THESIS FOR THE DEGREE OF DOCTOR OF TECHNOLOGY

A Life on the Ocean Wave

Exploring the interaction between the crew and their adaption to the development of the work situation on board Swedish merchant ships

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ABSTRACT

Working on board merchant ships implies being a part of an isolated context in a multi-cultural arena and spending a lot of time away from family and friends. The shipping industry has during the latest decades undergone major changes due to technical development, automation and increased requirements for profitability and competitiveness. The consequences of these changes have been reduced manning on board, changes in task performance and new tasks to perform. The overall aim of this thesis was to investigate the interplay between the ship, the technological system on board and the human system in order to understand how the developments in the shipping industry during the latest decades has affected the working conditions and well being of the sea farers and in particular the engine officers.

The results given in this thesis indicate that the engine crew has to adapt to the suboptimal prerequisites given by the technical and hull system in order to be able to perform their tasks as the prevailing knowledge in ergonomics is not being fully utilized in the design of the engine department. The consequences are less favourable behaviours which enhance the risk of injuries and enforce less effective accomplishment of the tasks. The engine officers also report an elevated level of stress and role conflict but no elevated levels of mental ill-health. However, it does not seem as the job content or qualification levels are the main source of work stress. Rather, as indicated by the highly elevated role conflict, the often contradicting requirements raised on the shipping operation seem to often create conflicts for the engine officers. They are supposed live up to their professional standards on shipping and at the same operate the ship with the reduced crew numbers at high speed to satisfy the requirements for profitability.

Keywords: Automation, engine room, ships, work environment, engine officers, evacuation, stress, role conflict

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SAMMANFATTNING

Att besluta sig för att gå till sjöss är mer än ett yrkesval. Att arbeta till sjöss innebär att man blir en del av en isolerad miljö på en mångkulturell arena och att man under lång tid är separerad från familj och vänner. Sjöfartsnäringen har under de senaste årtiondena genomgått stora förändringar på grund av den tekniska utvecklingen, automatiseringen och de ökade lönsamhets- och konkurrenskraven. Följderna av dessa förändringar har inneburit minskade besättningar, förändringar i arbetsuppgifternas genomförande och att nya arbetsuppgifter har tillkommit. Det övergripande syftet med denna avhandling har varit att undersöka samspelet mellan fartyget, tekniken och människorna ombord för att öka förståelsen för hur de senaste årtiondenas förändringar har påverkat sjömännens, speciellt maskinbefälens arbetsförhållanden och välbefinnande ombord.

Resultatet i denna avhandling visar på att maskinbesättningen på grund av brister i designen av maskinrum och kontrollrum måste anpassa sig på ett mindre ändamålsenligt sätt för att kunna genomföra sina arbetsuppgifter. En slutsats är att rådande kunskaper i ergonomi inte utnyttjas i designen av fartygens maskinavdelning. Konsekvenserna av detta är att besättningen hittar alternativa sätt att lösa uppgiften vilket ökar risken för skador och innebär ett mindre effektivt fullbordande av arbetsuppgiften.

Maskinbefälen rapporterar också en ökad stressnivå och en rollkonflikt men inga förhöjda nivåer av psykisk ohälsa. Det verkar inte som om arbetets innehåll eller kvalifikationsnivåerna är den huvudsakliga källan till arbetsrelaterad stress. Snarare, som indikeras av de höga nivåerna av rollkonflikt, är det motstridiga krav som ställs på driften av fartyget som verkar skapa en konflikt som maskinbefälen. Dessa förväntas leva upp till sin professionella roll samtidigt som besättningarna minskas och hamntiderna är korta för att kunna möta lönsamhetskraven.

Sökord: Automatisering, maskinrum, fartyg, arbetsmiljö, maskinbefäl, evakuering, stress, rollkonflikt

LIST OF PUBLICATIONS

This thesis is based on the work contained in the following studies, referred to by Roman numerals in the text:

I Lützhöft, M. and Lundh, M. (2009) *Marine Application of Control Systems* In Ivergård, T. and Hunt, B. (eds.) Handbook of Control Room Design and Ergonomics – A Perspective for the Future, (pp. 227-261) Boca Raton, CRS Press

II Lundh, M., Lützhöft, M., Rydstedt, L. and Dahlman, J. (2010) *Evacuation in practise – Observations from five full scale trials*, Journal of Maritime Affairs (accepted for publication)

III Lundh, M., Lützhöft, M., Rydstedt, L. and Dahlman, J., (2009) *Working Conditions in the Engine Department - A qualitative study among engine room personnel onboard Swedish merchant ships,* Applied Ergonomics (resubmitted pending minor revision).

IV Rydstedt, L. and Lundh, M. (2010) *An Ocean of Stress? The relationship between psychosocial workload and mental strain among engine officers in the Swedish merchant fleet,* International Journal of Maritime Health (submitted)

DIVISION OF WORK

Study I

Lützhöft, M. and Lundh, M. (2009) *Marine application of Control* Systems In Ivergård, T. and Hunt, B. (eds.) Handbook of Control Room Design and Ergonomics – A Perspective for the Future, (pp. 227-261) Boca Raton, CRS Press

The work in this study was divided equally by the authors. M Lützhöft had the main responsibility of the bridge department and M Lundh the main responsibility of the engine department. Joint authorship on the section of systems view of the ship. Orders of authors arbitrary. The section about the engine department originates from the finding from the project Engine Control Room – Human Factors (Wagner, Lundh, & Grundevik, 2008).

Study II

Lundh, M., Lützhöft, M., Rydstedt, L. and Dahlman, J. (2010) *Evacuation in practise – Observations from five full scale trials*

Lundh, M.: Responsible for the planning of the observations, the data collection, the analysis and the main part of the writing.
Lützhöft, M.: Proofreading.
Rydstedt, L.: Proofreading.
Dahlman, J.: Co-writer and proofreading.

Study III

Lundh, M., Lützhöft, M., Rydstedt, L. and Dahlman, J., (2009) *Working Conditions in the Engine Department – A qualitative study among engine room personnel onboard Swedish merchant ships*

Lundh, M.: Responsible for the planning of the observations, the data collection, the analysis and the main part of the writing.
Lützhöft, M.: Proofreading.
Rydstedt, L.: Proofreading.
Dahlman, J.: Co-writer and proofreading.

Study IV

Rydstedt, L. and Lundh, M. (2009) *An Ocean of Stress? The relationship between psychosocial workload and mental strain among engine officers in the Swedish merchant fleet*

Rydstedt, L.: Statistical analysis and writing.
Lundh, M.: Planning the study, contacts and negotiating consent with the Merchant Marine Officer's association, data collection, statistical analysis and writing, interpreting the findings into the applied context.

PREFACE

In one of the introductory courses in marine engineering at the College of Navigation in Gothenburg, the lecturer said to us;

“To go to sea is not a choice of career! You probably have some kind of genetic divergence or a birth injury! Because who, in full possession of all one's senses, would spend half the year at sea in a metal box?”

He said it with a glimpse in his eye, having many years of experience as a marine engineer. He also told us that we would probably experience some of the best times of our lives on board, but also some of the worst. Now, looking back some twenty-five years, I could not agree more.

Having experienced many peculiar and challenging situations on board, I, quite early, became interested in design solutions in the engine department, and the human role in a technical environment. After having spent eleven years at sea, the last five as an engineer, I went ashore and started my career as a teacher, teaching ratings and officers to be. During recent years I have had the opportunity to pick up and develop my previous interest in the interaction between design, technology and human. I have, through my PhD studies, been given the privilege to study different areas within the human factors domain and combine this knowledge with my previous experience of work in the engine department.

My PhD work has been carried out at Chalmers University of Technology in Gothenburg and was fully financed by the Swedish Mercantile Marine Foundation. The work could not have been accomplished without the assistance and support from seafarers who obligingly supported the work and kindly and patiently shared their experience and knowledge. All those who in different ways have been a part of this work all shared the same urge to contribute to a beneficial development of the sea farers situation on board.

ABBREVATIONS AND TERMS

Bulk carrier	A ship specially designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement in its cargo holds.
Container ship	Cargo ships that carry their load in truck-size intermodal containers.
DC/S	The Demand-Control-Support model
E0	A class notation which is considered to meet the requirements of the International Convention for the Safety of Life at Sea (SOLAS) regulation II-1/46-54 for a periodically unattended machinery space.
ERI	Effort-Reward-Imbalance model
Feeder ship	A feeder ship collects shipping containers from different ports and transports them to central container terminals where they are loaded to bigger container vessels.
IMO	International Maritime Organization
MARPOL	The International Convention for the Prevention of Pollution from Ships
OBO ship	An Ore-Bulk-Oil carrier, OBO, a ship designed to be capable of carrying wet or dry cargoes.
Offshore vessels	A ship specially designed to supply offshore oil platforms.
Ro/Ro ship	Roll on/Roll off vessel, a vessel designed to carry wheeled cargo such as automobiles, trucks, semi-trailer trucks, trailers or railroad cars that are driven on and off the ship on their own wheels.
SOLAS	The International Convention for the Safety of Life at Sea
STCW	The International Convention on Standards of Training, Certification and Watch keeping for Seafarers

CONTENT

"There are three sorts of people; those who are alive, those who are dead and those who are at sea."

