"SKILLS ANALYSIS ABOARD SHIPS"

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DECLARATION

I hereby declare that whilst registered as a candidate for the degree of Doctor of Philosophy with the Council for National Academic Awards, I have not been a registered candidate for another award of the Council nor of a university.

The following activities comprising the programme of related studies have been undertaken:

1. Open University course T301
2. A course of guided reading
3. Attendance at a variety of relevant conferences.
ABSTRACT

"SKILLS ANALYSIS ABOARD SHIPS"
by
DAVID PETER LAWRENCE

This thesis presents a detailed description, based upon the literature available, of shipboard organization and social structure, together with a descriptive summary of the dynamic environment in which ships operate. The literature relating to job and task analysis is also reviewed and examined for its relevance to shipboard studies. A picture emerges of an industry being forced by technical, social, legal and economic factors to rationalize the use of its manpower resources. It is found that many authors propose the adoption of a matrix manning model. The thesis is proposed that matrix manning is technically viable as a method of manning all types of merchant vessels. A methodology is developed which allows identification, observation, recording and analysis of shipboard operational functions. The methodology involves a unique amalgamation of Fine & Wiley's Functional Job Analysis with ratings of the frequency, criticality and difficulty of functional performance.

The identified functions necessary for ship operation are detailed. A rationale is included for the selection of ship types used for data collection during the research project. The process of observation and shipboard data gathering is described. The problems which arose with regard to data collection are mentioned together with their methods of solution.

The collected results are analyzed and show that there are three technical classes of ships for consideration when studying manpower problems. General concepts of function significance and complexity are derived from the results. These concepts are used to support the argument that there exist two levels of functional performance aboard ships. These separate performance levels are shown to be essential to the introduction of matrix manning. The concept of dual level performance is merged with the information from the function profiles (which illustrate the qualitative nature of shipboard work). This combination of data is then used to demonstrate that shipboard functions may be reclustered in an innovative fashion which supports the introduction of matrix manning.

Finally, the concepts of function significance and complexity are shown to have important implications in the field of manpower studies. In particular it is shown that conventional linear manpower policies are inadequate and that a two dimensional structure provides greater insight into the successful utilization of human resources.
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Finally, to my wife Edwina go my deepest thanks for supporting me in every way through the many troughs and I hope we can now enjoy a few crests.
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1. INTRODUCTION

For centuries all merchant ships were powered by sail and carried packaged cargoes (bales, bags, and barrels). The navigating and seafaring skills were readily transferrable between ships. The only imposed social division to be found on ships was between the officers (masters and mates) and the ratings (all other ranks). This division was maintained for disciplinary purposes during the long and arduous voyages of the period. The career structure of those times, together with the technically simple nature of the ships meant that the officers had all the skills of the ratings with the added knowledge and skills required for navigation and commercial activities. This system, together with the ships, remained little changed until the 19th century. However the merchant marine, in common with many other enterprises, was dealt substantial shocks during the period of the British industrial revolution. Within a short time span the old order was upset and the slow and elegant world of sail was replaced by the urgent and practical bustle of steam powered machinery.

With the introduction in the 1850's of steam power
came a new group of seafarers - the marine engineers and firemen. This introduction caused an increase in the size of ships' crews and created a specialist work group. Further, this introduction of a new group of seafarers caused a vertical division in the social structure, by segregating the crew into separate operational departments, the deck department and the engine department. This was in addition to the horizontal divisions (hierarchies) already present - Master, officers, and ratings. The advent of radio communication, around 1910, produced a further new group of seafarers, the radio operators, with similar effects to the introduction of the engineering group i.e. increased size of crew and the creation of a specialist department.

This continued expansion of crew size meant that the single original specialist, the ship's cook, needed assistance and support and this gave rise to another specialist group, the catering department. This accretion of specialists has continued to the present day with technological advances requiring the appointment of electronics officers, refrigeration engineers, electrical officers, and specialized cargo officers.

The structure of a modern merchant ship's crew may be as depicted in figure 1.1 which shows the horizontal and vertical social divisions within the ship:
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VERTICAL DIVISIONS

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<th>Master</th>
<th>Engine Officers</th>
<th>Catering Officer</th>
<th>Radio Officer</th>
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<td>Deck Officers</td>
<td>+ Specialized Cargo Officer</td>
<td>+ Electrical, Electronic, &amp; Refrigeration Officers</td>
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<td>Engine ratings</td>
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A major consequence of this structure is that officers' knowledge and skills are segregated into departments and the master has ultimate responsibility for some ship systems of which he has little knowledge and few skills. An important point to note, also, is that where specialists have been absorbed into the seafaring life they have, almost without exception, been accorded officer status.

The professional examination requirements for seafarers were introduced coincidentally with the advent of steam power, at a time when all ships were essentially cargo 'tramping' vessels i.e. they carried packaged cargo
1. INTRODUCTION

on an opportunistic basis. The system of competence testing has continued with few modifications and the possessor of a certificate of competency is free to serve on any vessel type. The huge proliferation of specialized ship types which has taken place since 1960 (see chapter 3) has had little effect on the examination requirements (with the exception of some dangerous cargo carriers).

Technological advances, automation, and the high cost of European labour have all joined together to force a reduction in crew complements and a redistribution of shipboard tasks among those remaining. To date this redistribution of tasks has taken place against a background of traditional training methods and historically established social divisions. In order for ships to operate safely and effectively in the 1990's, and beyond, a thorough appraisal of current shipping operations is required to examine the functions that must be performed and examine innovative crew structures. This appraisal must examine the social divisions aboard ships, the environment in which ships operate and analyze the work carried out by ships' crews. This thesis takes, as the field of study, ships' crews operating within changing technological, economic, social and legal environments. In order to understand the nature of the shipboard tasks, together with the skills and knowledge required to execute them effectively, analytical tools have been developed to
collect and interpret data.

Chapter 2 presents a review of the available literature regarding the environments in which ships operate together with a resumé of the literature relating to sociological issues aboard ships. The literature with respect to work analysis is also critically reviewed for its relevance and applicability to this particular research field. The conclusions drawn from the literature review are that, in order to survive, the British merchant fleet must restructure its ships' crews to produce integrated professional workforces. Emerging from the literature is the concept of matrix manning which many authors advance as the ideal manning structure. Chapter 2 contains a description of matrix manning as proposed by Herbst and Roggema & Smith. This thesis examines the technical viability of the adoption of matrix manning by means of identifying, observing and analyzing the performance of the functions necessary for the operation of modern merchant vessels.

Chapter 3 draws on the literature review to produce an analytical tool which, it is argued, enables identification and measurement of the necessary ship functions. It is further argued that the tool will allow conclusions to be drawn as to the technical validity of matrix manning as an organizational structure for ship operations.
Chapter 4 describes the collection of data aboard ship during a pilot study. The problems encountered and their solutions are presented. The final methodology for shipboard data collection is detailed. Finally a discussion is given as to the reasoning behind the selection of the sample of ship types observed during the course of the research.

Chapter 5 contains the results of the research. The data collected are analyzed for their support of the principle of matrix manning. The results show that there are three technically different classes of ships and that these distinctions must be reflected in any innovative manning system. Concepts and measures of functional significance and complexity are introduced. These are used to support the argument that there exist two levels of functional performance aboard ships. The functions at the highest level may be assigned to primary role operators and the remaining functions divided between the remaining operators to fulfill as part of their secondary roles. This allocation of functions is essential to the technical validity of the introduction of matrix manning.

Chapter 6 draws on the results of chapter 5 to support the validity of matrix manning as a technically and operationally possible method of manning ships. The concepts of significance and complexity are generalised and abstracted to demonstrate that manpower theories are two
1. INTRODUCTION

dimensional rather than the linear systems of current theory. Finally areas for further research are listed and described.
The object of the research programme is to obtain data on the skills and knowledge required to perform the necessary functions aboard ships. This entails, initially, a review of the literature in the following areas:

(a) That relating to shipboard organization and social structure.

(b) That relating to the environment within which ships operate.

(c) That relating to job/task and associated skills analysis.

The results of the literature searches are described separately and the synthesis of the results is presented in Chapter 3 where the development of the skills analysis technique is described.

2.1 SHIPBOARD ORGANISATION AND SOCIAL STRUCTURE

This section draws on the available literature to support an argument that the shipping industry is being forced to reduce manpower and that this is being achieved by implementing new technology and reorganizing labour resources.

Many authors have stated that, whereas it used to be a labour intensive industry, shipping is now (especially in the West) a capital intensive industry. Wall (1980, p.155)
makes this point and, in particular, stresses that capital investment per employee is large and rising. McConville (1979, p.39) states that an important reason for the reduction in labour intensity is 'the loss of the labour intensive passenger trade'. McConville, in the same paper (p.44), emphasises that increasing application of technology is increasing the intensity of capitalisation. Moreby (1975, pp.14-15) argues that it is probable that shipping has always been a capital intensive industry, 'but the evidence suggests that its capital intensity is increasing'. Moreby pursues the topic of capitalisation to include capital charges as opposed to capital costs. By this is meant the cost of finance for the purchase of a ship. He claims that 'capital charges and interest rates may form the major proportion of overall costs.' This intensity of capitalisation has forced the need for reductions in overall costs and Takuya Otonari (1980, p.28) has identified three main cost reduction aims of developments in marine technology:–

(a) To reduce labour costs

(b) To reduce energy costs

(c) To reduce pollution

Takuya Otonari poses a solution to cost reduction problems by dramatic crew reduction. However he acknowledges that crew reductions involve alterations to training, a change in the potential hazard posed by a ship
and a need for rethinking as to where responsibility for safety may truly lie.

Sagen (1984, p.17) recognises the new industrial revolution and speaks of the impact of advanced automation and microelectronics on ships. He 'believes that it is clearly demonstrated that the shipping industry is faced with reconstruction of a somewhat formidable character and intensity'. In postulating solutions to the problems of reconstruction he identifies three areas of shipping practice, similar to those of Takuya Otonari, and which require improvement:

(a) Technical improvement - To reduce energy and labour costs.
(b) Use of energy - To reduce energy costs and prevent pollution.
(c) Communications - To improve overall management

Sagen (1984, p.17) whilst dwelling at length on technical solutions, nevertheless makes the important point that 'the right combination of technology and people are the key to successful ship operations'.

Menzies-Wilson (1983a, p.102) writes that the 'relationships between the costs of labour, capital, fuel and hardware have shifted. This, together with spiralling inflation and wages, means that changes in manning arrangements have become inevitable.' Menzies-Wilson
expands the areas of needed change into four inter-related areas:

(a) Technological
(b) Organizational
(c) Managerial
(d) Social and living conditions

Many writers have discussed the likely technological advances in shipping. Sagen (1984, p. 18) in his comprehensive paper lists the areas of technological advancement which, he claims, will save labour and render ships more reliable:

* Use of materials with increased functional or maintenance reducing effect.
* Increased use of instrumentation and automation which improves monitoring and thereby increases operating reliability and safety.
* Greater efficiency in cargo handling and storage.
* Investment in design, equipment and operational systems that optimise fuel economy.
* Ergonomical considerations incorporated in the design of the ship.
* Investment in labour-saving aids that reduce or lighten the need for manual operation.
* Introduction of efficient and more human-oriented methods in organization of work and job satisfaction.
* Increased operational safety and cargo service.
accessibility to information and information processing by investments in communication equipment.

* Upgrading the management functions at the shipping office through increased use of system analysis and modern planning techniques, use of electronic data processing (EDP) as a management tool, etc.

Smit & Pijcke (1984, pp.66-68) do not list the many advances in technology with the same detail as Sagen but they indicate that these technological advances will result in yet more specialized ships serving special sectors of the shipping industry.

Yasumichi Koishi (1981, p.262) defined the technological structure of human activities aboard ship as 'the structure of distributing tasks and functions for the achievement of business goals'. After his investigations aboard a Japanese vessel, the 'Hakonesan Maru', he determined that further study was needed in order to reform the technological structure namely 'that the work as the business of operating ships can be understood as the system composed of man, machine, and material, and it will become important in future to analyse, evaluate, and design the system'. He continued to enumerate 8 points of technological advance which he had summarized 'from an original list of 132 :

1. Structural reorganization, including the head office.
2. The introduction of effective labour-saving equipment
and materials.
3. The improvement and standardization of working procedures.
4. Simplification of clerical systems (including procedures for reports).
5. The establishment of preventative maintenance systems.
6. Centralized control of the supply of materials.
7. Reshuffling of organization and job distribution
8. The elimination of potential hazards.

Other authors have explained how these technological changes will lead to the need for a more highly skilled workforce. Henry (1982, pp.124-125) claims that 'the complexity of shipboard systems will steadily expand, requiring an accompanying increase in the education and technical sophistication necessary on the part of the marine professional'. Henry, in his search for ways to impart this expertise, relies heavily on the use of marine simulation techniques. To support his reliance on simulators Henry claims in an amusing aside that 'Time at sea is traditionally thought of as "99% boredom, 1% stark terror." The simulator will enable trainees to concentrate on the 1% stark terror.'

Koburger (1984, p.11) states that increases in technology will lead to reduced manning and 'every man will have to do more, and what he does do will be intellectually
more stimulating. He will not chip paint endlessly. He will be primarily either a navigator or an engineer, with enough cross-training to allow each to stand in for short periods for the other." He continues 'He will be challenged all day, every day'. Koburger also describes effects of technology on the ships themselves as forcing them to become 'larger and with ever more dangerous cargoes, constituting major threats to the safety of a port, to other ships, to shoreside facilities, to the surrounding population, to the quality of life. It is no longer just the ship itself, her crew, passengers and cargo that is involved.'

McConville (1979, p.44) while describing and explaining the reducing numbers of seafarers within the British merchant fleet warns that 'even this modified picture of declining manpower overlooks the fact that the UK. shipping industry will increasingly demand a qualitatively different labour force from what is generally regarded as the traditional seafarer'.

New shipboard organizational structures have been proposed by many writers in the field. The consensus of opinion appears to be that an integrated professional workforce, by which is meant a crew which is capable of performing in unison towards a common goal, is the most viable long term solution. Henry (1982, p.125), in a paper exploring the nature of human errors at sea, predicts that,
with increased technology, 'participatory management by the crew will grow and will erode the traditional distinction between officers and rated crew members. Increased emphasis on shipboard equality and greater crew motivation and stability will lead to a reduction in the high crew turnover rate.'

In a plea for better utilisation of manpower resources at sea Hunter (1982, p.2) claims that 'the manning levels experienced nowadays, and those required in the future, will necessitate the total integration of the workforce aboard a vessel, releasing those much of whose time is spent in a supervisory capacity of one sort or another. This would be unacceptable unless everyone on board a vessel was a professional in his own right, had the same sense of responsibility and the same commitment to the commercial success of the voyage in progress.' Hunter continues to explain how modern technology and automation may be adapted and used to serve a small, cohesive, professional team, and that this must be the optimum method of utilising manpower at sea in the safest and most efficient way.

Moreby (1975, p.67) looks even deeper into the subject of shipboard organization and, following from Herbst (1968 & 1969), suggests that the basic design variable affected by modern technology is the allocation of tasks between the ship and the shore. The level of skills
required to be held aboard will vary depending upon this allocation. He suggests that it is possible to have a range of manning structures ranging from a permanent full-complement crew to a small permanent crew augmented by transient maintenance teams. Moreby suggests that the allocation of task decision will have direct effects upon:

1. the extent to which the shipboard tasks provide conditions for autonomy and self regulation;
2. the communication requirements between ship and shore;
3. the possible alternative work roles and social structures;
4. the possible alternative career structures for individuals; and
5. the hierarchical and departmental structure on board.

Smith & Roggema (1980a, pp.250-252) in an important series of papers make a plausible argument for the inception of a matrix type of organization. This effectively comprises a ship matrix of personnel skills on one axis and required tasks on the other axis. The tasks are performed by an individual or group which have the required skills. Smith & Roggema claim that this structure can accommodate the differing workloads at different stages of the voyage. The essential feature of the organization is that it disposes of the traditional hierarchies of crew members. This removal of officer-rating barriers has been put forward by Henry (1982), as previously quoted, where he
proposes participatory management which will erode traditional barriers.

Hunter (1982, p.2) agrees with the removal of these barriers but proposes a practical route to the achievement of non-hierarchical ships. He recommends a higher standard of new entrant into the profession thus raising the ratings to the standard of officers. Henry (1982, p.125), while writing primarily about the U.S. experience, detects that 'improving the quality of the U.S. seaman is a task that will receive emphasis in the 1980's.'

Managerial issues have also been addressed by many writers and the effects of communication technology have been cited as a very important factor. Sagen (1984, p.20) states that 'It is through the development of maritime communications that we can realize integrated, advanced ship operation aided by data. The key factor is data processing as an operational aid.'

Mackay (1980, p.11) discussing ship management of the future states that advanced communications will 'have the result of bringing the ship closer to the head office, or the head office closer to the ship depending on whether one is sitting in head office or on the ship. From the ship's point of view this will enable it to ask for information to help prepare budgets, consider alternative courses of action and make it easier to act as an independent unit able to take the initiative. On
the other hand, from the head office point of view, contacting a ship will be no different from having to contact someone in the same building and, hence, there could be a great temptation on the part of head office to ask the ship for information to enable persons in the office to make all but the most trivial decisions.

McConville (1979, p.45) emphasises that management has traditionally been split into commercial management ashore and man management afloat. Both Moreby and Sagen pursue this point and indicate the wide choice available to shipowners and fleet managers along an axis ranging from extreme centralization to extreme decentralization. Moreby (1986, section 5) states that organizational choice in this area has a major effect on the skills and knowledge required aboard a particular ship. He cites 15 different crewing structures which have been observed and indicates the variations in shipboard knowledge and skills required for effective performance.

Social and living conditions aboard ships have been the subjects of many texts. Recruitment and retention of seafarers were major problems in the 1960's with a rapidly expanding fleet and were carefully examined by Moreby (1968, pp 118-125). However, today the problem appears to be not so much one of recruitment but more a problem of ensuring crew stability through providing job satisfaction. Smith & Roggema (1979a, p.130) present a long and informed
argument in favour of increased crew stability. They cite two forms of stability:

1. The same persons continually being reappointed to the same ship and
2. The same persons being appointed, as a group, to different ships.

In either case Smith & Roggema maintain that stability causes a net increase in organizational competence. Recruitment has ceased to be a major problem due to the general level of unemployment ashore and crew stability is encouraged to cope with the increasing technical complexities aboard ships.

The stressful nature of seafaring is examined by many authors and careful socio-technical design has been advocated to reduce stress. Johansen (1980, p.223) identifies stress as being caused by a substantial imbalance between the task and the seafarer's ability or means to perform that task. He draws on the work of Herbst (1974, p4) to describe how crew performance is affected by both the technical and social systems. He further emphasises that the social system is based upon the requirements of the technical system and that imbalanced alterations to either system will produce dysfunctional results. This is shown in figure 2.1.
Plattelli and Soncin (1977, pp. 89-91), in a paper on the effects on human operators of dispersed automation aboard ships, argue that the stressed human operator 'is the main source of sea accidents.' They advocate his removal in all but the most necessary instances. They refer to the human operator as performing in three phases:

1. Surveillance (acquisition of data);
2. Decision making (optimal choice strategy for intervention);
3. Control action (error-free order execution).

Kaufman & Mitchell (1982, p. 4) claim that training is provided for situations which exist and will continue to exist. However in the 'real world' the unexpected frequently occurs. Thus Henry (1982, p. 125) calls for an
increase in simulation training for these dynamic situations which cause the mariner stress. Stress is also introduced by the necessity to maintain a 24 hour watch capability and this has been examined thoroughly by Colquhoun (1985, pp.637-653).

A major theme which runs through the literature is the constant interconnectedness of technological, organizational, managerial, and social issues aboard ships. Many writers emphasise the point that the introduction of new technology must be complementary to the people who operate it. Sagen (1984, p.19) states that 'advanced ship operation must not be a technological white elephant but a type of ship of which the technological level is compatible with the people who operate it'. King (1980, p.27) comments that the world is now engaged in its second industrial revolution. He says that the gap between our technological ability to control and use technology in a proper manner is widening rapidly. He continues, 'the role of man in technological systems seems likely to become one of the most important problems that has to be faced in the years that remain to the end of this century'. Singleton (1974, p.37) recommends that to design a man-machine system it is best to start with a functional diagram. The emphasis here is on ensuring that technological advance is introduced to enhance human performance and not simply to replace personnel with machinery.
In an important work (Herbst 1974, p.48) postulates that future ships will be manned by a highly skilled, professional work force consisting solely of 'officers'. The traditional hierarchy will be removed and a more flexible structure will be introduced. Considerable decentralisation of decisions will be transferred to the ship in order to create more satisfying jobs together with the removal of unimportant routine tasks by means of automation.

Herbst proposes an holistic, socio-technical view of ships which emphasises that a ship is a complex system composed of both technical and social systems operating within an equally complex environment. This view has been adopted by other nations, with some apparent success, notably Japan as described by Ebner (1980, pp.12-14), Takuya Otonari (1980, pp.28-35) and Yasumichi Koishi (1981, pp.261-266). Also Norway has taken this view as described by Koburger (1982, pp.7-10) and Johansen (1980, pp.223-240). Finally the Netherlands also supports a socio-technical system approach to ships as described by Binkhorst (1981, pp.97-102). Each of these authors describes experiments, within his own nation's shipping, where technical advances have been introduced coincidentally with social changes.
The review of the literature in this section argues that shipping has moved from being a labour intensive industry to a capital intensive industry. This shift in critical resource is forcing a reduction in overall costs, and it is argued that labour costs are a major item in this reduction. The examination of the literature reveals that where reductions in manpower have been planned or attempted there has been, of necessity, changes in both crew organization and application of technology. The argument is made, supported by authoritative writers, that for future ship operations a change in shipboard social structure is required which will provide an integrated professional workforce which has stability and where the traditional hierarchies are removed. The point is argued that to assist in the alleviation of stress the social structures and technological structures aboard ships must be complementary. A major facet of this inter-relation between social and technical structures is shown as the data flow between the components. Data flow and communications are also highlighted by many of the authors cited as being of importance in considering the division of shipboard management between the ship and the shore.
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2.2 THE ENVIRONMENT IN WHICH SHIPS OPERATE

The approach to ship operation suggested by Herbst (1974, pp.45-53) and others was to view the operation as a dynamic socio-technical system. Since this system is imposed upon by the social environment, technical environment, economic environment and legal environment, it is proposed to examine each of these in turn. The examination will ascertain the effects of each of these environments upon the shipping system as determined by authoritative writers and common themes will be detected.

2.2.1 ECONOMIC ENVIRONMENT

Since British merchant shipping is a commercial venture, the economic environment is more dominant than either the technical or social environments as explained by Moreby (1975, p.71). This is important because those nations which have nationalised or subsidised merchant fleets may find it easier to experiment with organizational changes when cost is not such an important factor as it is in Britain.

Parker (1984, p.23) demonstrates that during a period of trade growth the ship operator's 'priority is to sustain growth and maintain quality of service. In a period of recession the priorities are cost minimization whilst also having to increase the quality of service'. British
shipping, which is currently suffering a recession, therefore has to reduce costs and improve the quality of its services. Sagen (1984, p.17) describes the environments acting upon shipping as a series of 'pushes' and 'pulls'. Figure 2.2 shows the necessary controlling influence which the economic environment must exert in order to balance the capital expenditures forced onto the system by the other environments. A push is a capital expenditure which is forced upon a shipowner whereas a pull is a voluntary expenditure which is met to ensure continued existence in the market place. For example a shipowner is obliged to purchase specialized tonnage (tankers, container vessels) and fit them with minimum technical requirements (radar, emergency steering). He is forced to comply with pollution controls and traffic routeing schemes. He is pressured into providing improved working conditions by labour organizations, national and international. However, in order to remain competitive, he may decide to improve the technological standard of his vessels or spend more money on maintaining his fleet. The economic environment, the amount of money available, is then the controlling influence which limits capital expenditure. It is worthy of note that in times of limited finance, such as at present, it is the 'push' elements which dominate and are satisfied first. Thus 'luxuries' such as maintenance or better equipment are delayed until a better financial climate...
arrives. These pushes and pulls and the monetary control are shown in figure 2.2

![Diagram showing the relationships between technical, legal, and social environments and capital expenditure in the merchant shipping system.]

**Figure 2.2**

**Environmental Effects on Capital Expenditure in the Merchant Shipping System**
Many authors have detected enormous changes in the world trading patterns since the Second World War. Frankel (1983, p.15) in a wide ranging paper describes the 'mixed history' of shipping technology. He describes 'development in spurts with feverish advances over short periods of time followed by long periods of stagnation'. Metaxas (1983, pp.145-164) presents a detailed picture of maritime economics since the Second World War and forges links between the international trade cycle and international investment appraisal. He argues (p.159) that 'the real cost of maritime transport to the world community at large will go on increasing. Consequently, the minimization of the real cost of the maritime transport function to the world community is another significant area where further economic cuts are needed'. Moreby (1975, p.7) has described 'the explosive increase in the number of different ship types' that have emerged in the post war years. This subject is dealt with in detail later. The rapid increase in container ships in the 1960's is documented by Frankel (1983, pp.11-12) and McConville (1979, p.39) has shown how container ships now form part of a wider transport system. Container ships grew rapidly in size in the 1970's in order to take advantage of economies of scale. Frankel (1983, pp.10-12) has shown that bulk carriers (liquid and solid) also grew in size during the same period for similar reasons.
During this period many less developed countries with no shipowning history emerged as maritime nations. Frankel (1983, p.2) describes these changes in world trade in terms of 'composition, type and physical form of cargoes, cargo routes, terms of trade, and length of average trading distances'. McConville (1979,) describes the emergence of fleets of non-traditional maritime nations and details its effects on manpower patterns in the British merchant fleet. He argues (pp.45-46) that in order to compete within the international labour market new maritime careers should be created which are based on new manpower management principles.

