated to the line managers. In order to minimise the errors which can be caused by the misinterpretation of the complex interactions and to cover possible scenarios as well as the existing ones, this activity will be carried out by distributing automated worksheets given to the managers which will guide them in describing the existing and foreseeable decision envrionments and corresponding strategic and operational information needs. The chart so obtained will indicate the communication patterns and the details of the information that is exchanged between managers. Relationships will then be rationalised according to cybernetic principles, and significant changes and improvements will be confirmed by the decision makers. This approach will enable the designer to concentrate on the system as a whole and it will also point out how the existing management practice can be improved which in turn will influence the effectiveness of the business operations.

The second phase of the methodology is the development of the workstations that will be supplied to the decision makers. The object of this phase is to provide a workstation supplying the decision maker with the information which he needs for his decisions. Information is organised and manipulated by the unit according to his needs. The unit provides quantitative analysis support facilities and can be used as a medium for automating decision-making work by delegating it to the unit. The development of the system will be based on the requirements of the managers, and the managers will be responsible for the development and maintenance of the system.

The system that results from the proposed methodology is of a modular structure and therefore can easily be adapted to accommodate changes. The managers, being responsible for the design of their workstation, will know the details of the system and, being responsible for its maintenance, will be pressurised to adapt it according to the changes of their decision support requirements.

## 7.2 Implications of the System Implementation on Industrial Management

Implementation of the system will significantly contribute to the operational and strategic management of the business organisation. The use of the system as an on-line decision support tool will result in direct and indirect consequences with regard to the overall performance of the business organisation. It will contribute to the organisational effectiveness which results from better co-ordination of the decision process and it will improve the performance of the managers as decision makers.

The system provides a network for information exchange between various parts of the organisation. The information that is exchanged between departments is essential for the manager to be able to evaluate decisions. The continuous flow of significant information between various departments of the organisation increases, therefore increasing the awareness of the managers with respect to other departments. The time that is otherwise allocated to the act of acquiring the information is therefore saved, providing more time for analysis and evaluation. And the decisions are based on the most recent conditions.

Automation of information exchange has significant indirect consequences: A significant change in any part of the organisation is promptly communicated to the other parts. If the situation becomes critical for the management of the business operation, it is transmitted to the related managers as a request for action. For instance, in the sample application, initially the transportation requirements are provided as information so that the transport manager can preselect vessels that are suitable for the duty. But as time advances and provision of the tankers becomes critical, the system provides the transportation manager with a request which requires final tanker nomination. Another example is the relationship between the crude supply and the purchasing managers. As the crude levels approach a minimum, the system automatically requests new orders where typical time lags representing the purchasing and transportation are built in to the system.

Another significant example is information exchange between the transport managers of the different regional divisions. The manager allocates a tanker that is owned by a different regional division if he has knowledge about its availability. In this way the common usage of the corporate resources is enhanced. Any change which is significant for the business operation is therefore automatically communicated to the other parts of the organisation and corrective action is requested from the corresponding manager. As previously addressed in Chapter 3, this facility will enhance the autonomy and the self-regulation properties within the business operation [7.1].

Because they are provided with information about the operational situation in the other departments and the capabilities of the other departments, managers will tend not to make decisions that are impossible to achieve. Therefore, as previously described in Chapter 3, the decisions which are not acceptable for other departments will be avoided and homeostatic stability will be preserved [7.2].

A major problem that emanates from the implementation of traditional management information systems has been identified in Section 2.2 as overcentralisation of operational control.

As a result, a few managers at the top of the organisational hierarchy have attempted to control the business operation introducing significant rigidity into it. Eventually, the operation is incapacitated by the amount of variety that is created by the operational environment. The proposed system, which is based on decentralised and co-ordinated decision making, will prevent over centralisation. It is interesting to note, as has been emphasised earlier, that the proposed system contributes to the planning as well as the co-ordination of the strategic and operational decision making activities.