Anarchasis
Greek Philosopher

1 Introduction

Deciding to become a sea farer is more than a choice of career. Working on board a ship implies a lot of time spent away from family and friends (Aubert, 1968; Eldh, 2004). To be a part of a crew is to be a part of an isolated context (Aubert, 1968; Eldh, 2004). You are omitted to your own and your fellow crew members' knowledge and skills to solve problems and manage independently. Problems not only about your daily work, but also in difficult situations when a ship is in distress and the life of those on board are threatened.

Working on board also implies being a part of a cultural meeting arena. Not only in the contact with representatives from the harbour, cargo owners and different authorities abroad but also on board as the crew often consists of several nationalities and cultures (Bloor, Thomas, & Lane, 2000; Werthén, 1973a). The spare time on board is spent in the company of your crew members, the number of available recreational activities is limited and isolation is an evident contribution to the daily life on board (Aubert, 1968; Werthén, 1973a). A satisfactory work environment, comfort and well-being are important constituents in every place of work, demands which are further accentuated on board a ship.

1.1 Thesis outline

Study I was partly based on a research project performed before this thesis work addressing Human Factors (HF) issues in the engine department named Engine Control Room – Human Factor (ECR-HF) (Wagner, et al., 2008). The project was carried out by a project team consisting of SSPA Sweden, Chalmers Shipping and Marine Technology, MSI Design, World Maritime University and Kalmar Maritime Academy. Six Swedish ship owners participated in the project facilitating studies on vessels representing different type of ships. The project included on board surveys on seven different ship types within the Swedish merchant marine. Extensive interviews with engineering crew, detailed observations, tasks and link analysis and mapping of placement of instruments and the lay-out of the engine room (ER) and the engine control room (ECR) were included in the study. Some conclusions from the project were:

- Administrative duties have successively increased over time.
- The complexity of the control systems has increased but not their transparency.
- The design of the ECR does not optimally correspond to the role of today's engineers and their duties such as administrative, monitoring and operational duties.
- Recognised knowledge about design and lay-out is not utilized.
- Established guide-lines, rules and regulations are not consequently used in the design process.
- Separate technical solutions e.g. Commercial off the Shelf (COTS) panels belonging to different pieces of equipment may be quite acceptable, but problems emerge as they become an integrated part of the rest of the technology. An overall comprehensive attitude towards the design of an ECR is necessary.
- Which tasks and how the tasks in the ECR are performed need to be taken into consideration when designing the ECR.

More extensive research has been done concerning human factors issues on the bridge (Blomberg, Lützhöft, & Nyce, 2005; Hederström & Gyldén, 1992; Lützhöft, 2004; Nilsson, 2007).In addition, the guidelines for the bridge lay-out are more comprehensive and detailed than those of the ECR (IMO, 1998, 2000). Guidelines for bridge lay-out and the results from the field studies within ECR-HF project were put together and resulted in a contribution in an edited book (the chapter is in the thesis referred to as Study I). In this study, a comparison of the work situation on the bridge and the engine control room indicated parallel questions at issue, e.g., an increase in the use of computers, a change in work performance and subsequent different ergonomical demands and an increase in the amount of alarms. An attempt to investigate the prerequisites for adapting the prevailing regulation used in bridge layout to the layout of the engine control room was made.

To further illustrate and explore the working conditions onboard the second study illustrates the demands forced on the crew in an emergency situation i.e. an evacuation. The design and results in study II only provided a limited perspective of the ships prerequisites during evacuation and the organizational issues onboard which I believed needed to be further explored. During an evacuation of a ship, the entire organization, rules, regulation and guidelines are put in its context and can be observed as the different sub-systems interact and affect both crewmembers and passengers.

After having studied the ship as a whole, with the implications of rules, regulations and guidelines in both a bridge and ECR perspective and during a state of evacuation, the obvious continuance of my research was to; given my background, study the working environment from an individual perspective of the engine crew. A reason for this was the fact that little research has been devoted to the engine department compared to the ship bridge, although the engine department has undergone similar technological developments and thus share similar demands imposed on the individual crew member. The two final studies (III and IV) in this thesis aim to investigate the working conditions in the engine department. Study III investigates the prerequisites to perform the work from a crew member perspective given and study IV investigates the work conditions from an individual perspective considering the psychosocial environment and mental health.

The interdisciplinary approach in this thesis implies the need for an extensive introduction in order to explain the background to the aim and research questions in this thesis.

2 Background

Merchant navy ships refer to civil ships engaged in cargo and/or passenger traffic. The grouping of merchant ships can be determined by, e.g., Maritime Traffic Areas, route, type of hull, type of machinery, type of cargo and type of ship. Different types of ships can also be divided into subgroups (Table 1). Various types of ships also imply various types of demands. Not only are there differences in routes, working hours, time spent on board and skills, the training requirements and mandatory certificates differ as well (IMO, 1996a; Transportstyrelsen, 2010).

Table 1 Different types of ships

Type of ships	Examples
Tanker	Crude oil tanker, product tankers, gas carrier
Container ship	Container ships, feeder ship
Ro-ro ship	Ro-ro ship, car carriers
Bulk carrier	Bulk carrier, OBO carrier
Working and special-purpose ships	Tugs, icebreakers, offshore vessels
Ferries and cruise ships	Ferries, cruise ships

2.1 Rules, regulations and legislation

The shipping industry is governed by international as well as national rules and regulations (Figure 1). The shipping industry has over the years been subjected to increase in governing legislation and adherent inspections on board (Lützhöft, Ljung, & Nodin, 2008; Mårtensson, 2006).

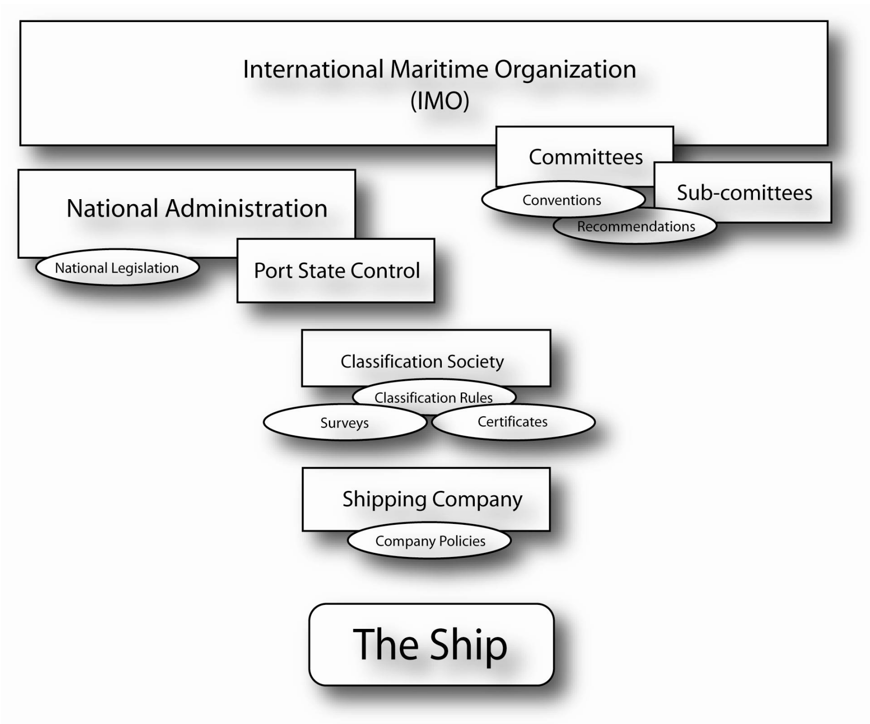

Figure 1. Rules and regulations affecting the ship.

The International Maritime Organization (IMO) is a specialized agency of the United Nations with 169 Member States and three Associate Members. The IMO's main task is to develop and maintain a comprehensive regulatory framework for shipping and includes safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping. IMO contains committees and sub-committees which are the focus for the technical work to update existing legislation or develop and adopt new regulations together with those from interested intergovernmental and non-governmental organizations (IMO, 2010; Mårtensson, 2006).

The result is an extensive body of international conventions which are supported by recommendations governing every part of shipping. They comprise measures aimed at the prevention of accidents, including standards for ship design, construction, equipment, operation and manning. Important treaties include the International Convention for the Safety of Life at Sea (SOLAS), the International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW) on standards of training for seafarers. The IMO also has rules which are applicable when accidents occur, i.e., rules concerning distress and safety communications, oil pollution and conventions which establish compensation and liability regimes.

The inspection and monitoring of compliance is the responsibility of the member States and their National Administration. The Swedish National Maritime Administration’s activities are mainly governed by five laws concerning ship’s safety, measures to take against pollution from ships, occupational safety and health, harbour protection and security (Riksdagen, 1977, 1980, 2003, 2004, 2006). The statue book of supervision gives guidance on how to perform the inspections and where the demands of the rules and regulations can be found (Transportstyrelsen, 2009b).