Metaxas (1983, p.157) describes the problems posed to the study of maritime economics by the emergence of the fleets of developing countries. He calls for further research and the application of scientific principles to the solution of these economic problems. The emergence of the fleets of developing countries was encouraged by UNCTAD (United Nations Conference on Trade & Development) which imposed restrictions to end the monopoly of the liner traders (Frankel 1983, pp.2-3). A further aim of UNCTAD was to curtail the activities of 'flag of convenience ships' and allow less developed countries to produce their own merchant fleets (Parker 1984, p.24). It was argued that sub-standard vessels were used to trade with lesser developed countries. UNCTAD enabled these countries access
to newer technology and thus gave a consequent boost to their national economies. (Frankel 1983, p.3)

The lesser developed countries had a further effect on global trading. After the ratification of the UNCTAD Code of Practice for Liner Conferences and in order to rationalize ship usage, many processing plants were constructed in the lesser developed countries near to raw or semi-finished materials. This has been described by Frankel (1983, p.2). This resulted in continuing growth in world trade but with a reduction in trading distances. (Frankel 1983, p.3).

Since 1974, the E.E.C. (European Economic Community) has included shipping in the economic principles of the 'Treaty of Rome' i.e. free trade within the E.E.C. This concept of free trade is part of the history of shipping but increased competition for less trade has led to protectionism (Sagen 1984, p.17) and to unfair trading from the Soviet Bloc (Parker 1984, p.23).

Moreby (1975, p.71) demonstrates that shipowners have 3 methods of earning revenue from ships:—

(a) Cargo carrying or chartering out;
(b) Speculating in the sale and purchase market;
(c) Using ships as 'vehicles' for fiscal advantages.

Shipowners now are forced to employ a dynamic balance of (a), (b), and (c) depending on trading patterns,
financial markets, and availability of tonnage.

Frankel (1983, p.4) describes how modern shipowning has changed from the image of the entrepreneurial individual to 'joint venturers' or 'cross national conglomerates'. He also emphasises that because of the intensity of capitalisation of the industry much shipowning is carried out with government or other public finance.

The dramatic increase in the size of merchant ships from the mid 1950's onwards was caused by the equally dramatic increase in seaborne trade, until 1973 when the sudden rise in the price of oil, plus increases in port costs and labour costs, dealt a blow to world shipping. This has been described by Wall (1980, p.155). Since the fuel costs were virtually the same for all shipowners the crew costs became the only variable over which the owners or fleet managers had any control. Koburger (1984, p.11) states 'the key manageable area is manning. We must become really capital intensive and efficient, leaving the labour intensive ships and trades for those with cheaper manpower.' Parker (1984, pp.23-24) examines the choices available to shipowners when considering crew costs. He proposes three solution sets:

1. Protect jobs - a political decision with monetary costs.
2. 'Flag out' - a commercial decision which will shed jobs but produce monetary savings.
3. Improve productivity by introducing new methods.

Thus the huge difference in the costs of western crews and crews from the less developed countries has led to 'flagging out' (Parker 1984, p.24) and the withdrawal of western shipowners to the liner trades and short sea trading (Koburger 1982, p.7).

A comprehensive view of the economic environment is taken by Metaxas (1983, pp.151-154). He draws trading patterns and ownership patterns together in a cyclic picture based on the 'theory of the firm'. Thus advantageous trading leads to more ships being built as newcomers enter the market; after an indeterminate time lag the trade has an excess of tonnage, so freight rates drop leading to 'lay-ups' and a cessation of shipbuilding. Again after an indeterminate lag there is insufficient tonnage and trading is once again advantageous to the shipowner, thus beginning the cycle again.

SUMMARY OF THE ECONOMIC ENVIRONMENT

The review of the literature pertaining to the economic environment surrounding the British merchant fleet reveals a complex and irregular cyclical pattern. Following the Second World War the increase in world trade and investment in specialized ships led to a period of growth. Then the emergence of less developed countries as maritime
nations together with the oil crisis of 1973 precipitated a recession. This recession has meant that ship operators have had to maintain services with minimum costs. This minimizing of costs has led to crew reductions and 'flagging out' to obtain the benefits of cheaper crews.

The literature reveals that during a recession, such as we are experiencing, shipowners have few variables which they can optimise. Crew reduction together with increased technological assistance is one ploy which finds approval among many authors, but this means a reorganization of work among those remaining and a careful reallocation of tasks between crew members and technological aids placed aboard.

2.2.2 TECHNICAL ENVIRONMENT

Many levels of abstraction of the technical environment have been observed and described. Frankel (1983, pp.1-15) has presented an exhaustive description of the choices of equipment technology currently available, while Moreby (1975, pp.6-10) has presented a description of the emergence of completely new trades and the application of technology to new maritime ventures.

At the macro end of the scale it has been shown that the shipping industry is volatile, interspersing periods of stagnation with periods of frenzied technical advance (Frankel 1983, p.15). One of the periods of stagnation has
been described by Moreby (1975, p.5) who demonstrates that from 1910-1955 shipping remained relatively unchanged consisting of three basic technical classes of ship - cargo liners, cargo tramps, and oil tankers.

Worldwide demand for the transport of raw materials led to the emergence of the bulk carrier specifically to transport ore, bauxite, cement, grain, fertilizers, and coal as described by Yolland (1974, pp.21-37). These bulk carriers essentially replaced the cargo tramp as economies of scale forced out the smaller ships and large companies began to transport cargoes in bulk. The carriage of these cargoes led to the development of specialized shore interface facilities - grabs, suction equipment, and conveyor belts. Bulk carriers have since diversified further to encompass what Frankel (1987, p.108) describes as pseudo-bulk cargoes ie. specialist timber carriers and car carriers, again requiring specialized shore facilities.

Oil tankers became more specialized in response to market demand and promoted the emergence of crude carriers, products carriers, chemical carriers, and liquefied gas carriers. The latter two classes especially demand very specialized shore interface facilities. Traditional cargo liners were replaced by container ships which again require a high degree of mechanization and specialized equipment at their terminal ports.

Thus the trend has been detected (Moreby 1975, p.9)
towards greater specialization of ship type and greater mechanization of cargo handling facilities. This is shown graphically as figure 2.3.

**Figure 2.3**

DIVERSIFICATION OF SHIP TYPES DUE TO SPECIALIZATION AND MECHANIZATION
This trend has also been observed and recorded by Frankel (1983, p.1) who stresses the importance of consumer demand on specialization of cargo form, containment, types of handling, methods of transport, and efficient inter-modal interface.

Many writers have highlighted the fact that modern shipping is now a more integrated part of a total transport structure and thus specialization and consequently technology are being forced onto ships. As Frankel (1983, p.4) expresses it, 'with transportation now increasingly designed as point-to-point systems in which shipping serves as but one link in a chain of transport links, new or different technology is often forced onto shipping for reasons of system consistency and efficiency and not necessarily shipping efficiency'. Sagen (1984, p.17) states that the advances in shipping technology are caused by :-

(a) The pull of the market forces

(b) The push of the technical environment

These forces are illustrated in figure 2.4.
These forces are similar to those mentioned earlier and indicate how the technical environment is pushing new technology and associated expense onto the transport pattern. Similarly, in order to remain competitive, a shipowner must expend finance in order to utilise the new technology which will place him ahead of his competitors. In this case he pulls the required new technology to him in order to aid the transport pattern.

The high degree of specialization has dangers for shipowners in that they are constrained to certain ports and cargoes and are relatively unadaptable in the event of a market collapse in their own specialised field. Moreby
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(1975, p.9) has drawn attention to this. The problem has been perceived by others (Smit & Pijcke 1984, pp.66-67) who predict that, although specialization will continue, it will lead to classes of multi-specialist vessels. They cite as examples the cases of OBO's (Ore & Bulk Oil carriers) and oil rig supply/anchor-handling/anti-pollution/fire-fighting vessels.

At the micro end of the technical environment significant advances have been detected in control systems. Parker (1984, p.27) selects the VDU concept of display as a prime advancement for ships with a central control unit on the ship's bridge and satellite controls elsewhere. Sagen (1984, p.17) states that 'advanced control automation equipment will be utilized more extensively on board. This applies to cargo-handling, mooring, maintenance, manoeuvring etc.' Smit & Pijcke (1984, p.64) agree that developments in automated control will grow steadily but urge caution and seek increased research into reliability and systems knowledge. Robotics is another area which has received attention. Frankel (1983, pp.14-15) argues that 'robotics, probably more than any other technological development, will affect shipboard employment both by number and skill as well as the shipboard social structure and lifestyles.' He therefore urges extreme caution in their application for although they can upgrade shipping services and the skills of people they can also cause
Irreparable losses. Parker (1984, p.27) claims that robotic solutions will evolve as crew numbers diminish, the speed of evolution being a function of relative costs. Communications will, according to Parker (1984, p.27), be used in the future to redeploy certain control functions to the shore and this will have the effect of reducing crew complements even further. Frankel (1983, p.13) describes the implementation of satellite communications but does not appear to consider modern communications as a major technological advance. Sagen (1984, p.20) however, sees maritime satellite communications as the key to future ship management and claims it 'offers the greatest challenges and possibilities for ship operations.' He sounds a small word of caution, however, by stating that, 'communications by themselves do not, of course, promote shipping competitiveness but, in the right context, this technology should be an effective aid in our continuous endeavour to keep up in the international chase to optimize costs/productivity within sea transport.'

Thus we have control systems, robotics and communications all of which will lead to reduced manpower requirements and a need for new shipboard organizational structures.

Maintenance technology is a field which many see as an area which should receive more attention as other technological developments combine to allow crew
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reductions. Yasumichi Koishi (1981, p.265) recognises this problem and proposes four strategies which may be employed to overcome maintenance problems:

1. REPLACEMENT of equipment to that which is easily maintained by replaceable components.

2. TRANSFORMATION of maintenance work performed by persons aboard into maintenance work performed by equipment ashore. This may be performed by the utilization of sophisticated diagnostic equipment.

3. TRANSFER of maintenance work from persons aboard to persons ashore.

4. TRANSFORMATION from reactive maintenance (repairs) to planned proactive maintenance.

SUMMARY OF THE TECHNICAL ENVIRONMENT

This review of the literature relating to the technical environment describes an industry which consists of ships which are becoming ever more specialized and mechanized. This increase in specialization and mechanization is leading to ever greater dependence on shore facilities and support. Ships are now seen as links in a total transportation system rather than isolated, unique modes of transport.

The increased dependence on shore facilities together with advances in automated control, electronic data
transfer and communications is enabling ships to operate with fewer crew members. However the crew remaining must be complementary, in knowledge, skills and organization, with the new technological systems which they are to operate.

2.2.3 SOCIAL ENVIRONMENT

Smith & Roggema (1979b, pp.145-156) have made an exhaustive search of available literature in order to extract the issues of social importance in shipping. Essentially they identify five areas which are receiving substantial international attention in order to improve seafaring as a way of life and the effectiveness of manning.

(a) Crew stability - by which is meant the formation of a group, enduring over time, and returning to the same ship.
(b) Clarification and redefinition of task allocation from shore to ship.
(c) Improvement in work planning.
(d) Improvement in job content of ratings.
(e) Development of shipboard training.

These five areas will now be considered in turn:

(a) CREW STABILITY

Many writers have commented upon the issue of
crew stability (Moreby 1975, pp.101-109, Sharpe 1979, pp.1-2, Smith & Roggema 1979a, pp.129-143). Moreby (1975, p.101) has described the transient nature of ships' crews. He emphasises the point that individuals may join and leave ships performing their allotted tasks but 'unable to give anything of themselves to their present ships' due to the transitory nature of their employment. Herbst (1974, p34) and Smith & Roggema (1979a, p.131) refer to this phenomenon as an 'exchangeable component structure'. This random formation of social groups which do not endure through time has important consequences. Moreby (1975, p.101) identifies the awareness of replaceability as a major cause for dissatisfaction amongst seafarers.

Moreby (1975, p.101), in pursuing the logic of this structure, states that 'it becomes necessary to think of the social system on board a ship, not in terms of individuals, but in terms of the tasks which must be fulfilled or, preferably, in terms of the roles that have to be filled.' The tasks will remain unchanged through time but the roles will alter depending upon the level of technology and the social structure aboard.

Smith & Roggema (1979b, p.154) expand on this point and indicate that in present day ships with 'unstable' crews, effectiveness is maintained by two main factors:

(a) High role prescription - i.e. role behaviour must be clearly and specifically delineated so that a
variety of individuals may learn to occupy the role in a relatively short period of time.

(b) Low role interdependency - i.e. roles are proscribed to minimize the degree of interdependence thus lessening the impact of the variability in individual performance.

Both Sharpe (1979, pp.1-2) and Smith & Roggema (1979b, p.154) state that a major result of role prescription and 'exchangeable components' is the necessary universality of the structure of ships' crews. This means, for example, that all second mates must share a common role in order that they may move freely from ship to ship and work safely and effectively. Sharpe further points out that it creates a need for a centrally established measure of role competence.

Moreby (1975, pp.101-104) proceeds beyond the theory of roles and addresses two major practical problems involved in maintaining a measure of crew stability. These are recruitment and retention of seafarers. Technological advances and economic forces alter the nature of shipboard employment to accommodate faster turnaround times in port and promote more efficient sea passages. This is at odds with the traditional recruiting image of an adventurous career with time to spend ashore in foreign ports. Either recruiting must be changed to reflect the truth and risk a consequent drop in applicant numbers; or recruiting
methods remain the same and disillusioned recruits will leave the sea at an early stage. This problem has abated since Moreby identified it in 1975 due to the general increase in unemployment ashore. It is however an issue which must be addressed for the long term benefit of the industry.

(b) TASK ALLOCATION FROM SHORE TO SHIP

Many authors (Moreby 1975, pp.10-28, Poole, 1981, pp.207-221, Sagen 1984, pp.17-22, Shuji Aoki 1980, 233-239, Smith & Roggema 1980b, pp.225-269) have examined the relationship between the ship organization and the shore organization with regard to decision-making. All of the named authors cite changing technology as having a major impact on the allocation of decision making between ship and shore. Smith & Roggema (1980b, pp.241-254) state that increasingly sophisticated technology tends to encourage decentralization. Shuji Aoki (1980, pp.233-239) notes the need, with reducing crew numbers, for democratic, decentralized manning structures which are flexible enough to adapt to environmental change. Poole (1981, p.214) emphasizes that 'decisions have come to reflect technical criteria rather than judgements based on experience. Thus persons in charge of technical apparatus must have more decision making power than was once the case.'

Moreby (1975, pp.10-28) suggests, as does Herbst
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(1974, p.28), that although in the past the technical systems determined the social system on board, it is now possible to select a centralized or decentralized decision making social system and choose the technology suitable to support the selection. Thus information may be sent to the ship to enable onboard decisions to be made or ship data may be transmitted ashore for analysis and subsequent decision making. Lawrence (1988, p.5) pursues this point and states that for optimal ship functioning the crew decision-making social structure must match the shore decision-making social structure. This is shown in figure 2.5. and from it can be seen two effective complementary structures:

1. A vessel in the liner trade (i.e. regular ports of call) may have a centralized shore decision making structure to allow scheduling of the total transport network. This will require a crew which will accept instructions, routes, and schedules from the shore authority - a 'dependent' crew. This organization will function effectively providing the communications channels from shore to ship are functioning correctly.

2. A vessel in the offshore industry which is in daily contact with its charterer will require the Master and officers to make on the spot decisions regarding schedules, downtime, and integration of the ship into the offshore operation. In this instance the shore decision making is
decentralized to the ship and the crew must be of an 'independent' nature to handle these decisions in an effective manner.

<table>
<thead>
<tr>
<th>SHORE</th>
<th>HIGHLY DECENTRALIZED</th>
<th>MIDWAY</th>
<th>HIGHLY CENTRALIZED</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGHLY INDEPENDENT</td>
<td>EFFECTIVE</td>
<td>INCREASED SHIP AUTHORITY</td>
<td>CONFLICT</td>
</tr>
<tr>
<td>MIDWAY</td>
<td>INEFFECTIVE</td>
<td>EFFECTIVE BUT PERSONALITY DEPENDENT</td>
<td>INCREASED SHORE AUTHORITY</td>
</tr>
<tr>
<td>HIGHLY DEPENDENT</td>
<td>VERY INEFFECTIVE</td>
<td>INEFFECTIVE</td>
<td>EFFECTIVE IF GOOD COMMUNICATION</td>
</tr>
</tbody>
</table>

**Figure 2.5**

**COMBINATIONS OF SHIP AND SHORE DECISION MAKING SOCIAL STRUCTURES**
Poole (1981, p.214) draws attention to the fact that higher technology and increased decision making aboard ship leads to the recruitment of individuals with a higher level of general education, and this causes patterns of authority and status to become subject to substantial pressure for change. Lawrence (1988, p.6) examines authority and accountability for decisions in depth and asserts that if there is an increase in decisions made by the persons in the shore office then they must, in some form, be held to be more accountable. This point has also been recognised recently by Mr. Justice Sheen (1987, p.36-40) during the formal investigation into the loss of the 'Herald of Free Enterprise'. This pressure for change is addressed by Shuji Aoki (1980, pp.233-239) who maintains that the shore employers must cease to view shipboard employees in a negative manner (as a manpower resource) and regard them in a positive manner by devolving more decisions to the ship and creating worthwhile jobs.

Moreby (1975, p.46) talks in terms of a move from military manning to industrial manning and poses, as yet unsolved, problems. Should the ship's master be viewed as a task leader, relaying orders from shore, or should he be viewed as an expressive leader, relaying crew feelings to the shore? Is it possible for one man to hold both roles effectively?
(c) IMPROVEMENT IN WORK PLANNING

The organization on board ship which leads to the accomplishment of work has been described by many authoritative writers as hierarchic (Moreby 1975, Poole 1981, Shuji Aoki 1980, Smith & Roggema 1980a). Herbst (1974, p. 33) goes further and describes the organization as bureaucratic of which a hierarchy is a necessary part.

Moreby (1975, p. 44) following Herbst (1974, p. 34) claims that this hierarchical structure implies psychological role attributes to the members of the hierarchy - thus ship masters are frequently viewed as infallible (regardless of the individual) and ratings are frequently viewed as irresponsible and incompetent (regardless of individuals).

Both Moreby (1975, pp. 49-51) and Smith & Roggema (1979b, 145-147) draw attention to the divide between officers and ratings. Smith & Roggema (1979b, p. 145) view the divide in terms of a 'caste-like' division with little commonality in tasks and strict social segregation. Moreby (1975, p. 28) pursues the consequences of the divide and shows how automation has left the residual tasks aboard as consisting of high level decision making and low level menial tasks. He therefore postulates that one detrimental result of automation is to perpetuate the officer-rating divide and, indeed, to make the divide more difficult to cross.
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Herbst (1974, p.36) has noted that in recent years the removal of many decisions to the shore and the reduction in crew numbers has effectively reduced the authority of officers. He notes that they now make fewer high level decisions and that there is less supervision of subordinates. Also, when there used to be large, separate departments the chief officer and the 2nd engineer worked separately and allocated tasks to their departmental ratings; now, with reduced crews and dual purpose ratings, collaboration is essential between the departmental heads, and sound work planning is crucial for the effective use of available manpower.

Moreby (1975, p.50), following Etzioni (1961), has outlined the differing means of control that can be exerted over a workforce - normative (moral influence), coercive (control by punishment), and remunerative (control by reward). He distinguishes between the balance of these used to control the officer class and the rating class. He stresses that an important point in future work planning is to achieve the correct balance of controlling influences.

Finally, Moreby (1975, pp.80-81) once again points out the wide variety of technical choices available to achieve objectives and the necessity of making the technical choice of work aids fit the desired social structure which is organized to plan and achieve the work.
(d) IMPROVEMENT IN JOB CONTENT OF RATINGS

Moreby (1975, p.26) quotes Maslow (1954) as describing our present age as that of 'psychiatrically healthy man', he proceeds to draw on Herzberg's (1966) description of 'instrumental man' to present a picture in accord with McGregor (1967) of a modern worker needing to exercise both intellectual as well as motor abilities and who is conscious of both personal abuse and global abuse of the seas as regards pollution.

Shuji Aoki (1980, pp.35-37) expands on this theme and indicates the need for shipping organizations to orientate their business behaviour towards a higher level of social responsibility. He suggests that the onboard work environment should be directed towards quality of work rather than quantity. He cites two youth culture movements - 'Work Worth Doing' in Japan and 'Quality of Work Life' in Europe - which arose simultaneously amongst educated youth who were not satisfied with increased leisure time and monetary reward, but demanded worthwhile careers as well.

Moreby (1975), Shuji Aoki (1980), and Smith & Roggema (1980a) are all in agreement with regard to the need for a fundamental reappraisal of the work content of ships' crews. Furthermore they all agree that, in reallocating tasks within the ship, the feelings and needs of seafarers must be taken into high account.

Yasumichi Koishi (1981, p.265) has shown, from
research voyages, how work restructuring to accommodate reduced crews has taken four forms:

"(a) The replacement of manual work by putting machines on board.
(b) The transformation of work on board into work done by machines on shore.
(c) The transfer of work previously done on board to the shore.
(d) The transformation of work within the ship."

The ship was considered as a 'technological structure' and a 'social structure' and, unfortunately, Yasumichi Koishi could only focus on the technological structure because methods for dealing with the social structure were not well developed.

(e) DEVELOPMENT OF ONBOARD TRAINING

Smith & Roggema (1979b, p.155) identify the need for new training courses ashore to prepare crew members for any changes in organizational structure. Herbst (1974, p.59) goes further and propounds a major learning programme to be pursued aboard the ship. His preliminary findings indicate:

1. A training scheme in which ships' officers perform the training function may provide the initial condition required for a change in the basic culture of ship organization. Such a scheme would tend to break down...
(2) Officers involved in teaching tend to acquire a better grasp of a subject and are motivated to acquire further appropriate training themselves.

(3) The emphasis should not be on the elementary training of young sailors, but on the provision of conditions for the development of a teaching-learning culture based on the total crew on board.

Herbst continues with a criticism of present training schemes by stating that they are not designed, nor sufficient, to create fundamental changes in organizational structure.

Herbst (1968 & 1969) notes the problem of ships' officers being given responsibility for operations for which, owing to technical and administrative changes, they have not had the requisite training.

Moreby (1975, p.25) builds on Herbst's observation and provides an insight into a practical problem of training which is emerging. He describes a cycle of technical innovation followed by obsolescence which is becoming of ever shorter duration. Thus persons on board must learn to familiarize themselves with technological advances and maintain a receptive, learning frame of mind.
SUMMARY OF THE SOCIAL ENVIRONMENT

The examination of the literature pertaining to the social environment presents a disturbing picture of a past and continuing disregard for individuals. It is seen that seafarers, for reasons of convenience, are seen as 'exchangeable components'. This leads to high role prescription, low role interdependency, and the necessity for a central measure of competence assessment. The conclusion is also drawn from the literature that many authors are sensing the need for change in the social structure aboard ships. This is principally seen as a move towards removing the traditional hierarchies and departmental barriers. It is also recognisable in the discussions as to task allocation between ship and shore and the variations possible in the location of managerial decisions.

Important points raised by the writers consulted include the recognition that shipboard organizations must become more flexible and adaptable to change. The social organization aboard each individual ship must match the technology provided on each ship. Also there should be a regime of continuous and ship-based training. Finally, but certainly not least, emerges the fact that it is the shipboard tasks, which endure through time, which should be examined; not the traditional and apparently questionable role structures.
2. LITERATURE REVIEW

2.2.4 LEGAL ENVIRONMENT

Dunning (1984a, pp.12-19) has outlined the legislative history affecting seafarers. He asserts that the first steps towards seafaring legislation began in 1836 and in 1854 certificates of competency for masters and mates became mandatory aboard British vessels. He notes that the early requirements for a certificate of competency were more in terms of the candidates' social suitability, sobriety and honesty than in the possession of professional skills. This point is also recognised by Tobin (1982a, p.11) who confirms that social attributes are, even today, given more emphasis than technical or commercial ability when considering 'the process by which an officer learns of the job he is to do, and is judged on how he has done it'.

Dunning (1984a, p.12) traces the emphasis in competency requirements through the changing social values of the last 150 years, from an emphasis on sobriety and integrity through an era of technical competence to the present day where great emphasis is laid on the protection of the environment.

Due to the international nature of environmental destruction caused by marine pollution, international bodies have been established. The International Maritime Organization and International Labour Organization (IMO & ILO), each charged with aspects of ensuring safe manning of ships plying the high seas (Parker 1984, p.28).
IMO has two important influential areas:\n\n(1) Standards of training and certification of watchkeepers (STCW) which define the skills, knowledge and experience which must be held by the master and watchkeeping officers aboard ship for it to be considered safe. It does not deal specifically with numbers of personnel which should be carried aboard ship. (Dunning 1984b, p22).

(2) Safe Manning Resolution - which encourages national regulatory bodies to issue safe manning certificates. It is very much concerned with numbers of personnel which should be carried aboard ship. (Anon. 1984a, pp.16-17).

Moreby (1981a, p.144) criticises IMO standards for training, certification and watchkeeping in that they are 'a rigid set of manning rules which cannot be relaxed for a particularly responsible country for fear that less responsible operators will take unfair advantage of the loopholes.'