The size and the complexity of the traditional strategic models that emanate from central planning activities is a familiar problem [7.3]. The resulting models are too complex, they necessitate expensive hardware and long setting up times. The proposed system enables decentralisation of strategic planning, where variety is progressively reduced through a hierarchical array of optimisation models. During the process, managers define operational scenarios which necessitate their intervention, and also their information needs, including a confirmation of sub-decisions from other managers. This exercice is very useful since it may indicate what further communication is needed to evaluate decisions more effectively.

Automated exchange of information prevents the occurrence of inter-organisational political problems that are often encountered in industry.

The workstations which will be allocated to the managers are designed to maximise the decision-making capacity of the managers, specifically for actual or foreseeable operational scenarios. They directly improve the decision-making capacity of the managers by providing them with the following facilities.

Workstations should provide managers with a continuous supply of critical information which they need in evaluating a situation which necessitates their intervention. The information that is supplied from other parts of the organisation is automatically manipulated and modified so that managers can directly use it. The time saved can be used for further analysis of the situation or for further interaction with other managers so that the final decision is refined. Managers have regularly to communicate their judgements about a scenario, which also often necessitates intervention of other managers. The collective decision making within the organisation is thus enhanced.

The complexity of the business environment necessitates that managers analyse the obtained information rapidly since the time available for intervention is usually limited. The use of computer management tools has not been accepted by line managers. The proposed system therefore provides decision makers with simple and reliable management science models which enable them to analyse the situation without the support of the technical staff. This means that the analysis can be carried out by a manager within a limited time period. The use of quantitative techniques by the managers will therefore be significantly increased.

As the operational business environment is competitive, decision makers are subject to stress. Fluctuations of market conditions and the general outlook of the business environment affect the psychology of the decision makers and accordingly the decision process itself. Within the oil industry, managers working in purchasing, sales, marketing and tanker chartering operations are exceptionally susceptible since their business environment is very dynamic and volatile. With the proposed system, line managers will be continually informed of and be expected to evaluate strategic issues by using the system, which will be, implicitly, in good contact with strategic developments. This will reduce the effect of temporary market fluctuations. Provision of well-defined decision rules to the system by managers themselves will enable them to use these rules as outline guides, further reducing the negative effect of swift fluctuations.

Relatively straightforward and trivial decision-making tasks of the subordinate managers are delegated to the system only requiring the confirmation of the manager. This enables managers to allocate more time to the evaluation of unstructured problems.

The system will also have indirect consequences. During the second phase of the design process, managers will be requested to write down the details of their decision process on the worksheets which have been given to them. This exercise, which will be conducted through the guidance of the worksheet, will enable managers to reassess the validity of their decision process. They may well discover false assumptions and this exercise will clarify their own decision process.

The provision of a data base dedicated to the management experience will contribute to the general learning process throughout the organisation.

# 8. CONCLUSIONS

Existing practice indicates that Management Information Systems, Operations Research and Management Science methods fail to deliver an effective Operational Decision Support function. As a result of the research, the failure of Management Information Systems is generally attributed to the following deficiencies:

i. The focus of MIS implementations is on the historical and precise information which is geared to monitor past events;

ii. The information content of MIS is formal, it does not include external and informal information which is essential for operational decision making;

iii. Typical MIS applications are large and centralised, they cannot be adapted in line with changing organisational requirements;

iv. Modifications to the existing system cause long and strenuous habituation periods;

v. It is inflexible, and restrictive for the local needs of different managers.

The failure of Operations Research and Management Science in being accepted as operational analysis support tools is attributed to the following deficiencies:

i. Traditional OR/MS applications are implemented by technical staff; in operational management there is no time for communication with the technical support staff;

ii. Managers are not involved with model development, often technical sophistication of the model exceeds the real requirements; as a result the model is complex and difficult to set up and use;

iii. The research in OR/MS has concentrated on the technology, undermining and neglecting other essential factors ; substantial research remains to be undertaken especially in the user interface area;

iv. There are no established methodologies for the development of OR/MS models other than solving particular and well-structured problems;

v. Available models are too rigid and does not meet the specific requirements of each manager;

vi. Application area is limited, and OR/MS models are not used to their full potential in, for example, co-ordination of the decision process ;

The research indicates that there is an increasing need for a system which provides direct and complete operational decision support function which can not be met with the existing MIS and OR/MS methods.