The port state control is an inspection of foreign ships in port of call. It is carried out by the national maritime administration and the inspection embraces safety, prevention of pollution by ships and living and working conditions on board ships (Eldh, 2004).

The classification societies are non-governmental organizations in the shipping industry. The foundations in the activities of the classification societies are to establish classification rules, to confirm that designs and calculations meet these rules, survey ships and structures during the process of construction and commissioning, and periodically survey vessels to ensure that they continue to meet the rules (Eldh, 2004). In closest contact with the ship is the shipping company with its company specific demands and policies.

2.2 Professional Categories on board and their roles

The master on board is responsible for the whole ship and belongs organisationally to the deck department. The deck officers are mainly responsible for the navigation of the ship and the cargo handling. They are assisted by the deck crew who are engaged in watch keeping duties, cargo handling and maintenance work on deck (Eldh, 2004).

The chief engineer is the head of the engine department. The engine officers are mainly responsible for the operation and maintenance of the engine equipment. To their assistance there are engine ratings that are mainly involved in different kinds of maintenance activities and repair work. Some ships also have an electrical engineer, or electrician on board (Eldh, 2004).

On board all ships there are crew members responsible for the service on board. This includes meals and to a certain extent laundry and cleaning of public areas in the accommodation. On board passenger ships they represent the largest category on board and provide different categories of passengers' service (Eldh, 2004).

2.2.1 The safety organization

In addition to their daily deed, the crew members also have a role in the safety organization on board (IMO, 2001; Transportstyrelsen, 2009b). The safety organization is utilized in case of fire on board and/or the abandoning of the ship. The requirements a particular role in the safety organization has to meet is dependent of the event or incident. The individual crew member could, e.g., be a part of the fire fighting organization on board or be responsible for evacuating the accommodation and prepare for an abandoning of the ship. These demands are further accentuated on board passenger ships as the crew also has to handle large groups of passengers (Timstedt, 2004; Transportstyrelsen, 2009a; Vanem & Skjong, 2005). The crew members are obliged to provide passengers with clear information about the development of the event, give the passengers instructions on what to do, support in the donning of life vests and manage the evacuation equipment (Andersson, 2005; Deere, Galea, Lawrence, Fillppidis, & Gwynne, 2006; Ohlsson & Johansson, 2001; Timstedt, 2004).

The SOLAS deals with maritime safety and covers a wide range of aspects designed to improve the safety on board including fire fighting and life-saving appliances and arrangements (IMO, 2001). The international standards for the life-saving equipment and its testing and evaluation is described in the Life Saving Appliance (LSA) Code and Resolution MSC.48(66) (IMO, 2003a). The evacuation and safety equipment on board is challenging to handle even under controlled circumstances during trials, and occasional accidents have been reported (Andersson, 2005; Ekman, 2005; Marine Accident Investigation Branch, 2001, 2003; Simões Ré, et al., 2007; Simões Ré & Veicht, 2001, 2002; Simões Ré, Veicht, & Pelley, 2003; Tsychkova, 2000). The safety and evacuation equipment is, according to current regulation, required to be tested during weather conditions declared in the LSA Code declared, 6 on the Beaufort scale and a significant wave height of at least 3 m (9.8 feet) (IMO, 2003a). Previous research has proved great difficulties in handling the evacuation equipment in more moderate weather conditions than those stipulated in the LSA Code (Ekman, 2005; Tsychkova, 2000).

The guidelines concerning the analysis of the evacuation of a passenger ship, stipulated by the IMO, are mainly based on the estimated time to clear out the accommodation and time to embark and launch the evacuation equipment to provide for abandonment by the total number of persons on board. In the guidelines for evacuation analysis for passenger ships (IMO, 2007), the main focus is on the passengers' travel time with consideration of, e.g., time to react, congestion and ship's lay-out to determine the calculated evacuation time and compare it to maximum allowable evacuation time (IMO, 2007). A correction and safety factor of 1.25 is added to compensate for ship's motion, passenger age and mobility impairment, flexibility of arrangements, unavailability of corridors and restricted visibility due to smoke.

2.3 The development of the shipping industry

In the late 1960s and early 1970s the shipping industry rapidly grew and during this period the containerisation further contributed to the development of ships and cargo handling (Bloor, et al., 2000; Höivold, 1984; Olofsson, 1995). After this period of high profitability, the 1980s followed with excess tonnage, falling freight rates and the implementation of "Flags of Convenience", that enabled the shipping companies to reduce labour costs and register ships in countries were taxes are low and labour is cheap.

One of the most important changes in the merchant navy during the last decades has been the rapid development of the technical equipment and ship design (Olofsson, 1995). The technical changes, engine room automation and changes in communication systems have further reduced the number of crew members on board (Bloor, et al., 2000). This technological development has implied changes in task performance, new tasks to manage and new routines to comply with (Hansson, 1996; Lützhöft, 2004; Lützhöft, et al., 2008; Mårtensson, 2006). The reduction in the engine crew has placed additional demands on the remaining crew as there are fewer crew members left to handle maintenance work, break downs and operational disturbances (Ankarberg & Dittmer, 1998; Bloor, et al., 2000). The enhancement of the environmental demands on reduced fuel consumption and emissions from ships has further added to the technological development in the engine room (Endresen, Sörgård, Behrens, Brett, & Isaksen, 2007; Hall, 2009).

The descriptions of the shipping industry implicate a complex environment that the seafarers are a part of. This environment has previously been described and analyzed from a sociotechnical perspective where the crews interact with technical and social systems (Grech, Horberry, & Koester, 2008; Moreby, 1975; Mårtensson, 2006; Olofsson, 1995).

2.3.1 Profitability

The earning potential of the ship is determined by three factors; cargo carrying capacity, speed and versatility, which are determined by several technical characteristics of the ship (Veenstra & Ludema, 2006). This implies that, to render the cargo handling as effective as possible, the design and utilization of the cargo hold has high priority when designing a ship (Veenstra & Ludema, 2006).

The requirements for profitability and competitiveness in the shipping industry manifests itself in a reduced manning on board, extended working hours and a larger proportion of crew members from nations where the claims for wages are lower (Mårtensson, 2006; Olofsson, 1995). An increase in automation, shorter turnaround time in ports, budget reductions and a striving to optimize the cargo hold with regards to capacity and logistics are other consequences of the strive for profitability (Bloor, et al., 2000; Nishimura, Imai, Janssens, & Papadimitriou, 2009; Veenstra & Ludema, 2006).

2.3.2 The impact on work performance

The described developments, reduced manning, extended working hours, mixed manning, technological changes and shorter turnaround times in port increase the demands and affect the situation on board. A reduction in manning has been made possible by technical developments and increase of automation, both on the bridge and in the engine department (Mårtensson, 2006). However, a lot of the maintenance work, repairs and different routines are basically not affected by the technological development, and still have to be carried out to the same extent despite reduced manning (Bloor, et al., 2000). The national Administration stipulate the minimum number of crew members on board necessary to uphold the safety on board (Riksdagen, 2003).

In the late seventies, a comprehensive study of the work environment on board the Swedish merchant fleet was carried out (Ivergård, Ekelin, Lundberg, Norberg, & Svedung, 1978). Parts of the results were discussed in relation to the design of the ship and the aim was to utilize the results in the ship building process to enhance the working conditions on board (Ivergård, et al., 1978). Research of later date confirms that a majority of the issues addressed in the report by Ivergård et al. (1978) are still subjected to discussion in the research community (Anderson, 1983; Forsell, Hagberg, & Nilsson, 2007, 2008; Ghahramani, 1999; Grundevik, Lundh, & Wagner, 2009; Jensen, et al., 2005; Kaerlev, et al., 2008; Nilsson, 1998; Nilsson, et al., 2004; Orosa & Oliviera, 2009; Seif, Degiuli, & Muftic, 2003; Seif & Muftic, 2005). In addition to these areas, the technological development has implied new problems such as changes in work performance, an increase in administrative demands and different ergonomic requirements due to the introduction of computers in the engine control room (Knudsen, 2009; Lützhöft, 2004; Lützhöft, et al., 2008; Wagner, et al., 2008).

2.3.3 Work conditions, health and stress on board

Working on board is considered a high-risk occupation (Jensen, et al., 2006). The International Labour Organization (ILO) is a tripartite UN agency that joints governments, employers and workers of its member states in common actions to promote decent working conditions throughout the world. ILO documents provide practical guidance on safety and health in shipboard work (ILO, 1996).

Periodical medical examinations are mandatory for all sea farers, excluding persons with lower health status and disabled from fitness for service. A healthy worker effect can therefore be expected among seafarers in active service (Bloor, et al., 2000; Carpenter, 1987). Healthy worker effect is used to cover for the bias when comparing morbidity and mortality experience of an occupational group which has a certain standard of health with the general population (Carpenter, 1987). A literature review revealed health problems including, e.g., hypertension, asthma, cardiovascular disease, stress, loss of hearing, suicide and cancer (Bloor, et al., 2000). A questionnaire study of 6461 seafarers (95% response rate) revealed that the self-rated health of the seafarers was good but varied by country and declined with age (Jensen, et al., 2006).