Dunning (1984a, p.19) pursues the point of irresponsible operators and argues that those responsible for making staff appointments to ships should themselves be adjudged competent and be accountable. He cites several cases of unsuitable people being appointed to expensive ships, some with hazardous cargoes, with the full knowledge of the shore operators.
Parker (1984, pp.28-29) points out that such occurrences are not problems of legislation but of enforcement. He proceeds to draw attention to the conflicting interests of governmental regulatory bodies, employers' organizations, and trades' unions. He makes out a case for professional institutes to be more involved with competency assessment.

Dunning (1984a, p.14) questions the validity of a 'certificate of competency' as demonstrating competence. He claims the certificate demonstrates only two things:

(i) The possessor has served a minimum period at sea satisfactorily (which may only mean he was not demonstrably unsuitable).

(ii) He has been able to demonstrate a broad appreciation of basic professional and technical skills.

International standards of ships' equipment have also been produced by an international convention, Safety Of Life At Sea (SOLAS 1974), which defined the statutory equipment outfit for various ship types (Miller 1980, p.10). Moreby (1981a, p.144) notes that such are the international anomalies between responsible and irresponsible countries that trends are to make a ship safe to enter port rather than safe to go to sea.

Not only does national and international legislation impinge on ships' crews and ships' equipment but it can also impinge on the routes which ships may follow by the
imposition of compulsory traffic schemes and vessel traffic services. Once again the problem here is one of enforcement rather than legislation.

**SUMMARY OF THE LEGAL ENVIRONMENT**

This brief review of the literature relating to the influences of legislation on ships' crews demonstrates that competence requirements of the officers have passed through three eras. They were initiated to safeguard the venture capital of merchants and progressed to become assurances of an individual's technical competence safely to take charge of a ship. They are now not only an assessment of social suitability and technical skills but incorporate an international awareness of the risks which a modern merchant vessel poses to human life and its physical and financial environments. This moral factor is seen as important since most authors note that enforcement of legislation is extremely difficult and it is thus very much left to individual masters and officers to comply with the appropriate legal requirements even though sanctions for non-compliance are highly unlikely.

Most of the literature relating to legislative requirements for ships, and not referred to in this thesis, is aimed specifically at the initial strength and seaworthiness of the vessel and the items of equipment with which she is fitted. By comparison the legislation
2. LITERATURE REVIEW

concerning the personnel aboard is minimal. The real effect of the legal environment is to provide minimum standards of safety and providing these are met there is little to prevent the introduction of innovative shipboard organizational structures.

SUMMARY OF THE SHIPPING ENVIRONMENTS

A summary of the findings of the review of the literature describing how the environments affect the operation of ships is presented as figure 2.6. This illustrates that the economic environment, via recession and third world competition, is pressuring for a reduction in crew sizes. This pressure is being augmented by the technical environment which, by demanding more specialized and mechanized ships, is removing traditional labour intensive functions from the ship. As the crew sizes are reducing then the level of technological support is increasing so that the remaining crew members may still perform satisfactorily.

Pressures for change have arisen in the social environment causing variations in the organization of shipboard work groups in order to produce more industrial democracy and worthwhile jobs.

The combination of changing technology and revised social work groups can provide an integrated professional
Environmental factors demanding an integrated professional workforce

Figure 2.6
workforce capable of achieving the functions which are necessary safely to operate ships. The legal environment, which imposes minimum standards of personnel qualifications and minimum standards of equipment, whilst not preventing the formation of such an integrated group will closely monitor performance of such a group and adapt legislation accordingly to either support or inhibit such organizational advances.

Herbst (1974, pp.54-62) and Smith & Roggema (1980a, pp.241-254) both suggest, without empirical evidence, that the ideal solution to the shipboard organizational problems presented by the shipping environment is a matrix manning system.

MATRIX MANNING

Herbst (1974, p.54) defines a matrix organization in the following terms:

"A matrix organization is one that does not have any single division of functions, such as deck and machine, but permits the formation of these and other subgroups according to the nature of the task to be performed. The matrix organization does not contain built-in status differences; it is based on the assumption that each officer has a specialist role together with a range of task
competences which partly overlaps the competences
of other officers. Any officer may thus,
depending on the nature of the task to be done,
take on a leadership role or act as a member of a
specific task group."

This definition is supported by Thorsrud (1980, p.19)
who states that,

"Matrix organisation is based on two principles
opposed to that of uniform, hierarchical
organisation. Each person is assumed to cover
more than one work role. And each person is
assumed to alternate between different roles and
status levels. The overlapping between roles is
limited because some degree of specialisation is
required."

Smith & Roggema (1980a, p.249) assert that the matrix
concept presupposes officers with a broader range of basic
and specialist skills. They then proceed to enumerate the
four basic characteristics of a matrix organization.

1. Primary and secondary roles. Each officer has a
sufficient range of skills so that he can take up primary
and secondary work roles in the organization. The officer
is trained to a basic proficiency in a number of skills,
for example navigation, mechanical engineering,
electronics. His further education involves an in-depth
training in one of the major areas of expertise, for
example navigation. On board ship his specialist skills define his primary role, and his basic proficiencies determine the areas where he works in a back-up or assistant capacity.

2. Task-based leadership. With the creation of primary and secondary roles in the matrix organization the level of responsibility and the work domain of the officer are both enlarged. In his primary role he will have a higher level of responsibility for a shipboard system which requires him to be responsible for the operation, planning, control and execution of maintenance, and administrative back-up, for that system. In normal conditions he will perform the majority of tasks himself. Occasionally the workload may be such as to require the assistance of other officers, or the task may require a degree of skill only possessed by others. These officers will be assisting him in their secondary role and the officer with the primary responsibility for the system will act as the task leader. At other times he will work in his secondary role, assisting the other officers in their areas of primary responsibility. In comparison to the conventional chain of command organization where leadership is based on rank, in the matrix organization leadership is based on task responsibility. Each officer in the matrix will therefore have both a leadership role and a number of subordinate roles, depending on the system being worked on.
3. Task-based group formation. The primary and secondary role structure of the matrix organization gives rise to a variety of sub-groups of officers based on task requirements. In his primary role the officer will be a leader of one such group, and in his secondary role he will be a member of other task groups. The organization is essentially a matrix of functions on the one axis and individuals with multiple skills on the other. This is schematically illustrated in figure 2.7. The flexible internal structure of the matrix organization is in marked contrast to the department structure of the conventional organization. The formation of different task groups accounts for the capacity of the matrix organization to meet varying workloads based on the greater versatility of individuals.
2. LITERATURE REVIEW

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P = PRIMARY ROLE; S = SECONDARY ROLE

For example Function group 2 composed of leader A, members B & C.
Officer E, Primary role function 7, secondary roles 5 & 9.

FUNCTION ALLOCATION UNDER MATRIX MANNING

Figure 2.7

It is important to note that within the literature are comments such as Herbst's "assumption" that each officer has a specialist role, and Smith & Roggema's "presupposition" that officers have a broader range of basic and specialist skills. Thorsrud makes the "assumption" that persons alternate between different roles and status levels.

Clearly if matrix manning is to work in practice then it must be determined that there exist primary and secondary roles aboard ships. It must be demonstrated that there are two levels of performance of functions, one of
which demands a primary role operator and the other which may be performed by an operator acting in a secondary role.

Equally, the functions for allotment to primary and secondary operators must be identified and recorded in order completely to define the matrix.

Thus it is necessary to identify the fixed functions which must be performed and a method of analyzing such functions so that they may be allotted as primary or secondary role functions. In order to assist this process a literature search was instituted into the fields of job/task and skills analysis to locate a suitable analytical tool.

2.3 JOB/TASK AND SKILLS ANALYSIS

Originally job analysis techniques were used for the purpose of job evaluation, i.e. the assessment of the monetary worth of a job (Livy 1975, p.13). Many authors have written guidance texts on analytical methods which assist in the evaluation process, notably Bradley (1979, pp.3-9), Burns (1978, pp.1-35) and Thomason (1980, pp.6-28 and 60-179). Between them they provide 9 methods of analysis, some qualitative and some quantitative.

Husband (1976, p.39) is quite categorical in stating that analysis for evaluation should be addressed to the job alone and the abilities of the worker are of no concern. He
states 'job analysis is what it says: the analysis of the job in terms of the content and requirements of the job. It is not at all concerned with the abilities of the worker who does the job.' This contrasts with Elizur (1980, p.78) who maintains that there are 3 main factors in job analysis - identification; description; human requirement. Thus Elizur tacitly assumes that it is not possible practically to separate the worker from the work being analyzed. He maintains 'Human requirement information is of major importance for recruitment, selection and training'.

However both Elizur and Husband agree that job analysis may be used for purposes other than wage bargaining. Husband (1976, p.47) particularly mentions 'job analyses and descriptions can be used as basic building blocks for organization restructuring, where responsibilities are moved from one job to another and individual jobs are rationalized to allow for optimal use of skills and abilities'.

Paterson (1975a, pp.23-30) selected decision making as the main criterion for wage structures and produced six decision bands which, he claimed, cover all levels of jobs:—

- Unskilled
- Semi-skilled
- Skilled Supervisor
- Department Manager
- Works Manager
- Chairman

In order to perform a job evaluation exercise
Paterson (1975a, p.29) recognizes that job analysis is necessary. He states (p. 31) that 'A job can be analysed in terms of the activities involved, either by analysing the major function and breaking it down into its parts then grouping some of these parts as the structuring of the job, or by directly observing the activities of the job and constructing the job from them'. Further, he makes the important point (p.28) that a job analysis should be made for each decision band using descriptions of the elements that are necessary to the operations of each band. Thus unskilled work is described by means of simple tools and achievements whereas the work of the department manager would be described in terms of decisions and responsibilities.

However Livy (1975, p.52) warns against this essentially analytic approach and states that "the totality of a job is greater than the sum of its parts". This is important because it has implications for the 'exchangeable component manning' identified earlier by Smith & Ruggema (1979a) and Herbst (1974). It would appear that, according to Livy (1975, pp.127-129) it is not sufficient to identify a role by the number and nature of tasks of which it consists; rather a role would be better identified by describing holistic functions which must be achieved. This would appear to agree with the stricture of Husband (1976, p.39) inasmuch as the functions required to be performed could be
described with no reference to a worker. Indeed the function may be fulfilled by man or machine or by some combination of each. At first glance this would appear to invalidate the work of Paterson since he uses personal terms such as Chairman and Works Manager. However if one looks past the terminology to the underlying band of decisions then it is clear that if a series of functions are performed then some will have higher decision levels in terms of the criticality and time span of effect of the function. Whether the decision is made by man, machine-assisted man, or totally automatically does not affect the level of the decision.

A feature of workers moving through the decision bands of Paterson is promotion which is frequently allied to training. Job/task analysis has been found to be of use in the field of training. Brock et al. (1975, pp.28-31) describe how job/task analysis has been used by the US Navy to assist in training by detecting common core knowledge and skill objectives. The job/task analysis procedure was then utilized to produce five specialist training programmes which were followed after students had completed the common core programme. DeCotiis & Morano (1977, pp.20-24) emphasise the need for training schemes to be based on sound job or task analysis methods. Foley (1973, pp.28-39) describes how task analysis can be used (1) for determining precise objectives and content of
initial job training and (2) for preparing instructions for tasks of maintenance jobs. The task analysis process includes both task identification and the analysis of identified tasks. Freda & Loolioan (1975, pp.22-27) also describe the application of task analysis to training needs in a single organization. In the literature pertaining to training a useful concept of competence has been developed by which is meant more than just the skills and knowledge required for a job. Rakow (1982, pp.18-19) states that for an operator to be competent he must be capable of performing five separate functions - preparation; performance; monitoring; troubleshooting; and evaluation. Zemke (1982, pp.28-31) speaks of 'competency modeling' where 'we are after a functional analysis rather than a complete description of all possible job tasks'. Zemke draws on previous unpublished work by Arthur E. Worth where he (Worth) divides competencies into three classes:

1. Administrative competencies - Involving DATA.
2. Technical competencies - Involving THINGS
3. Personal competencies - Involving PEOPLE

Becker (1977, pp.21-22) cites six areas that together comprise competency: Knowledge; Understanding; Skill; Value; Attitude; Interest. This is in broad agreement with the competency demanded of ship's officers as described by Dunning (1984a, pp.12-19), where knowledge, understanding and skill are assessed as technical
competence; values and attitudes are fostered in terms of environmental awareness, and interest is assumed at recruitment stage. However training is, for seafarers, a phenomenon which they experience only early in their careers. During a long career at sea much technological change will be experienced and some of these advances will certainly entail the restructuring of jobs. This has already occurred with the advent of radar, satellite navigation, and the unmanned machinery space.

Job and task analysis has been used for the restructuring of jobs due to the advent of new technology. Bailey (1983, p.241) poses the question 'are there alternatives and options available which can lead to a satisfactory fit between the new technical and social systems involved?'. He also (p.225) determines the existence of key variables which have implications for the application of new technology. These variables, figure 2.8, bear great similarity to those detected in figure 2.6, page 66, as a result of the environmental literature survey.

![Diagram]

**KEY VARIABLES AFFECTED BY APPLICATION OF NEW TECHNOLOGY**

*(AFTER BAILEY 1983)*

*Figure 2.8*
Bass (1982, p.179) informs us that modern technology forces the use of work teams. Further, these teams frequently have to be set up to perform specific functions where no one specialist can have all the necessary skills. Birchall (1975, pp.39-44) also stresses the importance of team groups. He describes a team group as 'a group in which members designate the positions to be filled and the people to fill them, changing allocation of members to positions as required. Such groups are fairly autonomous, receiving very little supervision, and often working within broad terms of reference established by supervision'. Birchall while describing the characteristics of such groups informs us that 'The primary operational purpose of the formal work group is to facilitate the efficient subdivision of work which is beyond the capability of the individual alone. In such cases, members of the group generally will possess complementary and specialist knowledge or skills'. Bass and Birchall both stress the need to identify the correct linkage between the social and technical systems for maximum benefit both to individuals and to organizations. Bailey concentrates on finding alternative methods which lead to a satisfactory fit between social and technical systems. Bass promotes the thesis that new technology leads to complex organizations which need team approaches to cope adequately. As Bass (1982, p.180) states "complexity of technology puts a
premium on team effort". Birchall (1975, pp.29-37) remarks on the inefficient use made of individuals and stresses the lack of fit between individual capabilities and job requirements. Blackler & Brown (1980, p.24) lay emphasis on the growing importance of social science in job design and redesign. They assert 'socio-technical thinking, with its biases towards 'systems theory' is better equipped to deal with structural and contextual features'. These links between social and technical systems has been emerging throughout the literature and the notion of team effort appears to be of importance when considering ships' crews.

Job analysis has also been utilised as a method to compare jobs and assess the transferrability of skills. Ashley & Ammerman (1978, pp.1-87) attempt to classify jobs which have much in common in order to facilitate labour movement and improve essential training. They made measurements in five areas:

1. general skill of task performed
2. psychological process of task
3. content domain of task
4. task action process
5. task objects used.

Fine & Wiley (1972, pp.73-83) have attempted to produce a method of job analysis which is applicable throughout the entire universe of work. They maintain that any worker performing any job utilises DATA, employs
equipment, machines or THINGS, and interacts with other PEOPLE. In order to assess transferenceability of skills they produced scales of interaction between the worker and DATA, THINGS & PEOPLE. This allowed jobs with common content to be readily identified. Transferenceability of skills is important in the restructuring of work in order to make the maximum possible use of the incumbent workforce. Thus methods which indicate how the reallocation of a ship's operations may be achieved amongst existing crew members are of importance.

The final grouping of literature found in job/task analysis was the critical appraisals of the techniques found elsewhere. Hannum (1980, pp.6-7) differentiates thoroughly between task analysis for learning and task analysis used for other purposes. Task analysis for learning is decided upon by areas of difficulty of task performance, criticality of task to success, and frequency of task performance. These criteria are also determined by others for example Roff & Watson (1961, pp.28-30) recommend that, as a job analysis procedure, main duties should be listed and rated for difficulty; frequency; and importance.

Weissman (1981, pp.176-185) presents a review of Fine & Wiley's Functional Job Analysis and its use by the U.S. Department of Labor. Weissman, as with Hannum, determines the extra analytical areas which turn a comparative job analysis into one which yields training information. He
identifies the three areas of difficulty, criticality, and frequency amongst others. Of the several job analysis techniques reviewed by Weissman it is interesting to note that many are an adaptation of Fine & Wiley's Functional Job Analysis and use their ratings of DATA, THINGS & PEOPLE interactions as a starting point.

Peterson & Bownas (1982, pp.55-56) describe the Functional Job Analysis (FJA) of Fine & Wiley. They state 'the Functional Job Analysis model classes jobs as a whole, rather than investigating task structures within jobs'. Peterson & Bownas recognise the value of Functional Job Analysis in assessing human abilities but assert 'much more research needs to be done showing linkages between abilities and performance in each of the most heavily populated cells of the FJA taxonomy'.

Peterson & Bownas (1982, pp.56-64) examine at length the Position Analysis Questionnaire of McCormick. They remark that this rating 'instrument focuses most heavily on work behavior in blue-collar skilled and semi-skilled manual jobs'. This concentration on analysis of manual work renders it unlikely that the Position Analysis Questionnaire is applicable to shipboard functions which have a high content of managerial functions. Peterson & Bownas (1982, p.64) finally mention the Job Inventory Technique which has been developed and used by the U.S. Air Force. They state,
In this method, tasks are identified through a combination of reviewing existing job documentation, observing workers, interviewing workers and supervisors, and having preliminary lists reviewed, edited and modified by job experts. The final task list is submitted to a large number of job incumbents, and each task is rated on any of several factors, including whether the task is performed at all, the level of involvement in performing the task (e.g., helper versus doer), the task's criticality, the impact on mission accomplishment of failing to perform the task, the amount of training time required to perform the task proficiently, the proportion of time spent performing the task, the frequency with which the task is performed, etc. The particular rating factors used depend on the purposes of the job analysis. Thus, various task difficulty measures (number of tasks performed, task difficulty, amount of training required to learn the task) are useful for job evaluation, whereas task criticality and frequency measures seem most relevant for job description, and criticality and difficulty together provide information for training design.

As with both Weissman and Hannum, Peterson and Bowness identify criticality and frequency as important ratings
with regard to training and point out that only the Job Inventory Technique has ratings for these factors.

**SUMMARY OF THE LITERATURE RELATING TO JOB/TASK ANALYSIS**

It has been found that job analysis emerged as a tool to assist in the process of job evaluation, whose purpose was to compare jobs in terms of monetary worth. It is clear from the literature that job analysis consists of a two-fold process:

1. a description of the job
2. an analytical method applied to the description.

An apparent contradiction emerged from the literature where some authors advocated that only the job should be described and analyzed; whereas other authors argued that the worker also should be included in the analysis. It is felt by the author of this thesis that where job analysis is used for reward assessment then the 'job only' school is correct, but where the analysis is used for other purposes then the 'job plus worker' school is correct. The concept that the job is more than simply the sum of the individual tasks to be performed led to the concept of competency where the link emerged between task, technology, people, and structure, (figure 2.8).

The advantages of describing work at a functional level emerged from the literature. It produced the major
advantages of dealing with objectives only and appeared to produce worthwhile results regardless of whether man, machine, or a combination of both was performing the actual work. Also the functions remain constant over time whereas tasks and jobs change with new technology and work practices.

Functional Job Analysis, the rating of work in terms of worker interactions with DATA, THINGS, & PEOPLE emerged as having been proved successful in many studies requiring comparative assessments of jobs. Also the rating of work in terms of FREQUENCY, CRITICALITY, & DIFFICULTY appeared to enjoy almost universal approval as an analytical technique to produce valid data for studies other than comparative ones eg. as a training analysis technique.

Finally, again great stress is laid by many authors on the correct linkage between the social and technical systems to produce effective, worthwhile, satisfying jobs. Many authors argue that the way forward, in many industries, is by the establishment of work teams or groups built upon socio-technical system criteria. Herbst (1974, p.61), in particular, argues for the provision of autonomous work groups aboard ships. He claims that the structure of ships' crews should be designed on matrix principles whereby responsibility is allocated to non-hierarchical self-organizing groups.
2.4 ANALYSIS OF THE LITERATURE REVIEW

The philosophy which has emerged from this examination of the literature pertaining to the ship and its crew is that a ship may usefully be viewed as a socio-technical system operating in a dynamic environment involving social, technical, economic and legal influences. The importance of communications has been determined and a view of the shipping industry is presented as figure 2.9.
The following key issues are drawn together from the points previously made.

1. The picture presented is one of economic factors, such as global recession, over-tonnaging, the emergence of third world nations as maritime nations and increased competition from the Soviet Bloc, forcing western nations into operating specialized, highly mechanized ships. The need for automation and robotics is a result of both the tendency to high specialization and mechanization and the increasing relative cost of western seafarers.

2. Automation and robotics are allowing, and costs are forcing, a reduction in the number of seafarers per ship, in western flag tonnage. This reduction in crew numbers is creating the need for a fundamental reappraisal of the onboard organizational structure and the relationship between the ship organization and the shore organization.

3. Certain social aspects of current manning are becoming viewed as undesirable — hierarchies, departmental divisions, and especially the officer-rating division. Social scientists are suggesting the creation of more worthwhile jobs at sea, and the technical environment is pointing to the need for a learning-based culture aboard ships.

4. The awakening international consciousness of the pollution hazards posed by ships is leading to pressure for international standards of competence. The existing
2. LITERATURE REVIEW

competency assessment methods are beginning to be questioned and governmental and intergovernmental regulatory bodies, employers' organizations, and labour organizations are in need of precise facts as to the nature of the tasks performed by seafarers and the necessary skills and knowledge required for their effective performance.

5. Since no specific job analysis technique could be found which encompasses the needs of work redesign from unskilled to managerial levels; then a technique would have to be constructed to allow conclusions to be drawn in the particular field of work redesign of an industry in a dynamically changing technical and financial environment and subject to influence from the social and legal environments.

CONCLUSIONS TO CHAPTER 2 AND IDENTIFICATION OF RESEARCH AIM

This literature review shows that the British merchant fleet, in order to survive and prosper in its hostile environment, must reorganize its onboard manpower from the traditional, hierarchical, departmentalized and socially divisive structure into an integrated, professional workforce. Many authors suggest, notably Herbst (1974, pp.28-62) and Smith & Roggema (1980a, pp.241-254) that the solution may be a matrix manning organization. Herbst states (1974, p.28),

Ph.D. THESIS
Since there exists in this case a wide range of possible technological alternatives, we can, instead of taking a specific technological system and working out the requirements for a supporting social system, consider the possibility of working the other way round. That is, we can attempt to specify initially the essential requirements for a social organization on board, and then work backwards to discover the critical supporting technological conditions that would need to be satisfied with respect to ship design.

Moreby (1975, p.25) also notes,

'In the past, technology had priority in dictating the type of social system required to operate it, but developments have reached a point where a range of different technologies can be provided for the accomplishment of a given objective. Some of the technological options are likely to be more congruent with the aspirations, demands and needs of those having to operate them while other options are likely to engender frustration and dissatisfaction resulting in increased difficulties to recruit and retain people.'

This thesis takes the matrix manning concept as a socially-inspired starting point; by deriving a functional
2. LITERATURE REVIEW

description of shipboard operations and analyzing their performance on a range of ship types by means of a suitably developed tool, the functional validity of matrix manning is evaluated as a means of organizing ships' crews.
3. DEVELOPMENT OF ANALYTICAL TOOL

The field of study, as explained in previous chapters, is ships' crews operating within rapidly changing technical and economic environments and subject to the influence of the social and legal environments. The picture presented in the literature review is of seafarers operating ever more highly specialized and mechanized ships. Even the most perfunctory observation of ship routine would convince the observer of the wide range of activities, sometimes performed simultaneously, which together make the ship and crew a viable economic socio-technical system. For instance a ship under way has persons engaged in guidance control (NAVIGATION SYSTEM) and propulsion control (MACHINERY SYSTEM) whilst other personnel are engaged in the transfer of information to and from the shore (COMMUNICATION SYSTEM). A ship in port has manpower involved with the loading and discharge of cargo (CARGO SYSTEM). At all phases of the voyage people are engaged in the preparation of food and general housekeeping of the ship (HOTEL & CATERING SYSTEM). There is a continual need for all these systems to be effectively controlled (MANAGEMENT & ADMINISTRATION SYSTEM). In addition to these six operational systems there is a need for all the ship's
crew to be able to act collectively to combat an emergency such as fire (SAFETY & EMERGENCY SYSTEM).

Some previous studies of shipboard routine have taken a work study approach. Takuya Otonari (1980, p.29) analyzed shipboard work for total working time and for the occurrence of simultaneous operations. Une & Nomoto (1980, pp.15-25) measured time spent by the crew fulfilling the differing functions of deep sea operation and coastwise operation to differentiate between the different stages of the voyage. Between them they have determined the amount of time spent on various operational tasks at different phases of the voyage with the objective of detecting those time-consuming tasks which could be removed by the application of improved technology. Others have concentrated on attitudes to seafaring work and environments. Smith & Roggema (1979a&b), Herbst (1974, pp.28-53), and Moreby (1975, pp.23-68) have all described the personal qualities and attributes required of seafarers. No previous attempt has been made to isolate and identify explicitly the specific skills and areas of knowledge required to be aboard in order for a ship to function effectively.