It is concluded that a multi-disciplinary approach is needed in tackling the problem. The focus is not on the solution of a particular problem, but on a system which will directly contribute to the management and control of the business operation as a system. Its design must be dictated by proper communication and regulation requirements of this system.

Following is a summary of principles which form a conceptual basis for the development of any solution to this problem :

i. The specific business operation(s) which requires support, must be defined as a system and must be abstracted from other operations;

ii. The system must directly emanate from the exiting practice and it must not cause restrictions to the existing communication patterns;

iii.Parts of the system must be co-ordinated through a regular supply of essential decision-making information; a significant change in any particular subsystem or element must be automatically transmitted to the other parts.

iv. A subsystem or an element must compensate for changes in other subsystems, and it must implicitly prevent decisions which are not acceptable for other subsystems;

v. System must be adequately connected to the environment which is general business dynamics and must provide the decision makers with essential environmental information;

vi. It must implicitly conform to environmental changes: it must adapt and evolve in line with the environmental changes.

As a support tool to the operational manager, the system must focus on the entire decision process. The following general principles are essential for the design of the analysis support models :

i. The decision process of the manager must be abstracted for problems which require the use of OR/MS models.

ii. The use of the proposed model should not be restrictive to the natural progression of the decision process.

iii. The delegation of the decision-making work must conform to the requirements of the non-quantitative components such as psychological or social.

iv. The model should be adaptable to the changing requirements of the decision process.

v. Models must not only be based on formal and precise information: validity of results must be related to the quality of the input information.

It is concluded that, the problem of designing an Operational Decision Support System must be tackled at two different abstraction levels; the decision process which coordinates the entire business operation and the decision process of individual operational decision makers.

The proposed solution emanates from the analysis of these principles. It includes OR/MS methods integrated to an information system which is only provided to the selected range of operational managers and which only process information which is imperative for the evaluation and execution of operational decisions.

The proposed system and the methodology eliminate the following deficiencies:

The solution which integrates information System with the analysis models enables the essential information to be directly loaded to models, reduces the set up times and eliminates the need for support staff.

The modular structure enables the system to evolve in line with the organisational requirements. Because of its modular architecture, it can be progressively implemented in the organisation.

Since its structure emanates from existing practice, it does not restrict normal communication patterns.

The modular structure enables the analysis support requirements to be developed according to the specific needs of the operational managers.

Adaptation of the analysis models will be possible, because, according to the proposed methodology, the models will be developed directly by the manager.

# 9. RECOMMENDATIONS FOR FUTURE WORK

The implementation of the proposed methodology will be effectively carried out by system consultants. There is substantial scope for designing a complete library of standardised components that can be selected and used as building blocks during the design process. Because the proposed development will be carried out under the direct responsibility of the managers, this will significantly reduce the development period and therefore the development costs.

In-depth preparation of both types of computer-based worksheets will necessitate input from other specialisation areas of computer science such as knowlege acquisition.

The detailed design of the workstations, that are in principle standard and can be modified according to the needs of the situation, requires a significant amount of work. Such workstations should be able to transmit and receive information while performing other functions. Such a system would be designed for multitasking machines.

The system presents potential scope for incorporation of artificial intelligence techniques. Artificial intelligence techniques are particularly relevant to the automation of the design process and preparation of a sub-system which commmunicates managerial experience between managers. Such a system may eventually replace the proposed sub-system of an experience bank, which can currently be prepared using database software.

Throughout the research, it has been noticed that although Cybernetics provides fundamentally important theories, especially about the co-ordination and the regulation of managerial activities, the theories are not explicit and a significant gap has been noticed between pure and applied cybernetics. There is substantial scope for carrying out further research in applied Cybernetics. A categorical classification and a typical implementation of the essential cybernetic theories is needed. This will facilitate their specific contribution to the typical managerial problems of business organisations.

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