Rapid changes in technology, increased automation and the subsequent reduction in crew's size has, in interview studies and analysis of illness reports, been found to be a main sources for stress related problems reported by seamen of all ranks (Agerberg & Passchier, 1998; Zeitlin, 1995). Two questionnaire studies carried out on board Swedish merchant ships some 20 years apart both recommend a change in the work organization on board as a consequence of the reduced crew manning (Olofsson, 1995; Werthén, 1973a). Both studies propose operational teams with clear areas of responsibility. Werthén (1973a) suggested that the traditional division of the crew into officers and ratings should be replaced by a crew with a more unanimous education with a clear responsibility for different specialist skills on board. Olofsson (1995) recommend that the crew should consist of organized self-controlled teams with the ship's operation as a common goal. The engine crew was also found to be the professional group most negatively affected by the reduced manning levels on board (Olofsson, 1995).

During recent time, the working conditions in international seafaring has been studied as a part of a collaborative project: International Surveillance of Seafarer's Health and Working Environment (Jensen, et al., 2004). A questionnaire was administered in 11 countries to seafarers in different positions on board. In general, the seafarers' self-rated health was good but varied significantly depending on which country the questionnaire was distributed in and declined with age (Jensen, et al., 2006). In a previous study from the Finnish merchant fleet results showed that the sea farers perceived their health as rather good (Elo, 1985). Further, the engine ratings and the engine officers reported more problems connected with the work environment than the other occupational groups on board.

This study also indicated that the engine crew reported the highest stress incidence followed by the deck and engine officers (Elo, 1985). This can be compared with a study performed on seafarers in the German merchant fleet which found that the engine room personnel had higher stress levels due to heat stress (Oldenburg, Jensen, Latza, & Baur, 2009). An interview study performed ten years earlier concluded that in addition to a decrease in number of crew members, the perceived stress levels on board have shifted from mainly physical conditions to more psychosocial, caused by modernisation, automatization and computerization (Agerberg & Passchier, 1998).

Further, illness-reports from 22 763 seamen in the US merchant fleet were analysed in a study by Zeitlin (1995) and the results revealed that the deck officers showed higher rates of cardiovascular diseases, heart attack, psychoneurosis, suicide and asthma while the engine officers showed higher rates of heart attack and asthma compared to engine ratings. The ongoing downsizing along with the swift technological and organizational changes in the merchant fleet was found to have the largest impact on the midlevel managers (Zeitlin, 1995). The enhancement in the organizational changes was by Zeitlin (1995) regarded as a situation which exposes the officers to role conflict.

A number of work characteristics, e.g., high work stress, job demands, lack of support and physical hazards has also been found to be associated with acute as well as long term fatigue (Wadsworth, Allen, McNamara, & Smith, 2008). Long time on shift, variable work hours, and high levels of perceived work stress, as well as high job demands were in turn strongly associated with higher levels of mental health problems. Variable work hours, high levels of work stress, as well as high job demands also had highly significant negative associations with self-reported general health (Wadsworth et al., 2008).

The hazardous effects of exposure to oil and chemicals have also been studied (Forsell, et al., 2007; Nilsson, 1998; Nilsson, et al., 2004). The incidence of lung cancer was found to be more than twice as high as expected among engine officers and ratings, which could not be explained by smoking habits (Nilsson, 1998). The exposure of polycyclic aromatic hydrocarbons found in oils, soot and exhausts gases can cause cancer in the lungs, skin and possibly urinary bladder (Forsell, et al., 2007, 2008; Nilsson, et al., 2004).

2.4 The engine department

The work in the engine department is often demanding due to the physical work conditions, especially with regards to high noise levels, heat, exposure to chemicals and vibrations (Eldh, 2004; Ivergård, et al., 1978). A recent study performed on seven Swedish ships showed that the noise levels in the ECR were within stipulated limits of 70 dB(A) (IMO, 1981; Transportstyrelsen, 2009c; Wagner, et al., 2008). The ships included in this study ranged from between being built from 1997 to 2007.

Work performed in the ER is mainly associated with operation, maintenance and repair activities of the engines and their auxiliary systems. Other tasks performed are services to the accommodation such as hot water, heat, drainage and water supply. The electricity throughout the ship is also the responsibility of the engine department. The monitoring and operation of the propulsion machinery and its auxiliary systems is performed from the ECR, as well as the planning of the work, administrative duties and communication (Eldh, 2004; Olofsson, 1995).

2.4.1 Demographic profile of the engine crew

The engine department is a male dominated work site. During 2008, 1397 crew members were active as engine room officers on board Swedish merchant ships, twenty of these were women (1.4 %) (active defined as crew members whom have served at least three months on board during the past eighteen months) (Transportstyrelsen, 2009a). The fleet also included 1055 engine ratings out of which 33 were women (3.1 %). The average age of the engine room officers were 45 years and the average age among engine ratings was 34 years (Transportstyrelsen, 2009a).

The engine officers have a higher education while ratings usually have upper secondary school education. The international minimum requirements of the education, certification and watch keeping for seafarers are stipulated in the STCW Code (IMO, 1996a; Transportstyrelsen, 2010).

2.4.2 The development of the work within the engine department

The work in the engine control room has undergone major changes due to the technical development and the introduction of computers (Hetherington, Flin, & Mearns, 2006; Olofsson, 1995). The IMO has stipulated guidelines for the engine-room layout, design and arrangement (IMO, 1998). The country of Liberia proposed a revision of these guidelines in order to provide the industry with more distinct guidance to meet the new demands, which the development of technology implies (IMO, 2006a). As more and more computers have been introduced into the ECRs, the cognitive ergonomics and physical work-place design demands have changed (Wagner, et al., 2008). The panels suited for the traditionally equipped analogous ECRs provided the crew with an immediate access to information that was easy to share. The panels were suited for a standing position as the engineer had to move back and forth to reach all the necessary equipment (Wagner, et al., 2008).

The number of alarms on board has steadily increased but the handling of the alarm systems remain more or less the same as of systems with fewer alarms (Sherwood Jones & Earthy, 2006a). A problem shared with many shore based industries (Thunberg & Osvalder, 2009). However, an automated engine room that complies with the requirements stipulated for a periodically unattended engine room, the so called E0-requirements, allows the engineers to work day-time with scheduled on duty call (Höivold, 1984; Mårtensson, 2006).

The administrative work used to be a minor part of the duties, and a small writing-desk was sufficient (albeit often placed away from the control panel) (Wagner, et al., 2008). As the technical development proceeded, time spent in front of a computer has steadily increased (Allen, 2009; Lützhöft, et al., 2008; Olofsson, 1995). The work on board has moved from a role as operator towards a more monitoring role which has changed the nature of the work as well as the demands imposed on the operator (Allen, 2009; Parasuraman, 1987). Allen (2009) indicated that the resistance to new technology could be related to age and level of computer skills. The vast majority of the participants in Allen's study (2009) were, however, in favour of better training on usage of ship technology. The questionnaire in Allen's study was sent out to 3000 respondents and was also placed on line and 819 questionnaires were returned. The sample consisted of mainly officers (98.7%). The author did not make any comparisons between the deck and the engine department but the engine department accounted for the majority of the completed questionnaires. An interview study with engine crew also revealed a wish for more courses about ships' systems (Grundevik, 2008).

The space allocated to the engine department is often limited due to increased cargo capacity and the optimization of the cargo space (Veenstra & Ludema, 2006). A limited area and/or a less well planned area leads to work areas crowded with equipment (Ivergård, et al., 1978). To perform maintenance and repair and even routine checks can be demanding due to awkward working postures and restricted access (Anderson, 1983; Ivergård, et al., 1978; Jensen, et al., 2005; Seif, et al., 2003; Seif & Muftic, 2005; Veenstra & Ludema, 2006). The risks of slip, trips and falls are present during these circumstances. Previous studies of accidents on board has concluded that falls from stairways and ladders in the engine room and in the accommodation occurred regularly (Anderson, 1983). Jensen et al (2005) found the lowest proportion of slip, trips and fall injuries in the engine department and on chemical tankers, although this was ascribed to a higher awareness of slipperiness due to oil-spill in these areas. Despite this, the proportions of injuries in the engine department that were related to slip, trips and fall were 36% (Jensen, et al., 2005).

3 Thesis rationale

This chapter aims at describing the approaches to the problems of each study.

In study I, "Marine Application of Control Systems", the two units, the bridge and the ECR are described. The section about the engine department is mainly based on the findings in the ECR-HF study (Wagner, et al., 2008). The prerequisites for adapting the bridge design guidelines to the design of the ECR were investigated.