Attempts have been made in other industries to capture essential knowledge and skills but the methodologies used have been specific to the industry and, even more importantly, specific to definite departments.
3. DEVELOPMENT OF ANALYTICAL TOOL

within the industries concerned. Thus Knaeuper & Rouse (1985, pp.708-719) attempt to model high level decision-making processes in complex and dynamic engineering systems, and Waldeman (1970, 13-16) has analyzed the physical activities of a milling machine operator.

Rasmussen (1985, pp.234-243) addresses the problem of differing levels of analysis and produces an axis of functions which range from the purposeful to the physical. This axis has been adapted for the purposes of this research and system terms have been ascribed to the levels as shown in figure 3.1

![Rasmussen's Axis of Functional Levels](image)

**RASMUSSEN'S AXIS OF FUNCTIONAL LEVELS**

*Figure 3.1*
3. DEVELOPMENT OF ANALYTICAL TOOL

The concept of functions and functional systems is pursued further by Price (1985, pp.33-45) and Nadler (1985, pp.685-697). Nadler argues that a complex entity, such as a ship, with multiple disciplinary departments can only be viewed successfully as a system with functional objectives. Price goes much further and states that complex man-machine organizations can be viewed as having a system mission and this can be achieved by the realisation of a number of functional statements which collectively fully describe the essential operations for successful mission accomplishment. Price, in his context of man-machine systems, suggests that functions can have two types of composition:

(a) Informational - using or producing DATA

(b) Material - using or producing THINGS

For the purpose of this research where man-man interfaces exist together with man-machine interfaces a third functional composition is found to be required i.e.:

(c) Interpersonal - using or liaising with PEOPLE

Also, at this stage, the work of Paterson (1975a, pp.23-30) and Jacques (1964, pp.1-48) is drawn upon as they have emerged from the literature survey as authorities in their field of job analysis for wage evaluation. Paterson identified 6 definable levels of decision making for wage bargaining purposes. Jacques, agreeing with these levels, goes a stage further and insists that the time-span over
which decisions are implemented is an important factor. These decision levels of Paterson are aligned with the functional dimensions of Rasmussen and the traditional maritime manning structure then imposed and the results, as shown in figure 3.2 give good agreement.

The time-dependent criterion of Jacques appears justified when it is shown that the decisions (affecting a ship) which take a long time to produce an effect are those invariably removed from the ship to senior shore management. This linkage of time of implementation of decisions to rank of decision maker is also identified by Lawrence (1986, section 4) who, after Sagen (1984, p.21), defines 3 ship operational decision levels - strategic, tactical, and operational. These are also indicated on figure 3.2.

The analysis of ship operations into systems, sub-systems, and functional statements therefore appears to be sound, and in accordance with accepted authoritative views. It enables detection and identification of those functions whose analysis satisfies the requirements of the research programme as described in previous chapters.
3. DEVELOPMENT OF ANALYTICAL TOOL

PURPOSEFUL

UNDERSTANDING & CONTROL OF WIDER SYSTEM

FUNCTIONAL

PURPOSE

ABSTRACT

FUNCTION

OPERATION OF SUB-SYSTEM EQUIPMENT

PHYSICAL FUNCTION

PHYSICAL FORM

LEVEL OF ABSTRACTION

RASMUSSEN (1985)

PATERSO (1975)

TRADITIONAL MANNING (1850 on)

PHYSICAL

SEMISKILLED & UNSKILLED

RATINGS

OPERATIONAL DECISIONS

TACTICAL DECISIONS

STRATEGIC DECISIONS

REMOVED FROM SHIP

MASTER

SENIOR OFFICER

JUNIOR OFFICER

SUPERVISOR

DEPARTMENT MANAGER

WORKS MANAGER

CHAIRMAN

EQUIPMENT

RELATIONSHIP OF DECISION BANDS TO SHIP FUNCTIONS

Figure 3.2
3. DEVELOPMENT OF ANALYTICAL TOOL

As a first step, and as stated earlier, the functions of the personnel comprising the total ship system at all phases of the voyage can be grouped into seven sub-systems:

(1) NAVIGATION SYSTEM
(2) CARGO & BALLAST SYSTEM
(3) MACHINERY SYSTEM
(4) HOTEL SERVICES SYSTEM
(5) COMMUNICATIONS SYSTEM
(6) MANAGEMENT & ADMINISTRATION SYSTEM
(7) SAFETY & EMERGENCY SYSTEM

This view is supported by Takuya Otonari (1980, pp.28-35) and Sagen (1984, pp.17-22) who independently identify six of these systems and only fail to identify the hotel & catering system because their attention was on specific areas of technology application and they were not attempting to describe the ship as a whole. These seven sub-systems are viewed as being comprised of abstract functions and these in turn are taken to be comprised of generalized functions which depend upon generalized knowledge, in accordance with Rasmussen (1985, p.235). This is shown diagrammatically in figure 3.3.
3. DEVELOPMENT OF ANALYTICAL TOOL

TOTAL SHIP SYSTEM

FUNCTIONAL PURPOSE OF THE SYSTEM
- the safe and economic carriage of goods by sea

NAVIGATION SUB-SYSTEM

FUNCTIONAL PURPOSE OF THE SUB-SYSTEM
- to get the vessel safely from berth to berth

ABSTRACT FUNCTIONS
- Passage Planning 1.1
- Passage Execution 1.2
- Pilotage 1.3
- Berth/Unberth 1.4
- Equip., maint. 1.5

GENERALIZED FUNCTIONS
- Selecting routes 1.1.1
- Obtaining route information 1.1.2
- Preparing detailed plans 1.1.3
- Storing & retrieving information 1.1.4
- Recording 1.1.5
- Training 1.1.6

PURPOSE OF ABSTRACT FUNCTION
- to pre-determine route of ship and display information to others

GENERALIZED KNOWLEDGE
- Understanding:
  - Criteria for route selection
  - Navigational info.
  - Physical hazards
  - Traffic hazards
  - Navigational systems
  - Weather routing
  - Vessel characteristics

PURPOSE OF GENERALIZED FUNCTION
- to select the optimum route

SPECIFIC KNOWLEDGE
- Understanding:
  - Safe routes for vessel
  - Economic factors
  - Company's regulations
  - Load line zones
  - Positioning systems
  - Vessel characteristics
  - etc

PHYSICAL FUNCTIONS
- Selecting optimum route
- Preparing alternatives for altered conditions
- Deciding on information required
- etc

EQUIPMENT

DETERMINATION OF ABSTRACT AND GENERALIZED FUNCTIONS

Figure 3.3
As can be seen from figure 3.3 the knowledge and skills could be further analyzed to a more detailed level, that of physical functions and specific knowledge. However the output required from the research does not warrant pursuit of this more detailed analysis. The aim of the research is to determine if the main ship functions can be sensibly reallocated amongst the members of the crew in a matrix format as described by Herbst (1974, pp.54-57) and Smith and Roggema (1980a, pp.249-253).

As stated earlier, following from the observations of Price (1985, pp.33-45), system functions may be stated as having three constituents - DATA, THINGS, & PEOPLE. During the literature review it was found that the Functional Job Analysis technique used by the United States Department of Labour and developed by S.A. Fine (1972, pp.73-83) also utilises these three constituents to describe worker actions. Fine justifies his tripartite approach to measuring worker actions as follows:

"All jobs involve the worker, to some extent, with information or ideas (DATA), with clients or coworkers (PEOPLE), with machines or equipment (THINGS)....While there may be an infinite number of ways of describing tasks, there is only a handful of significant patterns of behavior (functions) which describe how workers use themselves in relation to Data, People, and
3. DEVELOPMENT OF ANALYTICAL TOOL

People, and Things. Those patterns of behavior which can be articulated reliably have been defined in Worker Function Scales, the primary tools of FJA, which provide a standardized, controlled language to describe what workers do in the entire universe of work." Fine and Wiley (1972, pp 13-14)

The patterns of behaviour defined by Fine & Wiley are listed in Table 3.1 and their full definitions are contained in Appendix 1. DATA levels of behaviour commence with level 1, 'comparing', where the function performer uses little intellect but simply compares data to prescribed standards. The levels range up to level 8, 'synthesizing', where great use is made of the intellect to provide novel solutions or resolutions to problems which do not conform to a standard. THINGS levels of behaviour range from level 1, 'handling' where no judgement is required regarding tools used or standards achieved; through to level 8, 'setting up', where machines are adjusted or repaired, using particular tools, in order to achieve a high level of performance. PEOPLE levels begin with level 1, 'helping', where the function performer takes instructions from a superior and range to level 8, 'mentoring', where the performer guides others according to professional principles.

In order to give some idea of the amount of time a
worker devotes to each of the dimensions (DATA, THINGS, PEOPLE) in order to complete a function, the percentage of total time that the worker spends on each of these dimensions is labelled the orientation of the function. The three percentages total 100%.

In addition to these worker function scales and orientation percentages, Fine & Wiley produced other scales which were capable of recording work fields (methods, equipment, materials) and worker traits (aptitudes, temperaments, interests, and physical demands).

Weissman (1981, pp. 176-186) in his review of the Functional Job Analysis technique illustrates how any or all of these scales could be utilised depending on the requirements of the analyst.
3. DEVELOPMENT OF ANALYTICAL TOOL

<table>
<thead>
<tr>
<th>DATA</th>
<th>THINGS</th>
<th>PEOPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Comparing</td>
<td>1 Handling</td>
<td>1 Helping</td>
</tr>
<tr>
<td>2 Copying</td>
<td>2 Feeding/Offbearing</td>
<td>2 Informing</td>
</tr>
<tr>
<td>3 Computing</td>
<td>3 Tending</td>
<td>3 Persuading</td>
</tr>
<tr>
<td>4 Compiling</td>
<td>4 Manipulating</td>
<td>4 Diverting</td>
</tr>
<tr>
<td>5 Analyzing</td>
<td>5 Driving/Operating</td>
<td>5 Supervising</td>
</tr>
<tr>
<td>6 Innovating</td>
<td>6 Operating/Controlling</td>
<td>6 Instructing</td>
</tr>
<tr>
<td>7 Coordinating</td>
<td>7 Precision working</td>
<td>7 Negotiating</td>
</tr>
<tr>
<td>8 Synthesising</td>
<td>8 Setting up</td>
<td>8 Mentoring</td>
</tr>
</tbody>
</table>

DATA, THINGS & PEOPLE RATINGS

TABLE 3.1

With this particular research programme the emphasis was upon observing the experienced worker performing functions under varying levels of technological assistance. Thus it was decided that the use of the scales would be:

(1) WORKER FUNCTION SCALES

These were to be used in an attempt to identify how the seafarers' levels of interaction with DATA, THINGS, & PEOPLE, whilst accomplishing functions, changed with technical innovation.
3. DEVELOPMENT OF ANALYTICAL TOOL

(2) ORIENTATIONS

These were to be used in an attempt to determine if there was a shift in seafarers' efforts whilst accomplishing functions due to the implementation of new technology.

(3) WORK FIELDS

During the research voyages, detailed descriptions of work methods and equipment used were recorded but these remain in longhand form since the range of equipments was too large to allow for any simple comparison. These descriptions of work method and equipment assisted the later analysis of functions and provide a valuable record for future research effort.

(4) WORKER TRAITS

These would not be identified or recorded since their primary object is to identify criteria for the level of entry to the profession. This was not a factor to be considered within the confines of this research programme, since it infringes heavily on the domain of the individual employer and is not a subject of national policy.

Fine et al. (1974b, p.6) illustrate diagrammatically how the interrelation of WORK, WORKER, & WORK ORGANIZATION combine to produce EFFECTIVE PERFORMANCE and WORKER GROWTH. Their diagram has been extended and reproduced as figure 3.4 to show how the requirements of this research project
fit into their philosophical framework and lead to even greater system effectiveness and personal growth. The adaptations to Fine & Wiley's diagram are shown as dotted lines and italic script.

INTERRELATIONSHIPS OF WORK, WORKER & ORGANIZATION

FIGURE 3.4
After Fine, Holt, & Hutchinson 1974b
It was felt, at this time, that the Functional Job Analysis technique was not sufficient to provide the required data to confirm the technical practicality of the introduction of matrix manning. This was because Functional Job Analysis describes the general nature of a function eg. whether it is DATA based or concerns PEOPLE interactions, but gives no indication as to the importance of the function to the whole system or its frequency or difficulty of performance. Therefore an extra analytical aid was sought. The literature revealed that a rating technique used and described by Roff & Watson (1961, pp. ), Weissman (1971, p.183), Hannum (1980, p.6), and Peterson & Bownass (1982, p.64) could well supply the extra information that was required. The technique proposed was, in addition to Functional Job Analysis, to rate further the functional statements in terms of :

(a) FREQUENCY with which the function was performed.

(b) CRITICALITY of incompetent performance of the function.

(c) DIFFICULTY of learning how to perform the function.

The ratings previously used by other exponents had been specific to the nature of the industry under study and were not satisfactory for immediate application to ship operational functions. Therefore the following revisions
were made to the existing ratings:

(a) FREQUENCY

Ship operations extending as they do through cyclic phases, rendered it useful to adopt the following five point scale for the performance of functions. The ratings applied used the highest number possible

1. Randomly - possibly never.
2. Quarterly or more frequently.
3. Monthly or more frequently.
4. Weekly or more frequently.
5. Daily or more frequently.

(b) CRITICALITY

It was noted here that incompetent performance could have drastic effects in each of three fields - PHYSICAL ENVIRONMENT, HUMAN LIFE, & FINANCIAL ENVIRONMENT. Thus a five point scale of criticality was developed for each of these fields as shown:

PHYSICAL ENVIRONMENT

1. Annoyance or inappropriate.
2. Slight pollution.
3. Moderate pollution.
4. Severe pollution.
5. Catastrophic pollution.
3. DEVELOPMENT OF ANALYTICAL TOOL

**HUMAN LIFE**
1. Annoyance or inappropriate.
2. Slight personal injury.
3. Moderate/severe injury.
4. Severe injury or fatality.
5. Multiple fatalities.

**FINANCIAL ENVIRONMENT**
1. Annoyance or inappropriate.
2. Slight financial loss.
3. Moderate financial loss.
4. Severe financial loss.
5. Severe financial loss plus compensation claims.

**(c) DIFFICULTY**

Difficulty of learning as a subjective rating was found to be very difficult to quantify since the difficulty of learning to perform a function depended heavily on the initial ability of the seafarer. Therefore the original ratings of VERY EASY..........VERY DIFFICULT were replaced by a five point scale which, it is argued, gives a more realistic interpretation of the difficulty of a function to typical seafarers.
3. DEVELOPMENT OF ANALYTICAL TOOL

1. Requires little knowledge and low experience.
2. Requires little knowledge and medium experience.
3. Requires medium knowledge and medium experience.
4. Requires medium knowledge and high experience.
5. Requires high knowledge and high experience.

It is believed that this scale is capable of broadly recording all the ranges of balance of knowledge with experience which are essential for the successful accomplishment of all seafaring functions. There are other combinations of knowledge and experience. These fall into two groups. The first is where the knowledge level is considerably higher than the experience level. It is argued that this represents the performance of trainees and since the research is to rate 'skilled personnel' these combinations were not used. The second is where experience is much greater than knowledge. It is argued that this is a combination which would be observed on 'old fashioned' ships where workers performed functions without understanding, this is not the case with modern tonnage and consequently the combination was not used.

Thus the methodology consists of a set of ship systems split into abstract and then generalized functional statements. These statements are contained in Appendix 2. The accomplishment of each of these functional statements was then observed aboard ship (or the performers were interviewed if observation was not possible) and a longhand
3. DEVELOPMENT OF ANALYTICAL TOOL

A report was compiled for each of the ships in the study. The ship reports were paragraphed numerically by functional statement number to allow rapid comparison and reference. The ship types observed are listed in Appendix 3 but the ship reports do not form part of this thesis due to the volume of material.

Finally, the ship reports were available for analysis using the assembled tool consisting of elements of Functional Job Analysis, namely ratings involving DATA, THINGS & PEOPLE and analysis ratings of FREQUENCY, CRITICALITY & DIFFICULTY. This analytical tool is illustrated overleaf as figure 3.5 and an example of its application is given as figure 3.6.

The final output is thus a numerical matrix.
### 3. DEVELOPMENT OF ANALYTICAL TOOL

#### SUB-SYSTEM X

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>FREQUENCY</th>
<th>CRITICALITY</th>
<th>DIFFICULTY</th>
<th>DATA</th>
<th>THINGS</th>
<th>PEOPLE</th>
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<tbody>
<tr>
<td></td>
<td>E LF</td>
<td>E LF</td>
<td>LF</td>
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<tr>
<td>FUNCTION 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 3.5**

#### HOTEL SERVICES

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>FREQUENCY</th>
<th>CRITICALITY</th>
<th>DIFFICULTY</th>
<th>DATA</th>
<th>THINGS</th>
<th>PEOPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E LF</td>
<td>E LF</td>
<td>LF</td>
<td></td>
<td></td>
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<td>1</td>
<td>2</td>
<td>4</td>
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<tr>
<td>STOCKING</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5</td>
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</tbody>
</table>

**FIGURE 3.6**

#### FREQUENCY

<table>
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<tr>
<th>FREQUENCY</th>
<th>CRITICALITY</th>
<th>DIFFICULTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Randomly</td>
<td>1 Annoyance</td>
<td>1 Low</td>
</tr>
<tr>
<td>2 Quarterly</td>
<td>2 Slight damage</td>
<td>2 Low</td>
</tr>
<tr>
<td>3 Monthly</td>
<td>3 Mod. damage</td>
<td>3 Med.</td>
</tr>
<tr>
<td>4 Weekly</td>
<td>4 Heavy damage</td>
<td>4 High</td>
</tr>
<tr>
<td>5 Daily</td>
<td>5 Catastrophe</td>
<td>5 High</td>
</tr>
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</table>

#### DATA

<table>
<thead>
<tr>
<th>DATA</th>
<th>THINGS</th>
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<td>7 Coordinating</td>
<td>7 Precision working</td>
<td>7 Negotiating</td>
</tr>
<tr>
<td>8 Synthesising</td>
<td>8 Setting up</td>
<td>8 Mentoring</td>
</tr>
</tbody>
</table>

**TABLE 3.2: SYSTEMS FUNCTIONAL ANALYSIS RATINGS**

Definitions of DATA, THINGS, PEOPLE levels are in appendix 1
3. DEVELOPMENT OF ANALYTICAL TOOL

The developed method "SYSTEMS FUNCTIONAL ANALYSIS" thus consists of:-

(i) a set of operational systems and sub-systems together with the functional statements which satisfy those systems. This set of systems and functions provides a framework for effective observation and recording of shipboard operations.

(ii) a set of measurements which allow ratings to be placed on each function in terms of level of interaction of DATA, THINGS, PEOPLE, FREQUENCY, CRITICALITY, and DIFFICULTY.

CONCLUSIONS TO CHAPTER 3

This chapter demonstrates that a ship may usefully be viewed as a number of interacting sub-systems. It further shows that an analysis of skills required for a complete industrial organization has never before been attempted. Previous work has concentrated on specific areas of enterprises, eg. milling machine operatives. The work of Rasmussen shows that industrial functions may be placed along an axis ranging from functions at the physical extreme to functions at the purposeful extreme. This range of functions agrees with many other authors and observers and is seen to agree with the current hierarchical structure of work and decision making aboard ships. This scaling of functions allows the analysis of shipboard
functions into high level purposeful functions with a gradual degradation into functions at the physical level. This means that observations aboard ships may be made at any pre-determined level. The level of analysis chosen for this thesis is displayed in Appendix 2.

Functional Job Analysis emerged from the literature review as a potentially useful analytical technique. It is shown in this chapter how elements from the Functional Job Analysis are incorporated into the current research tool. The ratings of DATA, THINGS & PEOPLE are seen as capable of giving many comparative descriptions to shipboard functions. These comparisons of functional types are necessary to validate the reclustering of functions to accommodate a matrix type organization. However in order to fully test for validity of matrix suitability it is necessary to determine such things as criticality of function in order to ascertain those functions which may be considered as primary. Also ratings of frequency are necessary in order to assess the temporal disposition of workload amongst the matrix personnel. Ratings of difficulty of function performance are necessary to determine training requirements for a matrix organization, particularly the development of what Herbst (1974, p. 59) calls the development of a teaching-learning culture based on the total crew on board.

The developed analytical tool is capable of
3. DEVELOPMENT OF ANALYTICAL TOOL

providing answers to a host of questions pertinent to problems involving ships' crews operating within changing technical and economic environments and subject to the influences of the social and legal environments. The specific theme of this thesis is to verify that it is possible to recluster the ship functions into a form that allows their fulfillment by a crew organized on a matrix principle as described by Herbst (1974) and Smith & Roggema (1980a). The ratings of DATA, THINGS & PEOPLE allows similar function types to be clustered together. The CRITICALITY rate allows the detection of those functions which are primary as compared to those which are secondary. The rating of FREQUENCY allows the detection of those functions which may generate peak workloads. Finally the measures of DIFFICULTY will allow assessments to be made as to the possibility of producing an on-board learning culture.

The following Chapter describes the experience of obtaining the relevant data and Chapter 5 describes the results obtained.
4. DATA COLLECTION

USE OF ANALYTICAL TOOL ON PILOT VOYAGE

In order to assess the applicability of the designed recording and analysis method for use aboard ship a pilot study voyage was carried out in April 1985. This pilot study was carried out aboard a very large crude carrier (VLCC.) trading between North Sea oil production platforms and various ports in the U.K. and the near continent. The manning structure was typical of a modern vessel and conformed closely to figure 1.1 (page 3).

The ship proved to be an excellent first choice for research purposes due to :-

(i) the typicality of its crew structure

(ii) the short duration of its voyage phases - loading, sea passage, pilotage, discharging, pilotage, sea passage, loading......, which allowed two complete cycles to be observed in the available time.

(iii) the vessel comprised a reasonably standard construction VLCC but due to the relatively modern nature of its work, servicing North Sea installations, and its proximity to home ports, it was fitted with various high technology equipment in order to carry out operational trials of such equipment. Thus, for the purposes of this
4. DATA COLLECTION

research it was possible to compare both traditional methods of function accomplishment with methods utilising modern technological aids.

On commencing research activity during the pilot voyage, however, 4 major observational problems which had not been anticipated became immediately apparent.:-.

1. SINGLE OBSERVER

The complexity and simultaneity of operations, particularly at periods of peak activity, could not be observed by a single recorder.

This problem was circumvented by the use of the systems functional description of the ship. This was used as a checklist and aide-memoire in order to determine those functions which had not been observed due to the researcher's attention being directed elsewhere. Thus a function which had escaped observation was analyzed by means of structured interviews with those operators performing such functions. These structured interviews were designed so that during a discussion of the function needing analysis the researcher determined the highest level of DATA handling involved, the highest level of man/machine interaction, THINGS level, and the nature of the liaison between the PEOPLE involved for the accomplishment of the function. Further, the researcher enquired as to the FREQUENCY of performance of the function, the degree of DIFFICULTY the performer perceived
in learning to fulfill the function and finally to determine the immediate effects of incompetently performing that function in relation to the physical environment, human life, and the financial system.

For example, while the observer was on the navigating bridge during a mooring operation the practical function of securing the vessel with the ropes could not be directly observed. Discussion with those persons engaged in this function after the event revealed that:

(i) This function entailed the ad hoc modifying or altering of a standard mooring operation in order to meet the unique situation posed by the port in accordance with mooring principles. Thus the DATA handling level was accepted by both performer and researcher to be LEVEL 6 INNOVATION.

(ii) Since the function of mooring involved the use of humans and specific equipment (ropes, winches) with no latitude for selection of the equipment or standard of performance it was agreed between the performer and researcher that mooring fell into the THINGS LEVEL 1 HANDLING.

(iii) Since mooring involves the cohesive effort of several persons then the highest level of interaction is that of assigning the specific tasks and ensuring their completion which was thus recorded as PEOPLE LEVEL 5 SUPERVISING.
(iv) Mooring on this particular vessel was determined as occurring at approximately weekly intervals - FREQUENCY SCALE 4.

(v) The persons engaged in the mooring operation were of the opinion that the knowledge requirement was not high but that in order to perform competently the performer needed more than a little experience of mooring operations. Thus all concerned agreed that DIFFICULTY SCALE 2 would be appropriate i.e. LOW KNOWLEDGE: MEDIUM EXPERIENCE.

(vi) When, during the course of the interview, the effects of incompetent performance of the mooring function was discussed the consensus of opinion was:

a) there was no real risk to the environment as an IMMEDIATE effect of incompetently mooring the vessel and thus LEVEL 1 INAPPLICABLE was used.

b) due to the nature of the work, handling ropes under high tension, there was a risk, if incompetently performed, of suffering personal injury. It was agreed that the correct measure here would therefore be LEVEL 2 SLIGHT PERSONAL INJURY.

c) all concerned agreed that, as far as the whole financial venture was concerned, any incompetent performance would only be at LEVEL 1 ANNOYANCE.

These structured interviews, whilst consuming much time and involving much discussion enabled the researcher to clarify the definitions of each rating. It also served
to involve the ship's crew and to alleviate the natural initial suspicion.

2. UNIQUENESS OF SHIP

The observations which were made represented only a unique snapshot of one ship of the type selected, with an individual and unique crew, engaged in operations which were a mixture of 'standard' and unique.

It was found during the structured interviews that most crew members aboard the ship under study had sailed on other ships of a similar type. During the interviews it emerged that there are 'standard' operations on board each ship and that these standard operations are modified on each occasion, to a greater or lesser extent, to provide the unique operation which is observed. Therefore the structured interviews presented an analysis of the ship type rather than just an analysis of the vessel under study. The technique of enquiring as to the typicality of an observed function for other ships of this type was therefore pursued as a part of the analytical technique even for those functions which were directly observed.