Evacuation of any ship, and a passenger ship in particular, serves as an example of an extremely challenging situation for the crew members. The crew members not only have to manage their daily deeds but need also to have a preparedness of participating in the safety organization. This role is in many cases completely different to the tasks that the individual crew member is used to. During the observations made during five full scale trials (Study II), the various parts of the evacuation process and the difficulties that the crew had to manage were studied. The purpose of this work was to investigate how the crew members cope with the situation associated with an evacuation of a passenger ship and also to investigate how the passengers responded to the instructions of the crew and to the safety information on board.

In perspective of the rapid technological development on board it is of interest to investigate how engine department crew apprehends their work situation on board from a more ergonomic perspective. A study based on semi-structured interviews was performed in study III with the purposes: *i*. to describe how the engine crew perceives their work situation on board today, and, *ii*. to identify areas for improvement of the workplace design, that the engine crew consider important for a safe and operational work environment.

The technological development has not only implied changes in work performance. New tasks have been added and the demands put on the crew have changed as described previously. The engine officers on board have been subject to an increasing administrative burden, the degree of automation on board has also increased which has changed how tasks are carried out (Lützhöft, et al., 2008). The work role of the engineers has shifted from a more mechanical to a more operational role. It is therefore interesting to investigate how these changes in the engine officers' everyday life affected their comprehension of their work situation. A questionnaire was given to all engine officers in the Swedish merchant navy affiliated to the Swedish Merchant Marine Officers' Association. The first purpose of study IV was to compare the psychosocial working conditions and mental health of the sample of maritime engine officers with a broad sample of British wage earners. The second purpose was to analyse the relationship between the psychosocial working conditions onboard and mental strain. Role Stress, the Demand, Control Support (DC/S) model and work-family (WFI)/family-work (FWI) interference were used as workload indicators (Study IV).

4 Aim of the thesis

The overall aim is to investigate the interplay between the ship, the technological system and human system on board in order to understand how the technical and organizational developments during the latest decades have affected the working conditions and well being for the sea farers and in particular the engine officers.

The research questions addressed in the thesis are:

1. Are the prevailing rules and regulations for the design of the bridge applicable in the design of the ECR?
2. How does the crew interplay with the technical and organizational context in demanding situations?
3. How does the engine crew perceive their work environment from a functional as well as an ergonomic perspective?
4. How do the working conditions on board relate to perceived mental health of the engine officers?

The strategic, long-term research aims are to;

i. identify problematic aspects of the work organization and the working conditions for the engine officers,

ii. contribute to the discussion of revising the guidelines for engine-room layout, design and arrangement.

4.1 Limitations

The participants in this thesis have been mainly of Swedish nationality which may restrict the generalizability of the findings. This thesis will not focus on suggesting new design solutions or development of equipment. Nor does it aim to propose any organizational changes, alteration of routines or changes in work performance. Instead, this work investigates, from the crews' perspective, the prerequisites necessary, to cope with the work under the current conditions on board. Furthermore, it is beyond the scope of this dissertation to suggest further developments or to define usability criteria on the interface design of the control room.

5 Frame of reference

5.1 The work environment and ergonomics

In July 2003, the Occupational Safety and Health Act came to comprehend work on board Swedish ships (Arbetsmiljöverket, 2010). The fundamental paragraphs concerning a satisfactory work environment on board, the planning of the work and the work room within the law, also apply to foreign ships on Swedish territorial waters. The work environment embraces the entire work situation as well as psychosocial work situation.

Ergonomics is the science which describes the practice of learning about human characteristics and the utilization of the knowledge in order to improve humans' interaction with the things they use and the environment in which they do so (Wilson, 1999). There are different definitions of ergonomics, albeit with a similar approach (Wilson, 1999). The following definition of ergonomics was in the year 2000 approved by the International Ergonomics Association (IEA). "Ergonomics (or human factors) is the discipline concerned with the understanding of the interaction among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance" (IEA, 2010).

5.2 Stress, working conditions and health

One common definition of stress is the physiological and psychological reaction due to an experienced imbalance between the person's ability and the environment's demand (Karasek & Theorell, 1990). This imbalance can occur when an individual is facing a situation which contains demands that are perceived by the individual as threatening and/or to exceed his/her capacity (Ekman & Arnetz, 2005; Jones & Bright, 2001; Währborg, 2002).

In the transactional stress concept, stress reactions are thought of as an outcome from the interaction between the individual and the environment where coping is a central concept (Cohen, Kessler, & Underwood Gordon, 1997). Coping is defined as an individual's strategies to manage or resolve a stressful event and/or its emotional consequences (Lazarus, 1999). The coping process involves an active effort to manage the problem or a strategy to reduce or avoid its negative consequences (Lazarus, 1999).

5.2.1 Working conditions and health

One of the main reasons for the scientific interests in stress is its presumed potential risk of causing illness (Elliott & Eisdorfer, 1982). Work conditions which could cause stress reactions include i.e. low social support from colleagues and supervisors, high demands especially in combination with low control, rotating shift work or irregular working hours, ambiguous or contradicting work demands and poor physical working conditions (Frankenhauser & Johansson, 1986; Karasek & Theorell, 1990). The psychosocial work situation and the physical work environment are two factors which can interact to cause insupportable working conditions and thus risk contributing to a negative health outcome (Evans, Johansson, & Carrere, 1994). The psychosocial factors can also mitigate the effects of the physical environment and possible health outcomes (Jones & Bright, 2001; Karasek & Theorell, 1990).

5.3 Generic stress models

Two prominent generic stress models used for studying work-related factors are the Demand-Control-Support (DC/S) model (Karasek, 1979;. Karasek & Theorell, 1990) and the Effort-Reward-Imbalance (ERI) model (Siegrist, 2006). The DC/S model was used in the survey in this thesis.

The development of generic models aim at describing the complex relationship between the psychosocial work environment and the health reactions of the individual, by identifying core elements in the work-strain relationship (van Vegchel, de Jonge, Bosma, & Schaufeli, 2005). There is a discussion about how accurately these generic models can capture occupation-specific workload. Different types of working conditions can be of importance for the emergence of work-related strain in different occupations (Sparks & Cooper, 1999). The possible prize for the simplification may be the loss of knowledge of occupation specific sources of job strain. Other authors claim that a limited number of core dimensions of the working conditions are enough to explain the work-strain relationship in all types of professions (Van Veldhoven, Taris, de Jonge, & Broersen, 2005).

5.3.1 The Demand-Control-Support (DC/S) model

By identifying core elements in the work-strain relationship, the DC/S account for the complex relationships between the psychosocial work environment and health of the individual(de Lange, Taris, Kompier, & Houtman, 2003; Jones & Bright, 2001; Karasek & Theorell, 1990; Rydstedt, Devereux, & Sverke, 2007). The DC/S model identifies low control in combination with high demands and low support as key components in the stressor - strain relationship.

The demand-control model present two key work characteristics present in the work environment, the employees' perception of demand, which refers to perceived workload demands, and control (Karasek, 1979). The concept of control includes task authority and skill discretion. Task authority refers to the individual's authority to make decisions at work and skill discretion to the level and variety of skills required for the work task. It also involves the individual's long-term possibilities to acquire new skills in the work role (Rydstedt, et al., 2007). The combination of the level of perceived demands and perceived control results in four types of jobs, high and low strain along with passive and active jobs, which allow two types of predicted outcomes (Karasek, 1979).

A diagonal leading from a situation with low demands and high job decision latitude to a situation with high demands and low job decision latitude risk result in a situation where the employee experience unresolved strain. On the other hand, a situation leading from low job demands and low job decision latitude to high job demands and high decision latitude entails a situation leading to a development of new behaviour patterns and stimulates learning, so called active jobs (Karasek, 1979).

Karasek and Theorell (1990) later expanded the model to also include social support. The social support comprehends to both co-workers and supervisors and refers to the social interaction available at the work place. Karasek and Theorell (1990) identify several types of social support mainly socio-emotional support which buffers psychological strain and instrumental social support which is directed towards resources or assistance with work tasks from co-workers or supervisors.

Jones and Bright (2001) assert, however, that the model has had limited impact on practice. They claim this is due to the variables being too general and non-specific to suggest practical interventions and that it fails to add important factors such as how individuals differ in their appraisal of job characteristics, the roles of job, insecurity and aspects of new technology in the job stress process. However Karasek and Theorell (1990) address this latter issue when discussing socio-technical design where they note the necessity of recognizing technical systems together with social systems of work. They continue by emphasizing the tight linkages which are to be found between technological changes and changes in the psychological job structure in the areas of decision processes, skill allocation, psychological demands, social interaction and communication pattern. When the involvement of computers in the process implies little control over the process a higher level of psychological strain is risked, but on the other hand, computer-based systems can also be designed to serve as a tool to leverage the worker's existing skills (Karasek & Theorell, 1990).