3. EXPERIENCE OF OBSERVER

Inexperienced observers could only view operations at the 'physical' end of the Rasmussen axis and decisions at the 'purposeful' could very well be missed.

This problem was overcome by providing a research team of two people - one qualified navigator and a
qualified marine engineer - to visit each of the ship types. The engineer and navigator researchers sailed together on the same ships. In this way the non-apparent decision making processes could be observed because the technically experienced researcher could understand the operations at a level above the physically observable.

4. 24-HOUR OPERATION

The ship chosen for the initial study, in common with the vast majority of merchant vessels, is operational for 24 hours every day and therefore continuity of observation was impossible.

This problem was alleviated by the observer ensuring that all the routine functions were observed and recorded and by constant questioning as to what had occurred within all the sub-systems during the periods when the observer was not present. Also, if an unusual circumstance could be predicted then the observer arranged to be on hand in order to record the events.

Once the solutions to these four problems had been conceived and implemented the pilot voyage was concluded and the methodology, analytical tool, and data gathered were assessed.

**METHODOLOGY OF DATA COLLECTION**

After the experiences of the pilot voyage it was proposed to pursue the following methodology on subsequent
4. DATA COLLECTION

research voyages:

1. To take on board the list of functional statements to act as an aide-memoire and to assist in the compilation of the ship reports.

2. To have a professionally aware observer directly to record as much as possible of the ship operations ie. at least one navigator and one marine engineer.

3. To supplement the observations with questions designed to detect the typicality of the observation to other ships of similar class.

4. To utilise a structured interview technique to assess ratings of DATA, THINGS, PEOPLE, FREQUENCY, CRITICALITY, & DIFFICULTY for those functions not directly observed. Such interviews should draw out the ratings for the ship type rather than the unique ship under study.

USE OF ANALYTICAL TOOL

The experience of the researcher during the pilot voyage was that it was possible, with care, to impose unique levels of DATA, THINGS, PEOPLE, FREQUENCY, CRITICALITY, & DIFFICULTY to each of the functions observed or discussed. The care which had to be taken was fourfold:

1. Whilst using the Functional Job Analysis technique ie. assigning levels of DATA, THINGS, & PEOPLE it is important to assign the highest level observed as that
pertaining to the function. Thus the navigational function of determining the ship's position may involve data handling levels of comparison, compiling, computing, and analyzing but all these are prerequisites of the overall function which is LEVEL 7 COORDINATING.

2. Whilst assigning a measurement to FREQUENCY care has to be taken to record the usual frequency rather than that immediately observed. Thus a ship which traded across the North Atlantic would normally operate cargo handling equipment at weekly intervals and would receive a FREQUENCY rating of 4 even though the unique research voyage happened to observe two cargo handling operations separated only by a day, this being an unusual occurrence.

3. Care had to be taken when assigning measures of CRITICALITY that these referred only to the IMMEDIATE consequences of incompetent performance. For example badly prepared food is an immediate annoyance and demands LEVEL 1 even though the REMOTE consequence may be severe food poisoning leading to a catastrophe.

4. Finally, the allocation of levels of DIFFICULTY required careful discussion between the researchers and those being observed or interviewed in order to remove individual bias and subjectivity as far as possible.

SAMPLE OF SHIP TYPES

In order to observe and rate the performance of the
determined ship functions it was decided that a sample of ship types would be chosen which reflected, as far as possible, the future composition of the British merchant fleet. Gilman and Cox (1986, section 1) have analyzed the composition of the fleet in great detail for the period from 1972 to 1984. Their findings reinforce the assertions made in earlier chapters that there is, in their words, 'a steady and absolute decline of the total fleet in terms of numbers and total deadweight capacity.' Gilman and Cox assemble their figures using basically three categories of ships:

**LINERS**

They define these as dry cargo ships operating on a regular scheduled service. This grouping includes passenger ships, ferries, general cargo ships, and fully cellular container vessels.

**TRAMPS**

Gilman and Cox define tramps as dry cargo ships not operating on a regular scheduled service. They include in this group bulk carriers, large and small, in addition to the general cargo ships carrying parcels of packaged cargo.

**TANKERS**

They group all tankers together for statistical purposes but make it clear that this is a diverse group in both types and sizes. This group includes crude oil carriers, refined products tankers, chemical carriers, and
4. DATA COLLECTION

REDUCTION IN BRITISH MERCHANT FLEET 1972 - 1984

Figure 4.1
4. DATA COLLECTION

liquefied gas carriers.

The decline in each of these groups, and in the fleet as a whole, is depicted in figure 4.1. Gilman and Cox produce many more statistics which relate to the size groupings and trading patterns of these ships and present their conclusions as to the future in terms of the three groups mentioned above plus comment on the relatively new trade involved with supporting the North Sea Oil industry.

LINERS

Gilman and Cox demonstrate that the cellular container vessels have maintained their numbers over the twelve year period and have increased in average size. They indicate that short sea ferry operation has displayed growth in the trade with Northwest Europe. The major area of decline is determined as being dry cargo ships above 5,000 dwt. (deadweight tonnes). The conclusions which may be drawn from the analysis of Gilman and Cox is that the future British fleet will contain cellular container vessels, short sea ferries and a declining number of dry cargo vessels.

TRAMPS

The decline in the number of tramp ships is, according to Gilman and Cox, a composite of two factors. Firstly the large bulk carriers have shown a dramatic decline and have virtually disappeared. In contrast, the small and medium sized bulk carriers plying Northwest
Europe and the Mediterranean have shown an increase in numbers. Secondly the worldwide dry cargo tramps have decreased in number. Those that remain are more specialized, eg. refrigerated cargo ships, and are more mechanized, eg. labour saving cargo handling devices. The conclusions which may be drawn for the future from this analysis of Gilman and Cox is that the future British fleet will contain small and medium sized bulk carriers together with specialized dry cargo tonnage such as refrigerated vessels. Gilman and Cox also predict that oil rig support vessels will maintain a prominent position in the complement of a future British fleet and, whilst difficult to classify, may be considered to be tramping vessels.

TANKERS

The reduction in tanker numbers detected by Gilman and Cox is not as dramatic as that in the other two groups. However they stress that when sizes of ships are considered then the tanker fleet displays the largest decline. They demonstrate that the decrease in the number of large crude carriers and refined products tankers is compensated, in numerical terms, by an increase in the very specialized and highly mechanized chemical carriers and liquefied gas tankers. Their assessment of the likely profile of a future British tanker fleet is that, for politico-economic reasons, there will remain a core fleet of crude oil and
4. DATA COLLECTION

petroleum products tankers and an increased number of liquefied gas and chemical carriers.

Based on this analysis by Gilman and Cox the research sample was determined to include ten ship types representative of the future British fleet. The ten ship types were:

**TANKERS**
1. Crude Oil Carrier
2. Refined petroleum products tanker
3. Chemical tanker
4. Liquefied gas carrier

**TRAMPS**
5. Small dry bulk carrier
6. Medium sized dry bulk carrier
7. Refrigerated cargo vessel
8. Oil rig support vessel

**LINERS**
9. Roll on - Roll off cellular container ship
10. Short sea passenger and cargo ferry.

The complete list of vessels, shipping companies and researchers is contained in appendix 3.
CONCLUSIONS TO CHAPTER 4

This chapter describes the experiences of a pilot voyage and the difficulties encountered with rating the various functions while observing a unique organization which is spatially disparate and operates throughout 24 hours. The solutions to the problems are detailed. The chapter also demonstrates the need for a team of marine experienced researchers to be deployed in order to obtain the breadth and depth of data. A methodology for data collection is described which includes direct observation and structured interviews to rate all the functions specified in Appendix 2.

This chapter describes briefly the work of Gilman & Cox (1986, section 1) and how it is used to compile a sample of statistically sound ship types for observation.
5. RESULTS

5.1 DETERMINATION OF SHIP GROUPS

Herbst (1974, pp.54-60) presenting his argument in favour of matrix manning aboard ships dwells at length on the social advantages of such a system. He appears to assume that all ship types are essentially the same and that a universal crewing system can exist. Smith & Roggema (1980a, pp.249-253) also share this belief that one structure can be introduced, matrix manning, which will solve organizational problems on all technical ship types.

Patently ships are different and have different levels of specialization and mechanization as described in the review of the technical environment. There is clearly a distinct difference in the levels of performance required from the officers of a small dry bulk coaster and those demanded from the officers of a large chemical carrier carrying highly pollutant cargo. The criterion for assessing the competence which needs to be aboard the different ship types appears to be associated with the potential risk - to life, the environment and the financial system. It is first proposed to use the collected data to investigate this assumption of the universality of ships' crew structure and performance. The required result of this
investigation is to determine if all ships are similar for crew competence purposes. If they are not then it is proposed to cluster them into groups which may be considered to have similar properties.

Since it appears that the risk posed by a ship is a significant factor it is decided to pursue this aspect. The initial concept is that the ships which pose the highest risk to life, the environment and the finance system, and are the most difficult to operate, require the highest grades of qualified personnel. From the data gathered a numerical assessment of the risk posed by each of the ten ships is undertaken. The criticality of each function is multiplied by the frequency of occurrence of that function thus:

<table>
<thead>
<tr>
<th>CRITICALITY</th>
<th>FREQUENCY</th>
<th>RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENVIRONMENT</td>
<td>LIFE</td>
<td>FINANCE</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3+</td>
</tr>
</tbody>
</table>

This represents a small chemical tanker discharging cargo weekly (4) and capable of causing moderate pollution (3), a possible fatality (3), and a moderate financial loss (3) in the event of incompetence by those charged with the discharging function. Thus the risk assessment is:

\[(3+3+3) \times 4 = 36.\]

The three main operational sub-systems of the ten ship types are analyzed in this way and the figures for
5. RESULTS

risk obtained. It was expected that as the risk increased for the ship types the difficulty of learning the skills and knowledge required to perform the necessary functions would also increase, i.e., performance of the functions would require greater knowledge and experience. This is due to the expected technical complexities introduced in order to minimise the risks. The results were expected to appear as in figure 5.1.

![Graph showing increasing risk with cargo complexity, value, and hazard](image)

**EXPECTED INCREASE IN RISK & DIFFICULTY OF SAMPLE SHIP TYPES**

*Figure 5.1*

The actual results obtained for each of the sub-systems are displayed as figures 5.2, 5.3, and 5.4 and the
5. RESULTS

RISK
(frequency x criticality)

+ Short sea ferry
+ Large dry bulk coaster
+ Small dry bulk coaster
+ Rig supply vessel
+ Refrigerated cargo vessel
+ Product tanker
+ Chemical carrier
+ Crude carrier
+ Liquefied gas carrier
+ Container Ro-Ro ship

NAVIGATION SUB-SYSTEM

Figure 5.2
5. RESULTS

RISK
(frequency x criticality)

DIFFICULTY

LESS DIFFICULT
LOWER RISK SHIPS

+ Chemical carrier
+ Liquefied gas carrier
+ Crude carrier
+ Product tanker
+ Rig supply vessel
+ Large & small dry bulk coasters
+ Refrigerated cargo vessel
+ Short sea ferry

+ Container Ro-Ro ship

Figure 5.3

CARGO SUB-SYSTEM
5. RESULTS

RISK
(frequency \times criticality)

+ Liquefied gas carrier

HIGH RISK AND
HIGH DIFFICULTY SHIPS

+ Crude carrier
+ Product tanker

LOWER RISK AND
MEDIUM DIFFICULTY SHIPS

+ Short sea ferry
+ Container Ro-Ro ship
+ Chemical carrier
+ Refrigerated cargo vessel
+ Large dry bulk coaster

LOWER RISK AND
LOW DIFFICULTY SHIPS

+ Small dry bulk coaster
+ Rig supply vessel

MACHINERY SUB-SYSTEM

Figure 5.4
5. RESULTS

ALL OPERATIONAL SYSTEMS

Figure 5.5
composite summation of these figures is presented as figure 5.5. Each of these diagrams is now examined in turn.

**NAVIGATION SUB-SYSTEM - FIGURE 5.2**

Navigationally the ships fall into four groups:

1. The high risk, high difficulty group consisting of the four tankers. Their position on the diagram represents the cost of such ships and their cargoes, and the hazardous and pollutant nature of those cargoes. Reflected also are the practical problems involved with navigating large, deep draft vessels to any part of the globe; together with the problems of navigating the smaller tankers through the high traffic density areas with very short intervals between passages.

2. The high risk, not so difficult to operate group contains just one ship - the short sea ferry. The positioning of this ship type is due to the catastrophic loss of life which could occur and the high frequency of its operations in close, congested waters. The regularity of its trade renders it amenable to large shore support and assistance and this together with the navigational familiarity of its route reduces the difficulty of the operations.

3. The low risk, difficult to operate ships consisting of the container Ro-Ro vessel and the
refrigerated cargo vessel. Both these are technically sophisticated vessels but in the event of a disaster would not cause a pollution problem on the scale of the tankers. Both ships, but especially the container vessel, represent a high financial investment.

(4) The relatively low risk, less difficult to operate group which consists of the small dry bulk carriers and the rig supply vessel. The cargoes on either of these ships do not pose a great pollution or hazard problem, and, due to their size, the finance at risk is comparatively low. The small numbers of crew on board also tend to reduce the measure of risk since there are potentially fewer lives to lose.

CARGO SUB-SYSTEM FIGURE 5.3

In terms of the cargo sub-system there appears to be two clusters of ship types:

(1) The difficult, high risk group consisting of the four tankers. This is explained by the pollution and safety hazards, the high cost of the ships and their cargo, and the complexity and difficulty of operation of the cargo systems.

(2) The less difficult, lower risk group consisting of all other ship types apart from tankers. In general ships of these types do not carry hazardous or pollutant cargoes in bulk. The cargo handling facilities aboard are
relatively simple to operate, frequently there is no cargo handling equipment on the ship and loading and discharging is achieved by shore personnel using port facilities.

**MACHINERY SUB-SYSTEM FIGURE 5.4**

With regard to the machinery sub-system there appears to be three clusters of the ship types:–

1) The difficult, high risk group consisting of the liquefied gas carrier, and the crude and products tankers. Their position on the diagram is explained by the sheer size of the main propulsion plant, the size and complexity of the auxiliary machinery, (electrical generators etc.) the complexity of the cargo handling, monitoring and conditioning equipment, and the huge financial investment involved.

2) The moderately difficult, moderate risk group consisting of the short sea ferry, the container Ro-Ro vessel, the chemical carrier, the refrigerated cargo vessel and the large coastal bulk carrier. This group represents large or medium sized propulsion units but without the complex cargo control and handling systems found on the three large tankers. In general they present less hazard to the environment and human life and represent a lower financial investment. It is worthy of note that the chemical tanker visited during the course of this research was neither large nor very complex. It is expected that a
larger, more sophisticated vessel would be in the group posing a high risk and being relatively difficult to operate

(3) The less difficult, low risk group consisting of the small dry bulk carrier and the rig supply vessel. This group contains vessels with small propulsion units, few auxiliary units and little cargo handling machinery. They also represent a much lower level of financial investment than the other ship types.

**ALL OPERATIONAL SUB-SYSTEMS FIGURE 5.5**

The composite diagram of the three main operational systems displays each of the ship types as belonging to one of three groupings.

(1) The difficult, high risk group consisting of the four tankers.

(2) The less difficult, low risk group consisting of the coastal bulk carriers, the rig supply vessel, the refrigerated cargo ship, and the container Ro-Ro transporter.

(3) On its own the short sea ferry which presents a moderate risk owing to the number of passenger lives which may be lost. It is however a relatively simple ship to operate.

It would appear from this analysis that there should exist a base qualification which would enable an officer to
5. RESULTS

perform duties aboard a less difficult, low risk type of vessel. Those officers wishing to serve aboard short sea ferries would have to satisfy the regulatory body that they were capable of accommodating the increased risk inherent with these vessels. Since the increase in risk with these ferries is not due to technical complexity or difficulty it seems pointless to insist on higher technical qualifications. Therefore the need is rather to identify those persons capable of operating very routine, repetitive operations whilst maintaining a high standard of vigilance and continued peak performance. Such identification would appear to rely heavily on psychological selection of those individuals rather than testing technical competence.

Those officers who wished to obtain employment aboard the difficult, high risk group, the tankers, would need to demonstrate to the regulatory body that they possessed a higher state of technical competence in all the ship sub-systems than those seafarers who operate the less difficult, low risk ships. To an extent this system has operated informally for many years with owners of tanker fleets normally recruiting experienced personnel or training their own officers from entry into the industry, whereas owners of other ship types have been satisfied to accept an officer who holds the relevant qualification. The exception to this is the selection for employment aboard short sea ferries. Here a high standard of technical
competence has always been demanded but, until recently following the loss of the 'Herald of Free Enterprise', the unique risks inherent with ferry operations have not been recognised.

There is an analogy with road transport where there is a base qualification to drive a car or light commercial vehicle. A demonstration of technical competence in handling larger vehicles is required to enable an operator to drive a heavy goods vehicle and a special public service vehicle licence is required for the transport of passengers. The mechanized road transport industry is a much younger industry than that of the mercantile marine and is not yet so hidebound with tradition.

From the above facts there are key factors which affect the risk presented by a ship type and which contribute to the relative difficulty of operating it. These are therefore the factors which must be taken into account when devising a certification scheme to assess the competence of persons to operate particular ship types. These key factors are:

1. CARGO TYPE
2. SIZE OF VESSEL
3. FINANCIAL INVESTMENT (Dependent on size & cargo)
4. COMPLEXITY OF VESSEL (Dependent on size & cargo)
5. POWER OF MAIN ENGINE (Dependent on size & trade)
6. AUXILIARIES FITTED (Dependent on size & cargo)
In general trading, the power of the main engines has a high correlation with vessel size. However there are exceptions such as anchor handling and salvage tugs where powerful propulsion units are fitted into small hulls.

This analysis shows that there are differences between ship types as far as the competency requirement is concerned. The ships in the study fall into the three groups:

1. tankers;
2. short sea ferry;
3. all other ships.

This arrangement of ship types is in agreement with the three economic groups proposed and examined by Gilman and Cox. They defined the three groups as:

1. tankers, ships carrying liquid cargoes. Economic and trading factors caused Gilman and Cox to segregate these ships into a separate group. This research supports this segregation based on technical criteria and shows that tankers form a defined high risk group which, by virtue of their size and technical complexity, need high levels of knowledge and experience to operate safely.

2. liners, ships carrying cargo and passengers on regular scheduled services. Gilman and Cox isolate this group of ships economically because of the strong bi-partisan trading relations which develop between the involved countries. This research illustrates that technically the
liners form a unique group. While safe operations do not require the same high degree of knowledge and experience as that for the tankers there is still a substantial risk posed by these ships due to the possible catastrophic loss of passengers.

3. tramps, ships carrying dry cargoes on non-scheduled routes. Gilman and Cox regard these ships as a group due to the economic opportunism displayed by their managers. This opportunism is reflected technically in their ability to trade worldwide and carry a broad variety of cargoes. This class of ships does not pose the same levels of risk as tankers or liners but does demand a broad range of knowledge and experience to ensure safe operation.

It is now argued that it is justified to consider ships in these three categories - tankers, tramps, and liners, - for crewing purposes. It is therefore proposed that while examining the collected data in more detail to assess the viability of matrix manning, these three groups will be examined separately. It is hypothesised that while matrix manning may be applicable aboard one group of ships it may not be applicable to all.

CONCLUSIONS TO SECTION 5.1

This section has examined the underlying assumption of Herbst, Smith & Ruggema, and others that, for crewing
purposes, all ships are fundamentally the same. It has been shown that due to the varying risks and technical difficulties posed by the different ships they may best be seen as belonging to one of three groups - tankers, tramps, or liners. It is argued that any reorganization of ships' crews must recognize this distinction.

Based on this analysis it is possible to assert that the traditional criteria for qualifications to operate ships are in need of review. Navigational qualifications have been based upon the trading area of the ship. A ship which disappeared from sight of land and ventured into the, then, relatively unknown world demanded higher levels of competence than one which remained near to its home base and could be ensured of support and assistance. Engineering qualifications have been based purely on the power output of the main propulsion unit. If it is found that reorganization of ships' crews on matrix principles is technically feasible then it would now seem logical to base future categories of seafaring qualifications on the cargo type and the size of the ship. This would automatically ensure that important factors such as danger to human life, hazard to the physical environment and jeopardy of the financial environment are recognized and accounted for. Also the differing requirements of knowledge and experience for safe operation which differ between the ship types would be taken into account.
5. RESULTS

5.2 RESULTS OF FREQUENCY, CRITICALITY, DIFFICULTY DATA

Section 5.1 reveals that there are three ship groups which need further examination in order to validate the applicability of matrix manning. This section uses the accumulated data with respect to the frequency of function performance, criticality of unsuccessful performance of that function to human life, the environment and the finance system, and the difficulty of performance of the function in terms of knowledge and experience.

The structure of this section is that each of the seven ship sub-systems is examined in turn and similarities and differences between the ship types are noted and commented upon. Finally the three ship types are described separately in the light of the results obtained and the applicability of matrix manning to each ship type is discussed.

The results of the research with respect to FREQUENCY, CRITICALITY & DIFFICULTY are presented in the following manner.

1. The FREQUENCY ratings obtained for each individual ship are averaged to produce a set of figures for the 'average tanker', the 'average tramp' and the 'average liner'. For example a function which is performed monthly (rating 3) aboard the crude carrier, gas carrier and product tanker and performed weekly (rating 4) aboard the chemical carrier would acquire an average of:
5. RESULTS

MODULUS \((3 + 3 + 3 + 4)/4 = 3\).

For the 'average tanker' this function would receive the average rating of 3 (monthly).

2. Since the criticality rating is composed of three parts - life, environment, and finance - the three separate ratings are summed to provide a total criticality rating on a 15 point scale. These are then averaged as described above.

3. The number of functions with specific FREQUENCY, CRITICALITY and DIFFICULTY ratings are then summed and plotted on frequency histograms.

4. A 'SIGNIFICANCE NUMBER' is determined for each function as follows. The average ratings of frequency, criticality and difficulty are summed to provide the significance number of the function. The criticality rating carries greater weight than either of the other two ratings. This is because a function may be critical to human life only, the physical environment only, the financial system only or a combination of any two. It may possibly, in extreme cases, be critical in all three areas. Thus a function which is critical to life, physical environment and financial system attains a higher SIGNIFICANCE than does a function which only has an effect on the financial system. An example of a SIGNIFICANCE number determination is given below:

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<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>CRITICALITY</th>
<th>DIFFICULTY</th>
<th>SIGNIFICANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9</td>
<td>4</td>
<td>18</td>
</tr>
</tbody>
</table>

This represents a function performed very frequently (5), with a moderately high criticality rating (9) and which requires medium knowledge and high experience (4). The significance of the function is therefore 18 on a 25 point scale. Very frequent, critical and difficult functions receive high significance numbers and seldom performed, non-critical and easy functions receive low significance numbers. For each ship type the significance numbers are plotted as frequency histograms.

NAVIGATION SUB-SYSTEM

The frequency histograms for the average ratings of each of the three ship types are shown as figure 5.6

Examination of the FREQUENCY diagrams show that the liner performs the majority of navigational functions daily (rating 5). The average tramp performs the majority of navigational functions on a weekly basis (rating 4) and the average tanker performs them at monthly intervals (rating 3). This reflects the trading pattern of each of these ship types. The liner is constantly entering and leaving port and making short sea passages in its role as a short sea ferry. The tramp is visiting ports at approximately weekly intervals representing middle distance oceanic trading. The tankers are visiting ports at monthly intervals and are
5. RESULTS

Figure 5.6
engaged in long distance oceanic passages. With the tramp and the tanker there is a small number of functions performed daily. These are the navigational watchkeeping duties and are highly critical. It would appear that the large number of navigational functions performed daily aboard the liner means a greater daily workload on those charged with fulfilling the navigational functions.

The CRITICALITY diagrams indicate that in each of the ship types there are two distinct groups of criticality. There is a large number of functions which are not critical (rating <6) and a smaller group of critical functions (rating >11). The tanker has the highest CRITICALITY ratings because of the hazardous and costly nature of its cargo.

The DIFFICULTY diagrams illustrate the fact that navigational functions aboard a tanker require more knowledge than on the other ship types. This is due to the global nature of the operation and the size of the ships. The liner operation appears to require more experience than knowledge. This reflects the routine, repetitive nature of the navigation of a short sea ferry.

The SIGNIFICANCE numbers are depicted on figure 5.7. These diagrams show that in all three ship types there is a large number of low significance functions. There are also a fewer number but identifiable group of functions of higher significance. It appears that in the navigation sub-
system there is some basis for allocating the higher significance functions to a primary role operator and the lower significance functions to a secondary role officer. These data therefore support the concept of matrix manning by demonstrating that there are two definable levels of performance in the navigation sub-system of all three ship types.
5. RESULTS

Figure 5.7

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5. RESULTS

CARGO SUB-SYSTEM

The FREQUENCY diagrams in figure 5.8 reveal the daily nature of liner cargo work, the weekly nature of tramp cargo work, and the monthly intervals between cargo operations aboard the tanker group. The results also show that a large number of cargo functions are not performed aboard the liner (rating 1). This is due to the short duration of the passage during which many of the cargo and cargo space condition monitoring functions are not performed. This has been recognised by Mr. Justice Sheen during the formal inquiry into the loss of the 'Herald of Free Enterprise' and recommendations have been made to monitor cargo spaces on short sea ferries either by human agency or by closed circuit television.

The CRITICALITY diagrams show that aboard the tramp and the liner the vast majority of cargo sub-system functions are not critical. Aboard the tanker however, due to the pollutant and dangerous nature of the cargoes, the criticality levels are much higher. These results reflect the fact that on the liner and tramp the cargo work is generally a secondary role of the navigation officers. On the tanker however, the tendency in recent years has been to provide specialist cargo officers from either the navigating or engineering departments. These data tend to support the concept of matrix manning by illustrating that primary and secondary roles already exist in the cargo sub-
5. RESULTS

Figure 5.8
5. RESULTS

system. These results further indicate the fact that transfer of cargo officers from liners or tramps to tankers is not advisable because the criticality of tanker operations is that much higher.

The DIFFICULTY diagrams display the fact that aboard the liner and tramp ships the majority of functions require experience rather than knowledge. On the tanker however a greater degree of knowledge is required which indicates a need for greater training aboard these ships and further supports the argument that the transfer of primary cargo roles between these ships is not advisable.

The SIGNIFICANCE diagrams show that the tanker has two peaks which again supports the concept of a primary role officer coping with the functions which have a high significance number. Those functions with lower significance being undertaken by an officer acting in a secondary role. With the tramp ship the significance of functions displays a close group around a fairly low significance value of 9. This supports the reality that cargo operations aboard tramp ships are secondary role operations. The cargo functions aboard the liner display two peaks but they are both at the low significance end of the scale. This means that although the cargo functions may be considered as a secondary role due to their low significance it may be better to split them into primary
5. RESULTS

Figure 5.9
and secondary roles bearing in mind the high frequency and intensity of workload aboard these ships.

MACHINERY SUB-SYSTEM

The FREQUENCY diagrams of figure 5.10 indicate the similarity between the tanker and the tramp. The liner is seen as performing many of the machinery functions at frequent intervals. This once again reflects the nature of the short sea passages and frequent engine manoeuvering. The effort aboard the tanker and tramp for manoeuvering is carried out at much longer intervals and the frequent functions are the monitoring of steady running operations.

The CRITICALITY of functions is similar between the tramp and the liner. This in general is due to the similarity of their sizes and the simplicity of the equipment compared to the tanker. The tanker has generally much larger power units and the auxiliary units needed for cargo handling and conditioning are much more complex. This leads to the higher criticality of machinery functions aboard tankers and tends to support the argument that transfer of machinery operatives to tankers may not be advisable if they are to assume a primary role. The tanker especially displays two groups of criticality of functions supporting the concept of primary and secondary roles.

The DIFFICULTY diagrams illustrate that aboard all
5. RESULTS

Figure 5.10
Figure 5.11
ship types, the functions of machinery operation are in general experience based rather than knowledge based. This supports the argument that the transfer of machinery operatives between ship types may require experiential time-served training rather than extra college-based knowledge provision.

The SIGNIFICANCE diagrams of figure 5.11 show a wide spread of function significances compared with other sub-systems. This supports the concept of matrix manning in that it is possible to have a primary role machinery operative who can perform the more significant functions and the less significant functions may be allocated to other officers acting in their secondary role.
HOTEL & CATERING SUB-SYSTEM

Figure 5.12 shows that the hotel and catering sub-systems are substantially the same in all three ship types. The functions are all of low CRITICALITY and rely on experience rather than knowledge. The only difference between ship types is in terms of the FREQUENCY of some functions where the liner performs most functions daily since it is constantly feeding passengers and replenishing stores whereas the tramp and tanker tend to perform provisioning functions at longer intervals. These data illustrate that transferrability of catering skills between ship types should not cause any problem.

Figure 5.13 shows the spread of SIGNIFICANCE numbers within the hotel and catering sub-systems of each of the three ship types. They are fundamentally the same and support the argument that catering functions may be a secondary role for officers who have other functions as their primary role.
5. RESULTS

**Liner**

**Tramp**

**Tanker**

Figure 5.12
5. RESULTS

**Figure 5.13**

Number of Functions

<table>
<thead>
<tr>
<th>SIGNIFICANCE</th>
<th>LINER</th>
<th>TRAMP</th>
<th>TANKER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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COMMUNICATIONS SUB-SYSTEM

Figure 5.14 demonstrates that the communications sub-system is virtually identical in terms of FREQUENCY, CRITICALITY & DIFFICULTY on all three ship types. This means that communication skills are readily transferrable between ship types. On all ship types there are communication functions which occur at frequent intervals (daily). This fact together with the spread of SIGNIFICANCE numbers in figure 5.15 indicate that communication functions may conveniently be split into functions which are performed frequently being allotted to an officer as a primary function whilst those which are performed less frequently may be allotted to other officers as secondary roles.
5. RESULTS

Figure 5.14
5. RESULTS

Figure 5.15
5. RESULTS

MANAGEMENT & ADMINISTRATION SUB-SYSTEM

Figure 5.16 shows that the tanker and the tramp perform these functions at the same FREQUENCY rates but that the liner again performs functions at a greater frequency. This illustrates once more the relatively high daily workload aboard the short sea ferry. All ship types have a large number of low criticality functions and one single function which is rated as of high criticality. This function is the provision of suitably trained and qualified personnel. This one highly critical function is removed from all three ship types and is fulfilled by staff in the shipping management's offices. This fact renders the functions of the management and administration sub-system to be considered as secondary role functions to be fulfilled by officers who have other primary roles. The DIFFICULTY ratings of these functions show that experience is the primary requirement aboard the tramp and the liner but for the tanker some high level knowledge is required. This knowledge is due to the hazardous and pollutant nature of the cargo and familiarity with the necessary legislation associated with tanker operations. This fact again underlies the lack of transferrability of skills to tankers. In this instance it is argued that extra college-based knowledge is required by officers wishing to undertake a managerial role aboard tankers.
5. RESULTS

NUMBER OF FUNCTIONS
48
36
32
28
24
20
16
12
8
4
0

FREQUENCY
1 2 3 4 5

CRITICALITY
1 2 3 4 5

DIFFICULTY
1 2 3 4 5

Figure 5.16
5. RESULTS

Figure 5.17
5. RESULTS

Figure 5.17 displays the fact that on the tanker and the tramp the management and administration functions are grouped around a single peak of low significance and may therefore be considered as secondary roles. With the liner the functions are spread about two peaks. In view of the high workload aboard these vessels it may be prudent to assign those functions with a higher significance number to an officer as a primary role. Those functions with lower significance numbers may be given to other officers as secondary roles. In all three ship types the single function with high significance is performed by shore staff as mentioned above.

SAFETY & EMERGENCY SUB-SYSTEM

The immediate information which emerges from the FREQUENCY diagram of figure 5.18 is that the functions of this sub-system are either never performed or are performed on a long term random basis. The reason for this is that the functions are only performed in the event of an emergency which should never occur. The small number of more frequently performed functions refers to the testing and maintenance of emergency equipment. Due to the nature of the cargo of the liner - many human lives - these functions are performed more frequently than aboard the tramp or the tanker.
5. RESULTS

Figure 5.18

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It is also due to the risk to passengers' lives that the CRITICALITY ratings of the liner assume the highest numbers. The tanker has the next highest values for CRITICALITY due to the nature of its cargo and the tramp has the least high values. The data show that aboard the liner and the tanker there is a need for an officer to have safety and emergency functions as his prime role and for other officers to share in these duties as part of their secondary roles. The case is not so clear with the tramp and the data can only indicate that there is a secondary role to be shared amongst officers. However the very nature of crises requires that one person assumes the primary role for implementing action and therefore even on the tramp it is argued that there should be an officer with safety and emergency functions as his primary role.

The DIFFICULTY ratings of these functions indicate that they are all experience based. However the frequency of performance of these functions is such that they are either never or seldom performed. This means that in order to generate the required experience it is necessary to engage in simulation, drills and role play exercises. The tanker group indicates that a degree of knowledge is also required to cope with emergencies which affect the complex nature of their cargoes. This again supports the argument for non-transferrability of skills to the tankers without some form of extra training.
Figure 5.19 illustrates that by examining the SIGNIFICANCE numbers it is possible to assign primary and secondary role functions aboard each of the three ship types.
Figure 5.19
CONCLUSIONS FROM SECTION 5.2

This section reinforces the distinction derived earlier in section 5.1 that there are significant differences between tankers, tramps and liners which affect the performances of their respective crews.

The liner is seen to have a high daily workload, relatively few highly critical functions, and to require officers who are experienced rather than knowledgeable. It is seen that it is possible to allocate the functions of the liner into primary and secondary roles in accordance with the requirements of matrix manning. This allocation may best be done by examination of the SIGNIFICANCE numbers calculated for each function. The tramp is seen as having peak workloads which occur at weekly intervals. This vessel also had a majority of non-critical functions and required experienced officers rather than knowledgeable ones. The distribution of SIGNIFICANCE numbers also indicated the possibility of assigning primary and secondary roles in all ship sub-systems.

The tanker emerges as the vessel which has the most critical functions and also requires officers with a higher knowledge level than the other two ship types. It is argued that due to the specialist nature of tanker work as analyzed it is unwise to allow unconditional transfer of personnel to the tanker from either the liner or tramp. A mixture of college-based learning and on-board experiential
learning is advocated for officers wishing to transfer to tankers. The tanker, as with the other two ship types, appears from the data to be capable of being manned by officers organized on a matrix principle as described by Herbst (1974) and Smith & Roggema (1980a).

This analysis of the data relating to FREQUENCY, CRITICALITY & DIFFICULTY therefore supports the possibility of assembling ships' crews on a matrix principle.
5.3 RESULTS OF DATA, THINGS & PEOPLE OBSERVATIONS

It was shown in Section 5.2 that ship functions may be examined for SIGNIFICANCE and apparently segregated into two domains:

1. those functions which, by virtue of their FREQUENCY, CRITICALITY & DIFFICULTY may be considered highly SIGNIFICANT and form a core of functions whose fulfillment should be a primary responsibility of one officer and

2. those functions which are considered less SIGNIFICANT and whose fulfillment may be a secondary responsibility of an officer.

FREQUENCY and CRITICALITY may be accurately measured and a differentiation drawn between functions whose fulfillment requires the use of KNOWLEDGE and those requiring EXPERIENCE. But the qualitative nature of the functions is not addressed by these measures i.e. does the function involve DATA handling, is it a manual operation involving the use of THINGS, or does it require the supervision or cooperation of other PEOPLE?

In order to assess the quality of work required for completion of functions the Functional Job Analysis ratings of DATA, THINGS & PEOPLE are examined. The results of the research with respect to DATA, THINGS & PEOPLE are presented in the following manner.

1. The ratings obtained for each individual ship are averaged to produce a set of figures for the 'average
tanker', the 'average tramp' and the 'average liner. For example a function which requires DATA handling level 1 (comparing) in order to be fulfilled aboard the crude carrier may require level 2 performance (copying) aboard the gas carrier, product tanker and chemical carrier. Such a function would acquire a mean value of:

\[
\text{MODULUS } \frac{1 + 2 + 2 + 2}{4} = 2
\]

2. The number of functions with specific DATA, THINGS & PEOPLE ratings are then summed and plotted on frequency histograms.

3. A 'COMPLEXITY NUMBER' is determined for each function as follows. The average ratings of DATA, THINGS and PEOPLE are summed to provide the complexity number:

\[
\text{DATA} + \text{THINGS} + \text{PEOPLE} = \text{COMPLEXITY}
\]

\[
5 + 4 + 2 = 11
\]

This represents a function which requires ANALYZING data (rating DATA 5), MANIPULATING some equipment (rating THINGS 4) and INFORMING others of the action taken (rating PEOPLE 2). The COMPLEXITY of this function is therefore 11 on a 24 point scale. Functions which require a high level of data handling, precision use of equipment and involve important interactions with people receive a high complexity number. Those functions which require only low data handling ability, the simple feeding or tending of
machinery, and involve merely assisting other people receive low complexity numbers. The complexity numbers are plotted as frequency histograms for each sub-system.

**NAVIGATION SUB-SYSTEM**

The distribution of DATA, THINGS and PEOPLE ratings for the navigation sub-system is shown in figure 5.20.

![Figure 5.20](image)

The figure demonstrates an important point. The levels of interaction of the function performer with DATA, THINGS & PEOPLE are identical regardless of the type of ship involved. This means that the function of, say, collision avoidance poses exactly the same challenge to the
navigator of a small dry bulk coaster as it does to the
navigator of a large crude oil carrier. The consequences of
error are substantially different as described in sections
5.1 and 5.2 but the ability requirements of the operators
are the same. In section 5.2 the claim is made that
officers from tramps and liners should not have ready
transfer to ships of the tanker group. This means that,
although technically capable of navigating tankers, they
must have the extra knowledge of the risk posed by
incorrect function performance before being allowed to
navigate such vessels.

The DATA distribution illustrates that much of the
work of the navigator is high level data handling.
Information is compiled and analyzed and innovative
decisions are made to meet the unique hazards presented to
the vessel at any stage of its voyage. Coordination of
other sub-systems is necessary to meet performance
requirements and ensure the objective of safe and efficient
navigation is achieved. There is also a block of low level
data handling consisting of comparing incoming data to
determine if subsequent analysis is necessary and an amount
of copying in order to store and disseminate data. It is
argued that by examination of the frequency histogram these
data handling functions may be split into primary role
functions and secondary role functions. The higher level
functions, which indicate superior human performance, being
allotted to primary role operators and the lower level functions to officers operating in their secondary role capacities. Therefore the possibility of matrix manning is supported by these data.

The THINGS distribution also displays the possibility of separating functions into primary and secondary role functions. In this case it is argued that the primary role operator should be accorded the functions whose fulfillment involves the high level functions of operating and controlling navigational equipment and especially those functions which require precise results or involve the setting up of complex instruments. The secondary role operator should be assigned those functions which require only handling and do not involve judgement or the attainment of specific standards.

The distribution of PEOPLE ratings supports the separation of navigational functions into primary and secondary matrix functions. The secondary role operator in this instance would be assigned those functions which involve the conveying or exchanging of information. The primary role operator would receive the functions which involve supervision and the instruction of trainees in the navigational functions.

The distribution of the COMPLEXITY numbers as shown in figure 5.21 draws together the values of DATA, THINGS & PEOPLE ratings and further supports the separation of the
5. RESULTS

navigation sub-system functions into primary and secondary role groups.

![Bar chart](image)

**Figure 5.21**

**CARGO SUB-SYSTEM**

Figure 5.22 illustrates the spread of DATA, THINGS & PEOPLE ratings in the cargo sub-system:
5. RESULTS

NUMBER OF FUNCTIONS

DATA
THINGS
PEOPLE

LINER

DATA
THINGS
PEOPLE

TRAMP

DATA
THINGS
PEOPLE

TANKER

DATA
THINGS
PEOPLE

CARGO SUB-SYSTEM

Figure 5.22

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5. RESULTS

The distribution of DATA ratings is identical for all three ship types. There again appears to be two separate levels of interaction depicted. There is a high level group of functions which involves analysis of information and innovative decision making in order to accommodate the unique problems posed by specific ports and cargoes. There is a small amount of coordination which involves coordinating other sub-systems to achieve a successful cargo operation. A separate group of functions exists, as with the navigation sub-system, which involves comparing and copying. Again it is proposed that these two blocks of functions could be allotted to primary and secondary role operators.

The distribution of the PEOPLE ratings is also the same for all three ship types. The distribution is very similar to that for the navigation sub-system PEOPLE ratings and similarly shows a possibility for separating the functions into primary and secondary roles.

The patterns displayed by the THINGS ratings, however, are very different between the ship types. The liner indicates fewer cargo functions than the tramp or the tanker. This is due to the short nature of the ferry voyage and the fact that many cargo monitoring functions are not performed. It is also caused by the nature of the cargo. Ferry cargoes, being passengers, cars and lorries are all self loading and self discharging and require few functions
to be performed by the crew. The tramps show a large amount of low level 'handling', some 'feeding' and 'tending' and an amount of manipulation. This reflects the extremely manual operations of cargo space preparation, together with the tending and manipulative skills required to operate the specialized cargo handling equipment such as cranes, grabs and conveyors. Together these functions form a group at the lower end of the interaction range and it is argued that these functions could be assigned to an operator who is performing in his secondary role. Herbst (1974, p.29) asserts that

'many tasks may be wholly or partly shore based. If tasks are split up so that one part is carried out on board and the other part ashore, then the significant decision variable is the location of task components that involve:

(a) decisions requiring a high level of skill and judgement
(b) work and decisions at technician level
(c) unskilled and semi-skilled labour.'

By referring to figure 5.8, page 140, it is seen that many cargo operations have a low level of CRITICALITY. It has now been shown that many cargo functions are also capable of being performed by operators who are handling DATA, THINGS & PEOPLE at low levels. This should identify a group of functions whose performance may be passed to shore
based operatives. This is indeed the case and it has been observed during the research voyages that on the tramps and liners, especially the smaller ships, many of the cargo functions are performed by shore operatives. These data therefore support the theories of Herbst and others that, in order to introduce matrix manning, certain functions may be devolved to shore operatives.

The histogram displaying the THINGS interactions within the cargo sub-system of the tankers, however, exhibits a different distribution. The vast amount of cargo functions performed aboard the tanker are those which involve 'controlling'. This is because the personnel aboard the tankers load and discharge their own cargoes with little assistance from shore staff. They monitor gauges, pressures, flows and control pumps and other specialized equipment. This is also reflected in the large amount of functions involving 'precision working' and 'setting up' relative to the tramps and liners. The tankers do have an identifiable lower level group of functions which is small and involves the tending of cargo machinery and the manipulation of valves, flexible hoses etc. Aboard the tankers this group of functions is performed by ratings and the higher level functions are performed by officers. Whilst these functions are not separated according to a matrix scheme their very separation shows that the possibility of reallocating them as primary and secondary
officer roles exists.

Figure 5.23 illustrates the distribution of the COMPLEXITY numbers within the cargo sub-system. The diagram illustrates that there is a substantial block of functions which are of low complexity and may be assigned to an officer acting in his secondary role. There is also an identifiable group of functions which are of greater complexity and which should be fulfilled by a primary role operator.
MACHINERY SUB-SYSTEM

The levels of DATA, THINGS & PEOPLE interactions within the machinery sub-system are shown in figure 5.24. The most obvious result emerging from this diagram is that aboard all three ship types the PEOPLE interactions are identical. Further they apparently only involve low level interactions of 'informing' and 'persuading'. This is understood to reflect the fact that many machinery functions are performed by single individuals working in isolation with machinery. The interaction with other people occurs when informing others of the status of the machinery and the efficacy of maintenance work. The large amount of 'persuading' represents the mechanical, electrical and electronic advice and assistance which is given by machinery personnel to effect the correct use of equipment and machinery from all the sub-systems.

The distribution of the DATA results demonstrates that the tramp and the liner are identical in the interactions necessary for fulfilling the machinery sub-system functions. The skills involved here are those of compiling the relevant information on the state of the ship's machinery and analyzing the need for action to obtain optimal performance. The group of tankers has a substantially greater number of higher level functions than the tramps or liners. There is a need for innovative functions to be performed. This is because, due to the nature of the cargoes carried, there is much extra
5. RESULTS

Figure 5.24

DATA
THINGS
PEOPLE

NUMBER OF FUNCTIONS
40-
36-
32-
28-
24-
20-
16-
12-
8-
4-
0

DATA
THINGS
PEOPLE

NUMBER OF FUNCTIONS
40-
36-
32-
28-
24-
20-
16-
12-
8-
4-
0

DATA
THINGS
PEOPLE

NUMBER OF FUNCTIONS
40-
36-
32-
28-
24-
20-
16-
12-
8-
4-
0

DATA
THINGS
PEOPLE

MACHINERY SUB-SYSTEM

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machinery and equipment involved with the maintenance of the cargo and cargo space conditions. For example there are cargo heating systems, inert gas generators, and specialized pumping equipment, none of which is fitted to the tramps and liners. This once again underlines the fact that mobility of personnel from the tramps and liners to the tankers should be made only with the provision of extra training.

The THINGS distribution shows the liner as being the simplest to operate of the three ship types. This is because it has regular base ports and the provision of maintenance facilities is easily arranged. The shipboard operators therefore utilise the majority of their skills in tending the machinery and are not required to perform functions at a higher level, these being performed by shore based personnel. In contrast, due to their remoteness from shore support, the operators of the machinery sub-system aboard the tramps and tankers are required to perform equipment related functions at higher levels. This involves manipulatory and driving skills which necessitate greater judgement and precision.

The distribution of the COMPLEXITY numbers is shown in figure 5.25. This illustrates that there are two levels of complexity of functions within the machinery sub-system but the span of complexity is not great. The lower level, which could be assigned as a secondary role, involves the
simple tending of automated machinery. The higher level, or primary role functions, involves some judgement in manipulating tools and equipment and driving or operating equipment with a degree of precision.

The machinery sub-system results support the segregation of ship functions into the primary and secondary roles which is necessary to sustain the matrix manning system. It further emphasises the dissimilarity between tanker operations and those of the other ship types and supports the argument for more training for those persons charged with operating the tankers.

**Figure 5.25**
5. RESULTS

HOTEL & CATERING SUB-SYSTEM

The distribution of the functions in this sub-system is shown in figure 5.26 and is identical for all three ship types.

The DATA ratings show that there is an amount of high level data handling occurring within this sub-system. There is coordination both with other systems aboard and with the suppliers of stores who are based ashore. There is compilation of records and analysis to ensure that
standards are being met and costs are under control. There is also low level recording of catering information and 'comparison' functions which ensure that standards of cleanliness and hygiene are assured.

These data handling functions can apparently be separated into primary and secondary role blocks and assigned to appropriate officers.

The THINGS interactions also fall into two groups. There are the high level, primary functions which entail the precision work involved in meal preparation and the manipulation of equipment to produce the finished product. There are the low level 'handling' functions which encompass the menial duties of cleaning accommodation and preparing food.

The distribution of PEOPLE interactions illustrates further the possibility of splitting the catering functions into primary and secondary role functions. The primary role here involves the supervision and instruction of personnel aboard in catering functions in addition to the skills of negotiation with shore suppliers. The secondary role involves low level 'helping' and involves team effort at performing the menial functions necessary for maintaining a safe, clean and tidy vessel.

The COMPLEXITY numbers derived from the observations of the catering sub-system are shown in figure 5.27.
The distribution of complexity numbers supports the argument that there exists within the hotel and catering sub-system two clearly definable levels of performance. It is argued that the functions contained within these two blocks could be assigned to primary and secondary role operators and assist in the formation of a crew organized on matrix principles.
5. RESULTS

COMMUNICATION SUB-SYSTEM

The frequency histograms representing the distributions of DATA, THINGS & PEOPLE interactions within the communication sub-system are shown on figure 5.28. All three ship types produced identical results.

The DATA results separate into two functional performance levels. The high level group of functions suitable for a primary operator are those concerned with the analysis of available communication channels and the
innovative use of communication systems dependent upon geographical location and the type of data that it is required to communicate. The lower level group of functions suitable for performance by persons acting in their secondary role is concerned with maintaining a listening watch and recording details of communications such as weather reports and navigational warnings.

The THINGS component of the communication functions may also be divided into two functional performance levels. The lowest or secondary group involves the manipulation and tending of communications equipment. This covers the simple, routine operation of such equipment. The initial 'setting up' and maintenance of such equipment are operations which require the highest level of THINGS interaction and are therefore the functions which may be assigned to a primary role operator.

The PEOPLE interactions reveal only a single group of functions which it is claimed are the preserve of the primary operator. The functions concerned involve the supervision of communication channels and procedures and the imparting of training in the correct use of the sub-system components.

The arrangement of the COMPLEXITY numbers representing the communications sub-system, as shown in figure 5.29, displays two groups of functions. According to matrix manning principles these may be allotted to primary
and secondary role operators, the primary role operator performing those functions which are complex and other operators, acting in their secondary roles, performing the remaining functions.

Figure 5.29
MANAGEMENT & ADMINISTRATION SUB-SYSTEM

The distribution of the DATA, THINGS & PEOPLE results for the management & administration sub-system are shown in figure 5.30. For this sub-system, as with catering and communications, the three ship types display identical histograms. The immediately striking aspect of figure 5.31 is the single THINGS function which is recorded. This is because this sub-system deals with the management and the administration of PEOPLE and DATA. The single THINGS interaction involves the maintenance of stocks of spare parts. A 'tending' function is necessary to ensure that the stock is kept in optimum condition.

NUMBER OF FUNCTIONS

0. 20
10. 18
20. 16
30. 14
40. 12
50. 10
60. 8
70. 6
80. 4
90. 2
100 0

DATA
THINGS
PEOPLE

MANAGEMENT & ADMINISTRATION SUB-SYSTEM

Figure 5.30
5. RESULTS

The DATA functions include a large number which are rated as requiring innovative skills. These are necessary to overcome the unique and frequently changing managerial and administrative problems which occur on board. These are high level functions and form a group which may be assigned to a primary role operator. There is an element of lower level functions which comprise the recording of administrative data and which may be handled by an operator performing in a secondary role.

Similarly the PEOPLE results display two functional groups of performance. The lower level group is suitable for persons to fulfill whilst acting in their secondary roles. These functions include assisting with the administrative duties and influencing others to maintain morale and motivation. The higher level group may be assigned to an officer whose primary role involves management and administration. These functions involve a large number which are of a supervisory nature in addition to some requiring negotiating and mentoring skills.
5. RESULTS

The distribution of the COMPLEXITY numbers reinforces the claim that the functions within the management and administration sub-system may be separated into primary and secondary role functions.
SAFETY & EMERGENCY SUB-SYSTEM

All three ship types again display identical distributions of DATA, THINGS & PEOPLE interactions and these are illustrated in figure 5.32.