5.3.2 The ERI model

Another established scale is the Effort-Reward-Imbalance (ERI) model where the focus shifts from the control to the reward concept (Siegrist, 2006). Siegrist argues that work defines a crucial link between the social role of the worker and his/her self-esteem and self-efficacy. Siegrist further claims that failed reciprocity in terms of high effort spent and low reward received will probably evoke recurrent negative emotions and sustained stress responses in exposed people (Siegrist, 2006). High effort consists of an extrinsic source, the demands and an intrinsic source, motivation and need for control. High efforts are thought to occur from high extrinsic job demands and/or from the coping pattern of the individual. The ERI model predicts that the working conditions will most likely cause emotional and psychological strain when there is an unbalance between the extrinsic and/or intrinsic efforts invested into the work and the gained reward (Siegrist, 1996, 2006). On the other hand, positive emotions caused by positive social rewards will enhance well-being and health according to Siegrist (2006). The occupational rewards can consist of money, esteem and job security/career opportunities (Siegrist, 1996, 2006; van Vegchel, et al., 2005).

5.3.3 Role conflict

Work role conflict is defined as "when the behaviours expected of an individual are inconsistent" and work role ambiguity to be present "if an employee does not know what he has the authority to decide, what he is expected to accomplish, and how he will be judged" (Rizzo, House, & Lirtzman, 1970 p.151). Quite similarly, role ambiguity has been claimed to be present when the employees are unclear about role requirements and performance standards and role conflict are present when two or more requirements of an employee's role are conflicting (Jex, Adams, Bachrach, & Sorensen, 2003).

The work on board has moved from a role as operator towards a more monitoring role which has changed the nature of the work as well as the demands imposed on the operator (Allen, 2009; Parasuraman, 1987). These changes in demands suggest changes in the work role which risk cause a role conflict or ambiguity. Work role conflict and ambiguity risk causing i.e. stress, anxiety, reduced job satisfaction, and decreased job performance and work role conflict and role ambiguity has been found to be associated with mental and somatic complaints.(Hurell & McLaney, 1988; Jex, et al., 2003; King & King, 1990; Revicki, Whitley, & Gallery, 1993; Revicki, Whitley, Gallery, & Allison, 1993).

5.3.4 Family work conflict

A work-family conflict can be defined as “a form of inter-role conflict in which the pressures from the work and family domains are mutually incompatible in some respect” (Greenhaus & Beutell, 1985 p.77). The conflict can be composed by Work Family Interference (WFI) and Family Work Interference (FWI). In WFI the role requirements at work interfere with the family life and in FWI the demands from family life interfere with the requirements of work (Bakker, Demerouti, & Dollard, 2008; Brotheridge & Lee, 2005; Byron, 2005).

Seafarers are parted from their families during long periods, which has been found to be a prominent source of stress for of seafarers and associated with emotional problems among seafarers (Thomas & Bailey, 2006; Wadsworth, et al., 2008). Work-family conflicts have also been associated with i.e. reduced job satisfaction, perceived stress, depressive symptoms, subjective health symptoms, decreased compliance with safety rules and absence from work (Brotheridge & Lee, 2005; Clays, Kittel, Godin, Bacquer, & Backer, 2009; Cullen & Hammer, 2007; Hammer-Helland, Saksvik, Nytrö, Torvatn, & Bayazit, 2004; Hammer, Cullen, Neal, & Shafiro, 2005; Perrewé, Hochwarter, & Kiewitz, 1999).

5.4 Measuring the outcome of mental strain

The outcomes of the individual´s perceived stress can also be measured by the use of generic scales i.e. The Perceived Stress Scale (PSS10) and the General Health Questionnaire (GHQ).

5.4.1 The Perceived Stress Scale (PSS10)

PSS10 was developed to measure the perceived degree of which environmental demands exceed the individual's ability to cope and thus are apprehended as stressful (Cohen & Williamson, 1988). The development of the scale was based on Lazarus's concept of appraisal (Lazarus, 1999). The scale has been used on different populations, and has proven to be both reliable and valid (Cohen, Kamarck, & Mermelstein, 1983; Reis, Hino, & Rodriguez-Añez, 2010).

5.4.2 The General Health Questionnaire (GHQ)

GHQ was developed to measure minor psychiatric disorders or "strain" (Goldberg & Williams, 1988). The scale is validated and often used due to its good psychometric abilities and it includes different items which the subject has to score the presence or absence of. The scale score is then used to distinguish whether the individual can be classified as suffering from minor psychiatric disorder on basis of the assessment (Goldberg & Williams, 1988).

5.5 The sociotechnical system's perspective

The fundamental thoughts in the open system of the sociotechnical system's perspective theory are that the systems continuously interact with the environment, which is necessary for the survival of the open system. The open system is characterized by a continuous cycle of inflow, inner transformation, outflow and feedback. (Katz & Kahn, 1978). Another important concept is the principle of equifinality. According to this principle the same final goal can be reached through the use of different paths and strategies (Katz & Kahn, 1978). In the context of this thesis, an enhancement of the working conditions in the engine department demand changes in the social system as well as the technical system.

The concept of sociotechnical systems originate from studies in the British coal mining industry led by Eric Trist (Katz & Kahn, 1978; Pasmore & Khalsa, 1993). The sociotechnical systems perspective consider an organization to consist of the social system (people and the work organization), the technical system (tools and techniques) and an external environment with which the organization as an open system is involved in a constant exchange relationship (Burrell & Morgan, 1979; Clegg, 2000; Pasmore, 1988; Rollenhagen, 1995).

The essence of the message of the social technical system's perspective is that the effectiveness of the organization to a large extent dependents on how well the technical and social systems are designed with respect to each other and to meet the demands of the external environment (Katz & Kahn, 1978; Pasmore, 1988). The choice and design of technology is also regarded as a determining factor for individual performance and adjustment as well as organizational efficiency (Pasmore, 1988). Similar approaches to the source of what affects behaviour is found in risk management; "It is evident that a new approach to representation of systems behaviour is necessary, not focused on human error violations, but on the mechanisms *generating* behaviour in the actual, dynamic work context" (Rasmussen, 1997 p 190). Allocation of tasks between and amongst individuals and technology is present within the sociotechnical design and the technical system should be the "tool" that supports the individual in meeting the goals of the organization (Clegg, 2000).

Olofsson (1995) described the ship from a sociotechnical perspective where the ship is operating in an external environment which consists of different actors in marine transport, e. g., owners, port facilities, national authorities and brokers (figure 2). The management system is the external system that supports the operation of the ship. The ship itself is divided into three sub-systems, the hull, the technical and the human system (Olofsson, 1995). The hull system represents the structure and design of the ship, the technical system comprise all technical devises and the human system the crew that operates the ship (Olofsson, 1995). This perspective forms a basis for the discussion in this thesis.

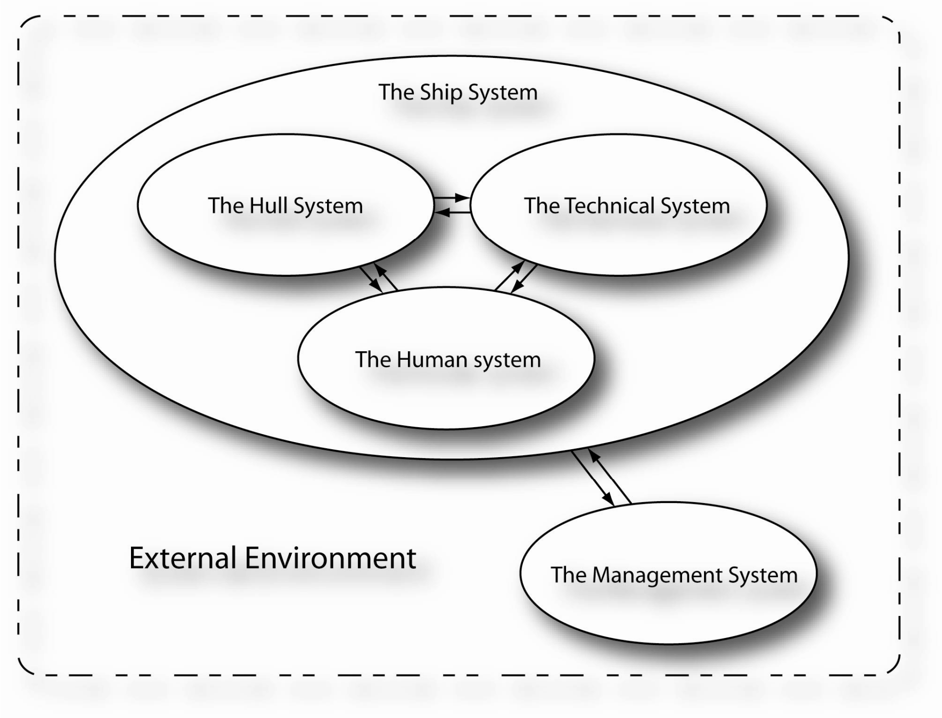

Figure 2 The ship in a system approach with interacting sub-systems and external environment (Olofsson, 1995).

6 Research approach

In this thesis, the work environment and the working conditions on board have been studied from a sociotechnical perspective. The overall aim of the thesis has been to describe and analyze how the changed conditions in the shipping industry has affected the working conditions and well being of the sea farers and in particular the engine officers. The research approach includes four different studies to explore the working conditions on board (Table 2).