The DATA interactions are seen to fall into two distinct groups. The high interaction level group which may form a set of primary role functions consists of many innovative functions together with many at the highest level of 'synthesising'. This reflects the nature of
5. RESULTS

emergency functions which are unique and unexpected. There is a lower interaction level which consists of recording safety and emergency information, inspections, drills etc. and 'comparisons' which involve checking whether safety standards are being maintained.

The THINGS interactions again appear to fall into two functional performance groupings. The high level group which may form a core of functions for a primary role operator, consists of functions which require a great deal of judgement in the handling of equipment. They also require the ability to repair machinery and equipment and restore normality in the event of crisis situations. The lower level functions which may be performed by other operators acting in a secondary role consist of 'tending' and 'manipulating'. These functions involve the routine testing and maintenance of emergency equipment and the use of such equipment, under supervision, during an emergency.

The distribution of the PEOPLE functions reveals a group of high level functions which involve 'negotiating' and 'supervising'. This means that the operatives who perform these functions must be able to liaise with others to produce solutions to emergency situations. They must then supervise the crew in effecting any corrective actions that are needed. There is a group of lower level functions which involve assisting in emergencies and the relaying of information. These may form part of the secondary roles of
officers whose primary roles involve other sub-systems within the ship.

The distribution of COMPLEXITY numbers, figure 5.34, for the safety and emergency sub-system show that there is a definite group of complex functions whose performance may be allotted to a primary role operator.

There is a second group of lower level functions whose fulfillment may form part of other officers secondary
roles. There appears to be a third group of functions at the low complexity end of the scale. Since these functions are not complex and safety and emergency functions affect all on board it may be that these functions should form part of the role of every person aboard. Included in this third group are such functions as using DATA to compare the standard of safety aboard to that which is required. Also the ability to use THINGS under supervision to fight fires, abandon ship or perform other emergency duties. The PEOPLE interaction of exchanging information is necessary to disseminate safety awareness and advise of unsafe conditions which are found to exist aboard the ship.
CONCLUSIONS FROM SECTION 5.3

The results as described in section 5.3 reinforce the findings from sections 5.1 and 5.2 that the tankers form a special group of ships. The analysis of the functions in terms of DATA, THINGS & PEOPLE demonstrates that human performance aboard the tankers is demonstrably higher than aboard the tramps or liners. This increased level of performance aboard the tankers is specifically within the sub-systems of cargo and machinery. This is due to the size, specialization and technical complexity of the machinery and equipment and the hazardous, pollutant nature of the cargoes. The remaining five sub-systems display no difference in the level of performance of the operators aboard the different ship types. This finding modifies the claim made earlier that transfer of personnel from tramps and liners to tankers should be conditional upon extra training. It is now claimed that personnel may move freely between all ship types except that officers who have primary role functions within the sub-systems of cargo and machinery must receive extra training before assuming such roles aboard tankers.

The results of this section show the importance of DATA interactions within every sub-system of all ship types.

The results illustrate that it is possible to separate the functions of each sub-system of all ship types.
into two areas of functional performance. This separation is assisted by the introduction of a COMPLEXITY number. The higher level functions may then be assigned to primary role operators and the lower level functions may be assigned to other operators for performance in their secondary role capacity. This possibility of creating two role levels therefore supports the supposition of Herbst (1974) and Smith & Roggema (1980a) who claim that matrix manning may be introduced aboard all ships based on the development of primary and secondary role operators.

Further, the results indicate that, due to the similarity of some of the histograms, it may be possible to cluster similar sub-systems together to provide functional groupings suitable for the autonomous work groups proposed by Herbst (1974, pp.55-57). For example the communication sub-system functional interactions with DATA, THINGS & PEOPLE are similar to those of the navigation sub-system. The functions of these two sub-systems may be combined to form a group of functions for completion by a primary role operator supported by one or more secondary role operators.

It is therefore argued that the results of the observations regarding DATA, THINGS & PEOPLE support the possibility of organizing the crew according to matrix manning principles.
CONCLUSIONS TO CHAPTER 5

In this chapter the data gathered during the sea voyages are examined and used to test the technical possibility of organizing ships' crews according to the matrix manning suggestions of, amongst others, Herbst (1974) and Smith and Roggema (1980a).

Section 5.1 uses the data to examine the assumption implicit in the works of Herbst and Smith & Roggema that all ships are fundamentally the same and may be crewed in a universal matrix format. The results indicate that all ships are not technically similar and further that there are three distinguishable technical classes. These three classes are:

1. tankers
2. tramps
3. liners.

These are also the three economic groupings of ship types identified by Gilman and Cox in chapter 4. This further stresses the link between the technical and economic environments which was described in chapter 2.

The results indicate that functional performance aboard the tankers is, of necessity, higher than aboard other ships. Further the results indicate that persons involved with the machinery or cargo sub-systems should receive extra training before transferring from tramps or liners to tankers. A corollary to these results is that the
system of competency testing of ships' crews is in need of reform and qualifications should be based upon:

1. Cargo type
2. Size of vessel.

Section 5.2 uses the data regarding the FREQUENCY, CRITICALITY & DIFFICULTY of performance of the functions identified in chapter 3 and enumerated in appendix 2. The results indicate that functions may be measured for their SIGNIFICANCE to the safe operation of the vessel. The measures of significance are seen to be separable into two groups of functions. The argument is made that functions at the higher level of significance may be assigned to a matrix-type primary role officer. Further, the functions of lower significance may be shared amongst other officers acting in their secondary roles according to matrix principles. The results of this section further support the emergence of tankers as a group of ships demanding higher functional performance.

Section 5.3 uses the observations regarding the interactions of function performers with DATA, THINGS & PEOPLE whilst performing the necessary ship functions. The results indicate that DATA handling is the most important interaction in all ship sub-systems. The results indicate that function performance may be measured in terms of the COMPLEXITY of the performers' interactions. The measures of complexity are seen to be separable into two groups of
functions. The argument is made that the highly complex functions may be assigned, in a matrix system, to a primary role operator. The less complex functions may be shared amongst other operators who are acting in their secondary role capacities. The results of this section further support the tankers as a separate group of ships but, as regards the quality of interactions, they are only seen to demand higher levels for performance of functions in the cargo and machinery sub-systems.
6. CONCLUSIONS

The conclusions to this thesis are presented in three sections. Section 6.1 draws together the results of the previous chapter and promotes a 'role assignment diagram' formed by plotting the measures of SIGNIFICANCE and COMPLEXITY on a graph. It is demonstrated that the majority of ship functions are neither significant nor complex and may form the basis of secondary roles. The remaining primary role areas are discussed and shown to support the matrix manning system proposed by Herbst and Moreby. In particular the skills allocation proposed by Herbst is seen to be sound and verifiable by the results of this research. Section 6.2 describes the findings of this research as they apply to the concept of matrix manning aboard ships. Section 6.3 describes the wider implications of the research results and the more general applicability of the developed research tool.
RESULTS OF COMBINED DATA

The results of the data regarding the FREQUENCY, CRITICALITY & DIFFICULTY of performing the various functions are described in section 5.2. These results show that it is possible to distinguish between two levels of performance aboard ship. It is claimed that the functions demanding the highest level of performance are the most SIGNIFICANT functions. It is argued that these functions may be assigned to operators as their primary role functions. The remaining functions are considered less significant and may be assigned to operators acting in their secondary role capacities. It is important to note that ratings of FREQUENCY, CRITICALITY & DIFFICULTY are all dependent on the ship and its cargo and are not dependent on the persons or equipment fulfilling the functions. The distribution of the SIGNIFICANCE numbers of all the ship sub-systems summed together is shown in figure 6.1.
6. CONCLUSIONS

NUMBER OF FUNCTIONS
70
69
68
66
64
62
60
58
56
54
52
50
48
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

SIGNIFICANCE

SIGNIFICANCE VALUES FOR ALL SHIP SYSTEMS

Figure 6.1
6. CONCLUSIONS

From this figure it is apparent that the majority of functions are towards the lower end of the significance scale and that there are few functions which are significant enough to warrant allocation to an operator as primary role functions.

The results of the observations regarding the interactions between the function performer and DATA, THINGS & PEOPLE are described in section 5.3. These results show that it is possible to distinguish between two levels of performance aboard ship. It is claimed that the functions demanding the highest level of performance are the most COMPLEX functions. It is argued that these functions may be assigned to operators as their primary role functions. The remaining functions are considered less complex and may be assigned to operators acting in their secondary role capacities. It is important to note that ratings of DATA, THINGS & PEOPLE are all dependent on the performance of the seafarer and in only two cases are influenced by the type of ship or cargo involved. The distribution of COMPLEXITY numbers for all ship sub-systems is given as figure 6.2
6. CONCLUSIONS

COMPLEXITY VALUES FOR ALL SHIP SYSTEMS

Figure 6.2
The argument produced here is that a function must be able to be represented on a diagram which has as its axes the SIGNIFICANCE and COMPLEXITY numbers. Any function must therefore be located in one of four quadrants as shown in figure 6.3.

![Figure 6.3](image)

This figure is termed the "ROLE ASSIGNMENT DIAGRAM" and may be used to assign functions to primary and secondary operators as follows:

**FUNCTION HIGHLY COMPLEX & SIGNIFICANT**

The functions in this quadrant are both SIGNIFICANT to the safe operation of the ship and are COMPLEX for the operator to perform. These functions therefore should be assigned to an operator as primary role functions. Collision avoidance is an example of a function which is...
located in this area. Collision avoidance is complex because it involves the knowledge and use of regulations and the knowledge and ability to manoeuvre a ship and it is significant because if not carried out correctly it could result in a catastrophe.

FUNCTION HIGHLY COMPLEX BUT LESS SIGNIFICANT

The functions in this quadrant while COMPLEX for the operator to perform are considered less SIGNIFICANT to the safe operation of the vessel. The training of junior operators is a function which is located in this quadrant. Training is, when undertaken properly, a complex and demanding task but does not appear to have any immediate effect on the safe operation of the vessel. It is possible that such functions are disregarded and not performed or, at best, are performed in a perfunctory manner. Functions in this sector may therefore be assigned to a specialist who has the necessary ability to handle the complexity of the operation but care should be taken to ensure that the function is actually performed and that the performance is satisfactory.

FUNCTION SIGNIFICANT BUT NOT COMPLEX

The functions in this quadrant while SIGNIFICANT to the safe operation of the vessel are not considered COMPLEX for the operator to perform. An example of such a function
is the maintenance of a bridge lookout. The function is not complex because it simply involves an operator remaining awake and reasonably alert. However it is extremely significant because if performed inadequately or not performed at all there is a likelihood that a ship could run aground or strike another ship or floating object. It may be considered that functions in this quadrant are assigned to operators as primary tasks due to their significance. However the lack of complexity may lead a primary operator to perform inadequately and apply his skills to more challenging functions. Alternatively it may be argued that these functions are assigned to operators as secondary role functions. In this case the operator may perceive the function as insignificant and not perform to the best of his abilities. It may be further argued that these functions should be the subject of a programme of automation in order to remove the 'human factors' of boredom, inattention and misperception. The author argues that no universal rule applies and that each function should be examined within the context of the ship type and sub-system to which it belongs and unique solutions applied. It is an important result of this research to have determined that there exists a group of functions whose role assignment is contentious. The analysis of functions in this quadrant requires examination in greater depth.
FUNCTION LESS SIGNIFICANT AND NOT COMPLEX

The functions which belong in this quadrant are considered less SIGNIFICANT to the safe operation of the ship and are not considered as COMPLEX for the operator to perform. It is argued therefore that these functions may be assigned to operators for performance while acting in their secondary role capacities. There are many examples of such functions. One example is the maintenance of standards of accommodation cleanliness. The function is not complex involving, as it does, comparing the cleanliness of the accommodation to the standard required and if an error exists then correcting it by the use of simple tools. If this function is not fulfilled however the result will cause no more than annoyance and will not materially affect ship safety.

The SIGNIFICANCE numbers and COMPLEXITY numbers calculated during this research are plotted on figure 6.4. This figure illustrates that the vast majority of functions (81%) are both insignificant and not complex. This means that they may be suitable for operators to perform in their secondary role capacities. The functions which emerge as both complex and significant are a minority (4%). Functions in this quadrant are from the navigation subsystem or the safety sub-system. This finding supports the traditional role of the master as senior navigator and
6. CONCLUSIONS

**ROLE ALLOCATION DIAGRAM**

**KEY TO SUB-SYSTEMS**
- N = Navigation
- C = Cargo
- E = Machinery
- H = Hotel & catering
- R = Communication
- M = Management & administration
- S = Safety & emergency
- X = Functions of low significance and complexity

**Figure 6.4**
6. CONCLUSIONS

commander of emergency situations. It appears that ultimate command of a ship may continue, in the future, to lie with an operator who has specialist navigation and safety subsystem skills. The functions which are rated as complex but insignificant amount to 7% of the total functions and are predominantly cargo and administrative functions. The quadrant which contains the functions which are significant but not complex involves 8% of the total functions and comprises predominantly navigational and machinery functions.

Herbst (1974, p.57) discussing future matrix manning systems suggested by Moreby arrives at an organization comprising composite roles based on certain skills being held by specialists. He entitles his specialists 'X', 'Y' and 'Z' and allocates the skills as follows:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>Navigation</td>
<td>Machine</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Computer use</td>
<td>Electronic</td>
</tr>
<tr>
<td>Cargo handling</td>
<td>Data handling</td>
<td>Electrical Communications</td>
</tr>
</tbody>
</table>

Based on figure 5.38 it is possible, as described above to select three definite specialist or primary areas.
6. CONCLUSIONS

These are:

1. Navigation and Safety & Emergency
2. Cargo and Management & Administration
3. Machinery.

Two other specialist skills emerge from figure 5.38. They are functions from the communication sub-system and functions from the hotel & catering sub-system. The functions of the communication system are similar qualitatively to those of the navigation system as described in section 5.3. The functions of the hotel & catering system are similar to those of the management and administration system, both involving high DATA and PEOPLE interactions. It therefore appears possible to support the composite roles of Herbst and Moreby and to redefine the skills of 'X', 'Y' and 'Z' as follows:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>Navigation</td>
<td>Machinery</td>
</tr>
<tr>
<td>Cargo</td>
<td>Safety &amp; Emergency</td>
<td></td>
</tr>
<tr>
<td>Hotel &amp; Catering</td>
<td>Communications</td>
<td></td>
</tr>
</tbody>
</table>

It is finally argued that the combination of results which rated the functions in terms of SIGNIFICANCE to safe ship operations and COMPLEXITY of interactions between functional operators and DATA, THINGS & PEOPLE yields the following points:
1. There are two distinguishable levels of performance aboard ships which may lead to the allocation of primary and secondary role functions.

2. Role allocation is assisted by the 'Role assignment diagram'. This diagram is seen as useful in determining functions where role allocation poses particular problems.

3. The possibility of assigning primary and secondary roles permits the possibility of organizing crews on a matrix principle as described by Herbst.

4. The suggested specialist skills clustering proposed by Herbst and Moreby is seen to be consistent with the results of this research.
6. CONCLUSIONS

6.2 CONCLUSIONS ON MATRIX MANNING

This thesis examines the environments influencing the shipping industry. As a result of this examination it is suggested that in order to survive in a hostile economic environment, volatile technical environment, advancing social environment, and controlling legal environment the organization of manpower aboard ships must change. From the extensive literature available regarding the social structure of ships' crews, the concept of matrix manning emerges as a possible solution to the environmentally induced problem. The work of Herbst (1974) and Smith & Roggema (1980) in particular are drawn upon as they describe in detail their concepts of matrix manning structures.

It is shown in chapter 2 how, to be effective, any innovative manning structure must represent improvements in five areas:

1. Crew stability
2. Allocation of tasks between ship and shore
3. Improvement in work planning
4. Improvement in job content of ratings
5. Development of shipboard training.

The work of Herbst (1974) and Smith & Roggema (1979a&b, 1980a&b) present the detailed arguments for matrix manning leading to improvements in these five areas. However all previous authors have assumed that all ships
are technically similar and may be crewed in a general matrix format. This thesis examines the technical and operational aspects of ten ships in order to determine if matrix manning is viable.

The ships are seen to separate into three distinct groups depending upon the risks which they pose to human life, the physical environment and the finance system. The functions performed aboard these three groups of ships are then examined to determine if it is possible to allocate primary and secondary role functions to ships' officers according to the matrix manning principle. It is shown how, using measures of SIGNIFICANCE and COMPLEXITY, it is possible to separate the functions into those requiring performance by a primary role officer and those which may be allocated to an officer acting in his secondary role capacity. It is further shown that by using a 'role allocation diagram' it is possible to cluster the functions in a coherent and unique manner to meet the requirements of a particular ship.

This thesis therefore examines the complex link between crew and ship, both operating in dynamic and hostile environments, to determine the technical and operational validity of matrix manning. It is argued that, after a thorough examination of the functions observed to be performed aboard the sample ships, it is possible to reorganize ships' crews on matrix manning principles.
CONCLUSIONS REGARDING GENERAL APPLICABILITY

The research culminating in this thesis concentrates on the British merchant fleet. However there is no reason why any industrial system should not benefit from manpower analysis as developed and described in chapter 3. In particular the production of a 'role allocation diagram' enables a manpower planner to detect and isolate functions which need specialist attention. Even more importantly those functions which may pose problems due to their requiring low complexity skills but whose incompetent performance may lead to catastrophe may be detected and coped with.

The role allocation diagram is seen to have a deeper conceptual significance. In the literature review, chapter 2, it is shown that many authors have detected and described decision bands (Paterson), functional levels (Rasmussen), time span criteria (Jacques). Each of these is examined and is shown to be consistent with present ship manning levels. However each of these describes a one dimensional, linear progression from 'unskilled' to 'managing director'. Examination of the role allocation diagram displays each of these previous scales as incomplete. Worker positions are now seen as two dimensional involving:

1. THE WORK DIMENSION. This involves measuring the SIGNIFICANCE of the functions performed. Are they frequent,
critical to the total operation, do they require experience or specialized knowledge?

2. THE WORKER DIMENSION. This involves examining the functions to determine the COMPLEXITY of skills required of an operator.

This means that the role allocation diagram may now be redrawn in an abstract form to illustrate the different levels of PERFORMANCE required in order to operate any system. Figure 6.5 illustrates the following points:

1. Authors such as Singleton (1978) examine the skills of workers in a manner which concentrating on the COMPLEXITY of PERFORMANCE. A 'manager' is seen to have high DATA levels together with high PEOPLE interactions producing a high COMPLEXITY job.

2. Authors such as Rasmussen (1985) regard the SIGNIFICANCE of PERFORMANCE of functions to the whole system operation. A 'manager' is seen to control critical operations which require a large amount system knowledge.

3. Paterson's progression takes into consideration both COMPLEXITY of functions and their SIGNIFICANCE to the system as a whole. However, implicit in Paterson's scale is linearity of progression from 'unskilled' to 'chairman'.

4. Each of the above linear progressions assumes a hierarchy of positions.
6. CONCLUSIONS

Purposeful SIGNIFICANCE (Depends on work) (vork)

Increasing significance of performance to total system

Increasing performance and levels of decision

MANY IMPORTANT DECISIONS

CHAIRMAN

PATERSON

SUPERVISOR

FEW DECISIONS

Increasing complexity of operator performance

Physical UNSKILLED

SINGLETON

SKILLED

COMPLEXITY (Depends on worker)

Figure 6.5
The proposition promoted as a result of this thesis is that PERFORMANCE may be seen to increase in an industrial manpower system as represented in figure 6.6.
This figure shows that an initial entrant to an industrial system is untrained and unskilled. Progression is made towards fulfilling a variety of 'secondary roles'. Advancement to primary role function fulfillment is a combination of both the ability to accommodate the COMPLEXITY of higher functions plus the acceptance of the SIGNIFICANCE of such functions. There exist divergent advancements which may variously appeal to different individual performers. Increased performance, and what Fine et al. (1974b) refer to as 'worker growth', may be achieved by operators concentrating on functions which while not immediately significant to the total system nevertheless require complex performance. Alternatively advancement may be achieved by performing functions which are significant to the total system but which do not demand complex skills.

One result of this approach is that the rigid hierarchies of industry may be abolished. Their replacement may be by work groups consisting of a primary operator assisted by secondary role operators capable of accomplishing functions across the entire two dimensional workspace of the performance diagram.

AREAS FOR FURTHER RESEARCH

This thesis demonstrates the technical and operational possibility of implementing matrix manning aboard British merchant vessels. In order fully to examine the potential of such a manning system the social
implications described in the literature review, chapter 2, need to be researched. Observations aboard small tramp ships engaged in the coastal trades have shown that manning systems proximate to matrix manning are emerging. These ships may provide a fertile ground for social research into the concept of matrix manning.

It is felt by the author that the conceptual framework of the performance diagram deserves further research effort to produce a cohesive functional skills theory. In order to pursue this paradigm it may be necessary to examine complexity and significance of functions in several diverse industrial units.

Finally the wealth of data accumulated during the research programme may be usefully employed to pursue research into many aspects of the shipping industry. Data exist for results to be extracted regarding:

1. the training of seafarers. For example, functions which are performed frequently and whose criticality is low may be learned aboard. However functions which are extremely critical and not frequently performed may best be learned by simulator training away from the ship.

2. the qualifications of seafarers. As described in earlier chapters, this research produces arguments in favour of reviewing the qualification system for seafarers. Assessment of competent performance of the highly critical functions may be the prerogative of governmental
6. CONCLUSIONS

Authorities. Less critical functions may be assessed by educational or professional bodies. Low criticality functions may even be assessed by officers on board.

3. the effects of new technology on seafarers. The interaction levels of the function performers with DATA, THINGS & PEOPLE may vary over time with the introduction of new technology. Functions which are currently manual in nature may be automated and become data handling tasks. Many engine monitoring tasks have changed in this manner. An engineer would previously have walked around the engine room using all his senses, whereas now he sits in a control room and monitors an alarm panel. PEOPLE based functions may be expected to alter dramatically with the advent of smaller crews and increased automation.

4. a core element of skills and knowledge for seafarers. Certain functions are performed so frequently and are so low in criticality that they may form a core of skills which all seafarers should possess and be able to perform in their secondary role capacity. These may include such functions as routine housekeeping and food preparation. Also, certain functions are so critical and so infrequently performed that they should be part of a core of skills of all seafarers. These may include such functions as firefighting and abandoning ship. Functions which are both frequently performed and are highly critical are specialist functions and may not form a part of core skills.
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APPENDIX ONE

DEFINITIONS

DATA

Information, knowledge, and conceptions related to data, people or things resulting from observation, investigation, interpretation, visualization, and mental creation. Data are intangible and include numbers, words, symbols, ideas, concepts, and oral verbalization.

1. COMPARING

Selects, sorts, or arranges data, people or things, judging whether their readily observable functional, structural, or compositional characteristics are similar to or different from prescribed standards.

2. COPYING

Transcribes, enters, and/or posts data, following a schema or plan to assemble or make things and using a variety of work aids.

3. COMPUTING

Performs arithmetic operations and makes reports and/or carries out a prescribed action in relation to them.
4. COMPILING

Gathers, collates, or classifies information about data, people, or things, following a schema or system but using discretion in application.

5. ANALYZING

Examines and evaluates data (about things, data, or people) with reference to the criteria, standards, and/or requirements of a particular discipline, art, technique, or craft to determine interaction effects (consequences) and to consider alternatives.

6. INNOVATING

Modifies, alters, and/or adapts existing designs, procedures or methods to meet unique specifications, unusual conditions, or specific standards of effectiveness within the overall framework of operating theories, principles, and/or organizational contexts.

7. COORDINATING

Decides time, place, and sequence of operations of a process, system, or organization, and/or the need for revision of goals, policies (boundary conditions), or procedures on the basis of analysis of data and of performance review of pertinent objectives and requirements. Includes overseeing and/or executing decisions and/or reporting on events.
8. SYNTHESIZING

Conceives new approaches to, or statements of, problems and the development of system, operational, or aesthetic "solutions" or "resolutions" of them, typically outside of existing theoretical, stylistic, or organizational context.

THINGS

Inanimate objects as distinguished from human beings; substances or materials, machines, tools, equipment, and products. A thing is tangible and has shape, form, and other physical characteristics.

1. HANDLING

Uses body members, handtools, and/or special devices to work, move, or carry objects or materials. Involves little or no latitude for judgement with regard to attainment of standards or in selecting appropriate tool, object, or material.

2. FEEDING/OFF-BEARING

Inserts, throws, dumps, or places materials in or removes them from machines or equipment which are automatic or tended or operated by other workers.
3. TENDING

Starts, stops and observes the functioning of machines and equipment. Involves adjusting materials or controls of the machine, such as changing guides, adjusting timers and temperature gauges, turning valves to allow flow of materials, and flipping switches in response to lights. Little judgement is involved in making these adjustments.

4. MANIPULATING

Uses body members, tools, or special devices to work, move, guide, or place objects or materials. Involves some latitude for judgement with regard to precision attained and selecting appropriate tool, object, or material, although this is readily manifest.

5. DRIVING/OPERATING

Starts, stops, and controls the actions of machines or equipment for which a course must be steered, or which must be guided, in order to fabricate, process, and/or move things or people.
6. OPERATING/CONTROLLING

Starts, stops, controls, and adjusts the progress of a machine or equipment. Operating involves setting up and adjusting the machine or material(s) as the work progresses. Controlling involves observing gauges, dials, etc. and turning valves and other devices to regulate factors such as temperature, pressure, flow of liquids, speed of pumps, and reaction of materials.

7. PRECISION WORKING

Uses body members and/or tools or work aids to work, move, guide, or place objects or materials in situations where ultimate responsibility for the attainment of standards occurs and selection of appropriate tools, objects, or materials, and the adjustment of the tool to the task require exercise of considerable judgement.

8. SETTING UP

Adjusts machines or equipment by replacing or altering tools, jigs, fixtures, and attachments to prepare them to perform their functions, change their performance, or restore their proper functioning if they break down. Workers who set up one or a number of machines for other workers or who set up and personally operate a variety of machines are included here.
PEOPLE

1. TAKING INSTRUCTIONS/ HELPING/ SERVING

Attending to the work assignment instructions or orders of a supervisor. Attending to the needs, requests and implicit wishes of people.

2. EXCHANGING INFORMATION

Talking with and/or signalling people to convey or exchange information. Includes giving assignments and/or directions to helpers or assistants.

3. PERSUADING

Influencing others in favour of a product, service or point of view.

4. DIVERTING

Amusing others. (Usually accomplished through the medium of stage, screen, television or radio.)

5. SUPERVISING

Determining or interpreting work procedures for a group of workers, assigning specific duties to them, maintaining harmonious relations among them, and promoting efficiency.

6. INSTRUCTING

Teaching subject matter to others, or training others through explanation, demonstration, and supervised practice; or making recommendations on the basis of technical disciplines.
7. NEGOTIATING

Exchanging ideas, information, and opinions with others to formulate policies and programmes and/or arrive jointly at decisions, conclusions, or solutions.

8. MENTORING

Dealing with individuals in terms of their total personality in order to advise, counsel, and/or guide them with regard to problems that may be resolved by legal, scientific, clinical, spiritual, and/or other professional principles.
APPENDIX TWO

NAVIGATIONAL FUNCTIONS

1000 NAVIGATION SYSTEM
To safely and effectively use navigation techniques and equipment in order to conduct the vessel safely from berth to berth.

1100 PASSAGE PLANNING SUB-SYSTEM
To perform passage planning functions in order to pre-determine route of the ship and convey the information to others.

PASSAGE PLANNING FUNCTIONS
1110 Selects the optimum route, in outline, to determine information required.
1120 Collates route information to determine predictable constraints for selected route.
1130 Uses acquired information to determine details of the selected route, and possible alternatives.
1140 Records details in an appropriate systematic form to convey information to others.
1150 Stores route information to facilitate future use.
1160 Effects the learning to acquire the necessary knowledge and skills to perform passage planning functions.

1200 PASSAGE EXECUTION SUB-SYSTEM
To perform passage execution functions during the period from FAOP to EOP.
PASSAGE EXECUTION FUNCTIONS

1210 Allocates manpower to ensure necessary functions are achieved having cognisance of legislation and recommendations.

1220 Distributes available manpower resources to enable function achievement.

1230 Determines vessel position to enable comparison between actual and desired positions.

1235 Exercises responsibility for controlling the direction and speed of the vessel.

1240 Operates steering equipment to control the direction of the vessel's movement.

1250 Understands and complies with International Regulations for the Prevention of Collisions at Sea to ensure collisions do not occur.

1260 Collects data on external factors which may affect ship in order to promote a safe and expeditious passage.

1270 Stores passage information to enable potential future use.

1280 Effects the learning to acquire the necessary knowledge and skills to perform passage execution functions.
APPENDIX 2

1300 PILOTAGE SUB-SYSTEM
To perform pilotage functions during the period from EOP. to FAOP.

PILOTAGE FUNCTIONS

1310 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

1320 Exercises responsibility to control the direction and speed of the vessel.

1330 Determines vessel position to enable comparison between actual and desired positions.

1340 Operates steering equipment to control the direction of vessel movement.

1350 Complies with International Regulations for the prevention of collisions at sea do ensure that collisions do not occur.

1360 Collects data on external factors which may affect ship in order to promote a safe and expeditious passage.

1370 Prepares mooring equipment to expedite the process of berthing/unberthing.

1380 Stores pilotage information to facilitate future use.

1390 Effects the learning to acquire the necessary knowledge and skills to perform pilotage functions.
1400 **BERTHING/UNBERTHING SUB-SYSTEM**

To perform the functions of securing to, or letting go from, a shore structure or anchorage.

**BERTHING/UNBERTHING FUNCTIONS**

1410 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

1420 Exercise responsibility to control the position, direction and speed of the vessel.

1430 Deploys and utilises mooring equipment to secure the vessel.

1440 Recovers and utilises mooring equipment to let go the vessel.

1450 Deploys, uses and recovers anchors to facilitate mooring and ship handling.

1460 Stores mooring information to facilitate future use.

1470 Effects the learning to acquire the necessary knowledge and skills to perform the berthing or unberthing function.

1500 **NAVIGATION EQUIPMENT MAINTENANCE SUB-SYSTEM**

The process of ensuring that the navigational equipment is functional when required.
NAVIGATION EQUIPMENT MAINTENANCE FUNCTIONS

1510 Examines navigational equipment to determine its condition and rectify potential faults so that the equipment is functional and effective when required.

1520 Rectifies breakdown to return equipment to a functional and effective state.

1530 Stores maintenance information to facilitate future use.

1540 Effects the learning to acquire the necessary knowledge and skills to perform the maintenance function.
CARGO FUNCTIONS

2000 CARGO OPERATIONS SYSTEM
The safe and expeditious handling of cargo, using the cargo and ballast systems.

2100 CARGO PREPARATION SUB-SYSTEM
To ensure vessel is ready and safe to transport specified cargo.

CARGO PREPARATION FUNCTIONS

2110 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

2112 Identifies standards to be achieved and constraints to be observed to plan necessary preparation.

2130 Carries out the necessary tasks to achieve the previously determined standards.

2140 Compares actual and desired states of cargo system to confirm that the process of preparation is satisfactory.

2150 Determines quantity and distribution of cargo to keep within the constraints of commerce and safety.

2160 Stores cargo preparation information to facilitate future use.
APPENDIX 2

2170 Effects the learning to acquire the necessary knowledge and skills to perform the cargo preparation functions.

2200 CARGO LOADING SUB-SYSTEM

To effect the safe and efficient loading of the ship.

CARGO LOADING FUNCTIONS

2210 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

2200 Communicates with the shore to expedite the transfer of cargo.

2230Links ship/shore cargo sub-systems to prepare for cargo transfer.

2240 Transfers cargo to load ship.

2250 Compares actual and desired states of ship condition and cargo transfer to confirm that the loading process is within specified constraints and parameters.

2255 Exercises responsibility for restorative decision and action.

2260 Determines when loading completed for that port and shuts down ship's cargo system to complete loading.

2270 Stores cargo loading information to facilitate future use.

2280 Effects the learning to acquire the necessary
knowledge and skills to perform the cargo preparation functions.

2300 CARGO CARRIAGE SUB-SYSTEM
To effect the safe and efficient conveyance of cargo from berth to berth.

CARGO CARRIAGE FUNCTIONS

2310 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

2320 Identifies standards to be achieved and constraints to be observed to effect safe and economical carriage of cargo.

2325 Exercises responsibility for implementing restorative action with regard to cargo condition.

2330 Compares actual and desired states of cargo condition to confirm the maintenance of quality control and safety requirements.

2340 Compares actual and desired states of cargo environment to confirm that the environment is contained within the desired parameters.

2345 Exercises responsibility for implementing restorative action with regard to cargo environment.

2350 Maintains cargo within stated physical parameters to ensure quality control and safety requirements.

2370 Stores cargo and environment information to
facilitate future use.

2380 Effects the learning to acquire the necessary knowledge and skills to perform the cargo carriage functions.

2400 CARGO DISCHARGE SUB-SYSTEM

To effect the safe and efficient discharging of the ship.

CARGO DISCHARGE FUNCTIONS

2410 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

2420 Communicates with the shore to expedite the transfer of cargo.

2430 Links ship/shore cargo sub-systems to prepare for cargo transfer.

2440 Transfers cargo to discharge ship.

2450 Compares actual and desired states of ship condition and cargo transfer to confirm that the discharge process is within specified constraints and parameters.

2455 Exercises responsibility for restorative decisions and action.

2460 Determines when discharge completed for that port and shuts down ship's cargo system to complete discharging.
APPENDIX 2

2470 Stores discharging information to facilitate future use.

2480 Effects the learning to acquire the necessary knowledge and skills to perform the cargo discharge functions.

2550 BALLAST OPERATIONS SUB-SYSTEMS

The movement of ballast to, from and within the ship to satisfy requirements of ship condition.

BALLAST FUNCTIONS

2510 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

2515 Predetermine ballast requirements.

2520 Loads ballast into the ship to satisfy predetermined requirements.

2530 Discharges ballast from the ship to satisfy predetermined requirements.

2540 Moves ballast within the ship to satisfy predetermined requirements.

2550 Compares actual and desired states of ballast sub-system to confirm that the ballast operations and ship's condition are within desired parameters.

2555 Exercises responsibility for restorative decisions and action.

2560 Stores ballast information to facilitate future use.
2570 Effects the learning to acquire the necessary knowledge and skills to perform the ballast functions.

2600 CARGO/BALLAST MAINTENANCE SUB-SYSTEM

The process of ensuring that the cargo/ballast systems are in a functional condition when required.

CARGO/BALLAST MAINTENANCE FUNCTIONS

2610 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

2620 Examines cargo/ballast equipment to determine condition and to rectify potential faults so that the equipment is functional and effective when required.

2630 Rectifies breakdowns to return equipment to a functional and effective state.

2640 Stores maintenance information to facilitate future use.

2650 Effects the learning to acquire the necessary knowledge and skills to perform the maintenance functions.
MACHINERY FUNCTIONS

3000 MACHINERY SYSTEM

The safe and efficient use of the ship's machinery.

3100 HULL & PROPULSION SUB-SYSTEM

The safe and efficient operation and maintenance of the vessel's hull and propulsion machinery to function commercially.

HULL & PROPULSION FUNCTIONS

3101 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

3102 Performs equipment dependent tasks to prepare/test relevant machinery.

3103 Compares the actual and desired conditions of a machinery sub-system to confirm that the process of preparation is satisfactory.

3104 Stores the details of preparation to facilitate future use.

3105 Effects the learning to acquire the necessary knowledge and skills to perform the preparation/testing function.

3106 Performs equipment dependent tasks to run up/shut down relevant machinery.
APPENDIX 2

3107 Compares the actual and desired conditions of a machinery sub-system to confirm that the process of run up/shut down is satisfactory.

3108 Stores the details of run up/shut down to facilitate future use.

3109 Effects the learning to acquire the necessary knowledge and skills to perform the run up/shut down function.

3110 Performs equipment dependent tasks to achieve steady running of relevant machinery.

3111 Compares the actual and desired conditions of machinery to confirm that the process of steady running is satisfactory.

3112 Stores the details of steady running to facilitate future use.

3113 Effects the learning to acquire the necessary knowledge and skills to perform the steady running function.

3114 Determines when maintenance tasks should be carried out, within the maintenance schedule, to ensure downtime has minimum adverse effect on vessel operation.

3115 Executes planned maintenance tasks to determine machinery condition and rectify potential faults so that the machinery is functional and effective when required.
3116 Stores the details of proactive maintenance to facilitate future use.

3117 Effects the learning to acquire the necessary knowledge and skills to perform the proactive maintenance function.

3118 Identifies fault to determine maintenance tasks required.

3119 Executes maintenance tasks to return machinery to a functional and effective state.

3120 Compares the actual and desired conditions of machinery to confirm that the maintenance tasks have been satisfactorily achieved.

3121 Stores the details of reactive maintenance to facilitate future use.

3122 Effects the learning to acquire the necessary knowledge and skills to perform the reactive maintenance function.

3200 CARGO OPERATION & DECK MACHINERY SUB-SYSTEM

The safe and efficient operation of cargo and deck machinery.

CARGO OPERATION & DECK MACHINERY FUNCTIONS

3201 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

3202 Performs equipment dependent tasks to prepare/test
relevant machinery.

3203 Compares the actual and desired conditions of a machinery sub-system to confirm that the process of preparation is satisfactory.

3204 Stores the details of preparation to facilitate future use.

3205 Effects the learning to acquire the necessary knowledge and skills to perform the preparation/testing function.

3206 Performs equipment dependent tasks to run up/shut down relevant machinery.

3207 Compares the actual and desired conditions of a machinery sub-system to confirm that the process of run up/shut down is satisfactory.

3208 Stores the details of run up/shut down to facilitate future use.

3209 Effects the learning to acquire the necessary knowledge and skills to perform the run up/shut down function.

3210 Performs equipment dependent tasks to achieve steady running of relevant machinery.

3211 Compares the actual and desired conditions of machinery to confirm that the process of steady running is satisfactory.

3212 Stores the details of steady running to facilitate future use.
3213 Effects the learning to acquire the necessary knowledge and skills to perform the steady running function.

3214 Determines when maintenance tasks should be carried out, within the maintenance schedule, to ensure downtime has minimum adverse effect on vessel operation.

3215 EXECUTES PLANNED MAINTENANCE TASKS TO DETERMINE MACHINERY CONDITION AND RECTIFY POTENTIAL FAULTS SO THAT THE MACHINERY IS FUNCTIONAL AND EFFECTIVE WHEN REQUIRED.

3216 Stores the details of proactive maintenance to facilitate future use.

3217 Effects the learning to acquire the necessary knowledge and skills to perform the proactive maintenance function.

3218 Identifies fault to determine maintenance tasks required.

3219 Executes maintenance tasks to return machinery to a functional and effective state.

3220 Compares the actual and desired conditions of machinery to confirm that the maintenance tasks have been satisfactorily achieved.

3221 Stores the details of reactive maintenance to facilitate future use.
3222 Effects the learning to acquire the necessary knowledge and skills to perform the reactive maintenance function.

3300 SERVICES SUB-SYSTEM
The safe and efficient operation of the ship's service machinery.

SERVICE FUNCTIONS
3301 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

3302 Performs equipment dependent tasks to prepare/test relevant machinery.

3303 Compares the actual and desired conditions of a machinery sub-system to confirm that the process of preparation is satisfactory.

3304 Stores the details of preparation to facilitate future use.

3305 Effects the learning to acquire the necessary knowledge and skills to perform the preparation/testing function.

3306 Performs equipment dependent tasks to run up/shut down relevant machinery.

3307 Compares the actual and desired conditions of a machinery sub-system to confirm that the process of run up/shut down is satisfactory.
APPENDIX 2

3308 Stores the details of run up/shut down to facilitate future use.

3309 Effects the learning to acquire the necessary knowledge and skills to perform the run up/shut down function.

3310 Performs equipment dependent tasks to achieve steady running of relevant machinery.

3311 Compares the actual and desired conditions of machinery to confirm that the process of steady running is satisfactory.

3312 Stores the details of steady running to facilitate future use.

3313 Effects the learning to acquire the necessary knowledge and skills to perform the steady running function.

3314 Determines when maintenance tasks should be carried out, within the maintenance schedule, to ensure downtime has minimum adverse effect on vessel operation.

3315 Executes planned maintenance tasks to determine machinery condition and rectify potential faults so that the machinery is functional and effective when required.

3316 Stores the details of proactive maintenance to facilitate future use.

3317 Effects the learning to acquire the necessary
knowledge and skills to perform the proactive maintenance function.

3318 Identifies fault to determine maintenance tasks required.

3319 Executes maintenance tasks to return machinery to a functional and effective state.

3320 Compares the actual and desired conditions of machinery to confirm that the maintenance tasks have been satisfactorily achieved.

3321 Stores the details of reactive maintenance to facilitate future use.

3322 Effects the learning to acquire the necessary knowledge and skills to perform the reactive maintenance function.
HOTEL FUNCTIONS

4000 HOTEL SERVICES SYSTEM
Provides catering and accommodation facilities to satisfy the domestic needs of those on board within prescribed constraints.

4100 CATERING SUB-SYSTEM
To provide food and drink for those on board.
4110 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.
4120 Plans menus to provide a varied and nutritious diet.
4130 Orders and purchases consumables to satisfy the domestic requirements.
4140 Loads, keeps and controls the stock of consumables in a desired condition to satisfy domestic requirements.
4150 Prepares food and drink to satisfy menu requirements.
4160 Assembles prepared consumables to make them available to consumers.
4170 Stores catering information to facilitate future use.
4180 Effects the learning to acquire the necessary knowledge and skills to perform the catering functions.
APPENDIX 2

4200 HOUSEKEEPING SUB-SYSTEM
Maintains domestic fabric and furnishings to satisfy the needs of those on board.

HOUSEKEEPING FUNCTIONS
4210 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.
4220 Cleans domestic spaces to maintain a hygienic condition.
4230 Manages linen stocks to satisfy domestic needs of those on board.
4240 Stores housekeeping information to facilitate future use.
4250 Effects the learning to acquire the necessary knowledge and skills to perform the housekeeping functions.

4300 HOTEL SYSTEM EQUIPMENT MAINTENANCE
The process of ensuring that the catering and housekeeping equipment is in a functional condition.

HOTEL EQUIPMENT MAINTENANCE FUNCTIONS
4310 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.
4320 Repairs, cleans and maintains appliances to ensure
availability for use when required.

4330 Stores maintenance information to facilitate future use.

4340 Effects the learning to acquire the necessary knowledge and skills to perform the maintenance functions.
COMMUNICATIONS FUNCTIONS

5000 COMMUNICATION SYSTEM
To transfer data in order to facilitate the operation of the vessel.

5100 EXTRASHIP COMMUNICATION SUB-SYSTEM
To transfer data between the ship and its environment.

EXTRASHIP COMMUNICATION FUNCTIONS

5110 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

5120 Selects communication method to optimise the data transfer.

5130 Operates communication equipment to transfer data.

5140 Stores extraship communication information to facilitate future use.

5150 Effects the learning to acquire the necessary knowledge and skills to perform the extraship communication functions.

5200 INTRASHIP COMMUNICATION SUB-SYSTEM
To transfer data within the ship.
INTRASHIP COMMUNICATION FUNCTIONS

5210 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

5220 Selects communication method to optimise data transfer.

5230 Operates communication equipment to transfer data.

5240 Stores intraship communication information to facilitate future use.

5250 Effects the learning to acquire the necessary knowledge and skills to perform the intraship communication functions.

5300 COMMUNICATION EQUIPMENT MAINTENANCE SUB-SYSTEM

The process of ensuring that the communications equipment is in a functional condition when required.

COMMUNICATION EQUIPMENT MAINTENANCE FUNCTIONS

5310 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

5320 Examines communication equipment to determine its condition and rectify potential faults so that the equipment is functional and effective when required.

5330 Rectifies breakdowns to return equipment to its functional and effective state.
5340 Stores maintenance information to facilitate future use.

5350 Effects the learning to acquire the necessary knowledge and skills to perform the maintenance functions.
MANAGEMENT & ADMINISTRATION SYSTEM

6000 MANAGEMENT & ADMINISTRATION SYSTEM
The performance of management and administration functions to facilitate the operation of the vessel.

6100 PERSONNEL SUB-SYSTEM
Provides ship's staff and support services to enable vessel to operate within specified constraints.

PERSONNEL FUNCTIONS

6110 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

6120 Provides staff with appropriate skills, knowledge and qualifications to operate the vessel.

6130 Ensures provision of welfare factors to satisfy the requirements of staff on board.

6135 Ensures provision of health and safety factors to satisfy the requirements of staff on board.

6136 Ensures provision of motivation factors to satisfy the requirements of those on board.

6140 Execute personnel appraisal functions in accordance with management requirements.
APPENDIX 2

6150 Stores management and administration information to facilitate future use.

6160 Effects the learning to acquire the necessary knowledge and skills to perform the management and administration functions.

6200 CONSUMABLES & SPARES SUB-SYSTEM
Provision of consumables and spares to enable vessel to operate within specified constraints.

CONSUMABLES & SPARES FUNCTIONS

6210 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

6220 Monitors quantity and use of stores and consumables to ensure an adequate provision.

6230 Orders stores and consumables to maintain a minimum stock level.

6240 Keeps stores and consumables to ensure quality is not impaired and they are ready for use.

6250 Stores consumables and spares information to facilitate future use.

6260 Effects the learning to acquire the necessary knowledge and skills to perform the consumables and spares functions.

6300 FINANCIAL SUB-SYSTEM
Execution of budgetary and accounting functions.
FINANCIAL FUNCTIONS

6310 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

6320 Identification of cost centres in order to exercise financial planning and control.

6330 Execute budgetary control techniques in order to stay within defined financial constraints.

6340 Execute cash accounting and control techniques in order to monitor cash flow.

6350 Stores financial information to facilitate future use.

6360 Effects the learning to acquire the necessary knowledge and skills to perform the financial functions.

6400 NATIONAL & INTERNATIONAL LEGAL SUB-SYSTEM

Enables vessel to operate within legislative parameters.

LEGAL FUNCTIONS

6410 Identifies legislative controls and statutory duties to ensure compliance with national and international requirements.

6420 Uses knowledge of commercial shipping practice to protect the interests of the contracting parties.

6430 Uses knowledge of fault liability to ensure compliance...
with civil law.

6440 Maintains, compiles and distributes statutory documents to facilitate vessel operations.

6450 Maintains, compiles and distributes company documents to satisfy company requirements.

6460 Maintains, compiles and distributes commercial documents to facilitate vessel operations.

6470 Stores legal documentation to facilitate future use.

6480 Effects the learning to acquire the necessary knowledge and skills to perform the legal functions.

6500 ORGANIZATION MANAGEMENT SUB-SYSTEM

Implementation of management techniques to promote safe and efficient operation of the vessel.

ORGANIZATION MANAGEMENT FUNCTIONS

6510 Recognizes company organizational structure to aid the achievement of company objectives.

6520 Decentralises objectives and the authority to enable achievement of those objectives.

6530 Ensures adequate information flow throughout the organization to assist the achievement of organizational objectives.

6540 Recognises the distribution of accountability for performance of the functions and duties of the ship system.

6550 Stores organizational management information to facilitate future use.
Effects the learning to acquire the necessary knowledge and skills to perform the organizational management functions.
SAFETY FUNCTIONS

7000 SAFETY SYSTEM
The proper and effective use of all shipboard equipment to ensure the safety and well-being of the ship and its personnel.

7100 WORKING PRACTICES SUB-SYSTEM
The encouragement of safe working practices aboard to promote the safety and well-being of personnel and to ensure compliance with current legislation.

WORKING PRACTICE FUNCTIONS
7110 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.
7120 Compares actual and desired conditions of spaces, equipment and working practices to prevent accidents.
7125 Identify and implement appropriate corrective action in the event of a mismatch of the above conditions.
7130 Receives and disseminates information to promote safety awareness and to prevent accidents.
7140 Promotes safe working practices to prevent accidents.
7150 Stores working practice information to facilitate future use.
APPENDIX 2

7160 Effects the learning to acquire the necessary knowledge and skills to perform the working practices function.

7200 SEA SURVIVAL SUB-SYSTEM
Use of techniques and equipment to ensure survival of personnel who have, or intend to, abandon own, or another, vessel.

SEA SURVIVAL FUNCTIONS

7210 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

7220 Practices using techniques and equipment available for use in abandonment situation to optimise the chances of survival.

7230 Examines sea survival equipment to determine its condition and rectify potential faults so that the equipment is functional when required.

7240 Stores sea survival information to facilitate future use.

7300 FIRE PREVENTION/FIGHTING SUB-SYSTEM
Use of techniques and equipment to prevent shipboard fires and to facilitate extinguishing of any fires which may occur.
FIRE PREVENTION/FIGHTING FUNCTIONS

7310 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

7320 Ensures personnel are aware of techniques and equipment to prevent fires.

7325 Ensures personnel are aware of techniques and equipment to fight fires.

7330 Examines fire prevention/fighting equipment to determine its condition and rectify potential faults so that the equipment is functional when required.

7340 Stores fire prevention/fighting information to facilitate future use.

7400 MEDICAL EQUIPMENT SUB SYSTEM

Equipping the ship with the necessary techniques and equipment to provide the capability of handling the immediate medical needs of the ship's personnel.

MEDICAL FUNCTIONS

7410 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

7420 Informs personnel aboard about medical hazards to maintain their good health.

7430 Effects the learning to acquire the necessary
knowledge and skills to perform the medical functions.

7440 Examines medical equipment, and stores, to determine their condition and rectify potential faults so that the equipment is functional when required.

7450 Stores medical information to facilitate future use.

7500 **EMERGENCY PROCEDURE SUB-SYSTEM**

Dealing with emergencies, not otherwise specified, to minimise effects and return to a safe condition.

**EMERGENCY PROCEDURE FUNCTIONS**

7510 Allocates and distributes available manpower to ensure necessary functions are achieved having cognisance of necessary legislation and recommendations.

7520 Determines nature of the emergency to implement corrective action.

7530 Applies knowledge and skills to deal with an emergency or unusual situation.

7540 Compares actual and desired conditions of vessel to determine if corrective action is effective.

7550 Stores emergency procedure information to facilitate future use.

7560 Effects the learning to acquire the necessary knowledge and skills to perform the emergency procedure functions.
## APPENDIX THREE

### RESEARCH VOYAGES

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<thead>
<tr>
<th>SHIP TYPE</th>
<th>SHIP NAME</th>
<th>SHIPPING COMPANY</th>
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<td>ROWBOTHAMS</td>
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<td>LAWRENCE</td>
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