Table 2 Each study's contribution to the research questions

Research question	***Study I***	***Study II***	***Study III***	***Study IV***
1	x			
2		x	x	
3			x	x
4				x

6.1 Study I

The overall purpose of this study was to serve as an introduction to the engine department and to describe differences and similarities within work environment on the bridge and in the engine department. The two departments on board, the deck and engine, are complementary in the ship's operation. The bridge is mainly responsible for the navigation and cargo handling, while the engine for the propulsion of the ship. Albeit the obvious difference in the responsibility of these departments they show many similarities and are facing similar problems. Study I aims at describing these two environments to increase the understanding of their differences and similarities.

6.2 Observations (Study II)

Observations have several limitations. The observer may affect the situation being observed and the participants, selective perception of the observer may distort the data (Osvalder, Rose, & Karlsson, 2008; Patton, 2002). Further, observations are limited to only focusing on external behaviours and risk being constrained to the limited sample of activities actually observed (Patton, 2002).

The choice to perform observation onboard during the full scale evacuation trials was given the perquisites. There was no possibility to participate in the planning of the trials nor was it possible to have any influence on the scenario which was to take place on board. Some information was available, i.e., type of evacuation equipment, other ships participating, but few details were given. The observers were given all available information but had to be prepared for changes such as changes of assigned location.

6.3 Interviews (Study III)

Interviews allow the researcher to explore feelings and thoughts (Patton, 2002). The open ended approach provides rich and dense data (Corbin & Strauss, 2008; Patton, 2002). The strength of an open ended approach is that it is flexible and deep but is time consuming and provides data that can be difficult to put together and analyse (Osvalder, et al., 2008; Patton, 2002). Standardized interviews minimize the variation among the participants, are time efficient and easy to analyze (Patton, 2002). However, the standardized interviews reduce the extent to which individual circumstances and differences can be queried (Patton, 2002). The participants had experience from several types of ships and ships of different age. To be able to obtain the possibility for the participant to express his/hers individual experience from the work environment and keep focus of the aim of the study a combined approach was used. The participants were presented to themes and back-up questions were prepared to ensure all participants covered the same areas within the engine room.

6.4 Questionnaires (Study IV)

The research questions concerning the perceived job stressors among the engine officers were covered by two well established inventories, the role stress scale (Rizzo, House, & Lirtzman, 1970) and a modified version of the job content questionnaire (Stansfeld, Head, & Marmot, 2000). Also for the mental strain measures two firmly validated scales were applied, the short version of the perceived stress scale (PSS) (Cohen & Williamson, 1988) and the short version of the general health questionnaire (GHQ12) (Goldberg & Williams, 1988).

Using a questionnaire enables the researchers to reach a large population and eliminates any interaction between the researcher and the participants as was the case during the interviews (Denscombe, 2000). There is, however, a risk of the participants misinterpreting questions (Osvalder, et al., 2008). Seafarers are generally away from home for approximately half of the year and have their residence all over the country. In order to be able to reach a larger population, a questionnaire was chosen for practical reasons. A potential disadvantage with this type of study is a low percentage of answers (Denscombe, 2000; Osvalder, et al., 2008). This was addressed by sending out a reminder after two months and yet another two months later. The duration of the data acquisition was extended to two months after the second reminder had been sent out, in total a duration of six months.

6.5 Triangulation

The use of triangulation, i.e. the use of several methods, sources and/or analysts offer strategies for reducing systematic bias (Patton, 2002). The choice to combine a qualitative and quantitative approach had several reasons. The context in which the full scale trials took place and the circumstances given gave little opportunity to use other methods than observations. The interviews gave rich and descriptive data but cannot be generalized for the whole population. The questionnaire was on the other hand sent out to 99 % of the population of engine officers. All methods contributed to investigate the interplay between the ship, the technological system on board and the human system.

7 Methods and Materials

7.1 Study I

Study I was based on on-board surveys performed on seven different ship types within the Swedish merchant marine fleet. Time spent on board on each ship was in average ten days. These ships represent different ages ranging between 30 years to 6 months old. Extensive interviews with engineering crew and detailed observations and measurements of the ERs and ECRs were included in the study. The engine crew members were interviewed and questionnaires regarding technical systems and environment were used. Field measurements of physical work environment factors were performed. The measurements were: lighting, noise, temperature, humidity, CO_2, vibration and electromagnetic fields. In the field study observations, different functionalities were highlighted. These include the layout of the ECR, switchboards, accessibility, console design, alarm management and monitoring outside the ECR, communication, administrative area and briefing/rest area. In addition to this task analysis and link analysis of the work in the ECR were performed (Wagner, et al., 2008). The results from link and task analysis constitute the basis for the results and recommendations presented in study I.

7.2 Study II

7.2.1 Design

This study includes observations accomplished on board five full scale evacuation trials carried out on different types of ships.

7.2.2 Participants

The participants volunteered to participate in the full-scale trials on board.

7.2.3 Measurements

Hierarchical Task Analyses of the tasks being performed by the crew members and passengers using different means of evacuation pointed out areas of interest. These areas were then observed at the full scale trials.

7.2.4 Procedures

The observers were provided with an observer's log. The scenario determined where the observers were placed.

7.2.5 Analyses

The observers' logs and observations were analyzed for common denominators.

7.2.6 Ethical considerations

Participants were informed by the shipping company about the study, while the shipping companies were responsible for the recruitment of the participants (valid for four full scale trials). The researchers were responsible for recruitment of participants to one of the full scale trials. The participants were on this occasion informed about the study by the researchers.

7.3 Study III

7.3.1 Design

A total of twenty engine crew members were interviewed.

7.3.2 Participants

The participants consisted of twenty engine crew members (19 Swedish and one Norwegian) in various positions, all male, ranging from 26 to 70 years in age with an average age of about 50 years. 15 of the participants were officers (engineers), 5 where ratings (repair- or motormen and one electrician).

7.3.3 Measurements

Verbal reports from semi-structured interviews with participants were affected.

7.3.4 Procedures

Fifteen of the interviews were performed on board different ships, four at Chalmers University of Technology and one at Kalmar Maritime Academy. The interviews consisted of two themes, “The ECR” and “The ER”, with follow-up questions prepared. The participants were interviewed individually and were asked to express their thoughts about the work situation on board. Follow-up questions were individually asked to further elaborate the answers given by the participants. The interviews lasted from one to one and a half hour each, they were taped, transcribed verbatim and consecutively analyzed.

7.3.5 Analyses

A Grounded Theory approach was used for the analysis of the interviews using the analytic tools of coding, constant comparison and theoretical comparison (Corbin & Strauss, 2008). Theoretical sampling was used in the selection of participants in order to develop concepts in breadth and depth. The concept of theoretical saturation by Corbin and Strauss (2008) was used to decide on the sample size.

7.3.6 Ethical considerations

The participants were, prior to the interview, informed about the purpose of the investigation, how the data was to be used and published. They were also assured confidentiality and that they had the right to withdraw their participation without reason and also their right to read the results prior to publication. The participants also signed a written consent to participate.

7.4 Study IV

7.4.1 Design

A total of 1383 questionnaires were sent to all engine officers affiliated to the Swedish Merchant Marine Officers' Association.

7.4.2 Participants

The sample consisted of 1383 engine officers. A total of 731 – which equals 54%, of the participants returned the completed questionnaire and were thus included in the study. The mean age of the participants was 47 years (Sd = 11.6), 99% were men, and 99% of the participants were Scandinavian; 76% of the participants were in a relationship while 24% were living alone; 41% had children living at home. The mean time in current occupational position was 13 years (Sd = 10.5) and their total experience at sea was in average 24 years (Sd = 12.8). The positions on board, represented in the sample, were Chief engineers (44.5%), Second engineers (29.5%), Third engineers (14.0%), Electrical engineers (11.5%) and Others (0.6%), all categorised as engine officers.

7.4.3 Measurements

Role Conflict and Ambiguity were measured by a slightly shortened version of the Role Conflict and Ambiguity Scale from NIOSH Generic Job Stress Questionnaire, initially developed by Rizzo, House and Lirtzman (1970).

The Demand-Control-Support model was assessed by the Job Content Questionnaire (JCQ) (Karasek & Theorell, 1990; Stansfeld, et al., 2000). Demands were measured by four items with Cronbach's α coefficient of

.69. Work-related control was measured by 16 items with Cronbach's α coefficient of .77, ten aimed at decision authority in the work situation and six items aimed at skill variety. Work-related social support was measured by seven items with Cronbach's α coefficient of .80.

Work-family interference (WFI) and family-work interference (FWI) was measured by single items.

The short version of the General Health Questionnaire (GHQ12) was used as an indicator of mental strain (Goldberg & Williams, 1988), with the Cronbach's α coefficient .85.

As a second indicator of mental strain, the 10 items version of the Perceived Stress Scale – PSS10 was used (Cohen & Williamson, 1988). The time frame referred to was "the last month", and each item had five response alternatives (0 never - 4 very often). Examples of items in the scale were: "In the last month, how often have you been angered because of things that were outside your control?" - "In the last month, how often have you felt that things were going your way?" The mean PSS10 score was 1.47 (Sd 0.59) – which is above the scores for PSS10 in reference data for an American population, presented by Cohen and Williamson (1988): The Cronbach's α coefficient for PSS10 in the present study was .84.

7.4.4 Procedure

The questionnaire in total with all measured scales described above included 129 items. The Merchant Marine Officers Association, which held the only reliable address register over the target group for this study, also administrated the dispatch of the questionnaire. This was followed by two reminders with two months in between. The Merchant Marine Officers Association agreed to assist with a mailing list of members with the reservation that the members' identity remained anonymous to the researchers. This rendered any drop-out analysis or longitudinal follow-up study impossible.

The British sample used in the comparison to the engine officers consisted of male and female workers from 20 organisations across 11 industrial sectors in the UK. Male and female workers within the age range of 18-69 years were included in the study. The response rate was 39% or 3139 persons with an overrepresentation (70%) of white-collar workers (office workers, computer operators, technicians etc) and 30% were blue collar workers (delivery drivers, manual handlers, production line workers, oil rig workers etc) (Devereux, Rydstedt, Kelly, Weston, & Buckle, 2004).

7.4.5 Statistical analyses

Inter-correlations for all the variables in the study were made. The statistical method used to analyse the data was hierarchic linear regression. Work role conflict was initially introduced while the dimensions of the Job-Strain model were introduced in the second step of the equation. In the third and final step, work-family and family-work interference were introduced.

7.4.6 Ethical considerations

An information letter was sent out together with the questionnaire to all participants. The participants were informed about the purpose of the study, that all participants would be anonymous, how the results were going to be presented and that their participation was completely voluntary. Who was responsible for the study and who to contact for more information was also stated.

8 Results

8.1 Study I

The ship´s bridge and the ECR share questions at issue, both departments have undergone changes due to the introduction of computers and automation. The development of the guidelines concerning the design of the bridge is more comprehensive than those of the ECR and the future development of guidelines for design might benefit from a comprehensive approach where both control centres design criteria are jointly developed.

8.2 Study II

Four key areas were identified from the analysis of the observations, and the interviews with the observers. These were the safety organization, the ability to perform the tasks, the handling of life vests and communication.

A malfunctioning organization was present in all five trials. Parts of the crew members acted unsecure, hesitated and were not confident in their roles and what was expected of them. In two trials the crew consisted of only two crew members which proved insufficient as the crew struggled to manage their tasks.

In all five trials, the crew showed lack of skills to handle the evacuation equipment and also in communicating with passengers, both with information in general but also in specific situations at mustering stations.

Problems with the life vests were seen in three of the four trials in which they were used. Adults used children's life jackets and vice versa and the straps were not tightened correctly (figure 3). Even crew members were reported to have great difficulty in handling straps and clasps. Only in the second trial, no problems with distributing and donning the life vests were reported.

Figure 3. Incorrect donning of life vest's straps

Difficulties in communication were present in all five observed trials. These difficulties consisted mainly of poor quality of the PA-systems with regards to the quality of the sound in the loud speakers, which made it difficult to comprehend the safety messages and information. Crew members were also insecure in the handling of the communication equipment within the crews (walkie-talkies).

8.3 Study III

The analysis of the interviews resulted in a number of categories that each have an impact on how the engine crew perceived their work situation and each will be reported below.

8.3.1 The Engine Room (ER)

One of the most important elements in the work situation in the ER was the logistics, i.e., the possibility to transport heavy pieces of machinery, equipment, spare parts and personnel. It was considered essential that the ER was equipped with appropriate lifting devices both for transportation in vertical as well as transportation in horizontal directions, i.e., between different floors in the ER, to and from the ECR, storage facilities, workshop and cleaning areas but also to and from the ship.

According to several of the participants, accessibility was further one of the determining aspects of the working conditions in the ER. Accessibility is referred to as sufficient space to perform maintenances and repair activities but also the placing of the equipment. Equipment frequently checked need to be easy accessible.

When one or both of these conditions were not fulfilled the crew members were obliged to find alternative solutions, e.g., clean equipment where it was dismantled or walk on top of equipment, actions that increase the risk of injuries and exposure to harmful substances.

8.3.2 The Engine Control Room (ECR)

Overview of the operating values in the ECR was frequently mentioned as one of the most important issues. According to the participants, the digital interface, that the computer based surveillance equipment offer, provided a lot of information to the engineer and offered a flexible system overview on limited space. However, the participants perceived that the comprehensive overall overview with an immediate access for everyone, that characterized the analogous equipment, was lacking with computer-based surveillance systems. The participants also reported that the information could be difficult to get access to and time consuming to retrieve due to a sometimes complex hierarchical menu structure.

Another consequence of the technical development that was stressed by the participant was the increase in number of alarms on board. They perceived the handling of the alarm systems as sub-optimized.

Further, the ECR should according to the participants provide an environment that enables rest, recovery and relaxation. Low noise level, a comfortable temperature and low vibrations were the most important constituents mentioned by the participants with regards to recovery possibilities. As a result of the changes in work conditions over the past years, the participants also expressed the need for a workplace ergonomically adjusted for a seated position in front of a computer and a work place suited for administrative duties.

8.4 Study IV

The engine officers reported significantly higher presence of role conflicts, they also reported a significantly lower degree of role ambiguity than the British sample. Engine officers reported significantly lower job demands as well as higher control than the British sample, while there were no significant differences in social support between the groups. In terms of work-family conflicts, there were no significant differences between the groups in terms of WFI, while the seafarers reported a significantly higher presence of family-work interference. With regard to the outcome variables, the engine officers reported significantly higher perceived stress while the two groups did not differ in mental strain as measured by GHQ.

8.4.1 Perceived stress

Role Stress accounted for almost a third of the variance (R2 =.319) in perceived stress and the conflict dimension was more strongly related to perceived stress than was role ambiguity. When introduced in the second step of the equation, the DCS model accounted for additional 5.4% of the variance in perceived stress. Psychosocial job demands, but neither control nor social support, significantly affected perceived stress. The third step of the regression analysis also showed that the relationship between work-family conflicts and perceived stress reached a significant level, albeit marginally so, WFI, but not FWI, was significantly related to perceived stress. Taken together, the model accounted for 39.1% of the variance in perceived stress.

8.4.2 Mental strain

Role stress accounted for 22.2% of the variance in this measure of mental health and the conflict, but not ambiguity, contributed significantly to this relationship. The D,C,S model accounted for 4.6% of the variance in GHQ, and all three dimensions of the model contributed to this outcome – although the contribution from job demands showed the strongest influence. The influence from work-family conflicts showed an almost identical influence on mental health as on perceived stress, that is a significant influence of WFI, but not of FWI.

9 Discussion

The ship as the hull and technical system provides a frame for the physical work environment on board and thus furnishing the prerequisites for the crew and their performance. The hierarchical organisational structure on board has not changed, despite the diminished manning. One of the main results in this thesis is that the crews had adapted to the prevailing sub-optimal conditions onboard as shown in study II and III in particular. In order to fulfil their tasks, the crew had to adapt to the existing physical context, technology, rules and regulations and organizational structure. The adjustment towards these prerequisites has forced the crew to, under certain circumstances; find alternative means of performing their work, an adjustment that will negatively affect performance, safety and the psychosocial environment.

9.1 Research question I

Study I in this thesis indicate that the technical developments on the bridge and in the engine department show many similarities. Despite this, the prevailing guidelines for the bridge design are more comprehensive than those of the engine control room (IMO, 1998, 2000). The initial stage of the technological and organizational changes on board ships, belonging to Scandinavian ship owners, originates from the mid sixties (Bloor, et al., 2000; Höivold, 1984; Olofsson, 1995). A study on well-being and work conditions on board Swedish merchant ships performed by Werthén (1973b) highlighted the differences in opinion among the ship's officers regarding the consequences of the ongoing technical development. One of the conclusions in the study by Werthén (1973b) was that the engine officers, in this early phase of the technological development, experienced an increased work satisfaction on board new and more technologically advanced ships compared to older ships. The more technologically advanced ships offered an environment which entailed a development of the engineers' skills (Werthén, 1973b). This was by the author ascribed to the education of the engine officers, which was suited for a more technologically advanced environment.

The development of fully automated engine rooms, complying with the E0-requirements, also implied an organisational change in the engine department. The engineers who served on board these ships started working day-time with scheduled on duty call which relieved them of watch keeping duties (Höivold, 1984). The early stages of the technological development thus provided the engine officers with more interesting and challenging tasks and improved working conditions. The nautical officers on the other hand did not experience any major advantages in the technologically more advanced ships, instead they felt worried about the new demands (Werthén, 1973b). This difference in apprehension between these two professional categories on board may have contributed to the shift in attention towards the working conditions for deck personnel, which were perceived as the most troublesome.

9.2 Research question II and III

The technological development on board has continued. Study II and III indicate that working on board render an adaption to the technological and organizational context. One of the most challenging situations onboard is the adaption to the role in the safety organisation. The number of crew members on deck and in the engine room is not sufficient to man all positions of the safety organization on board a passenger ship, which entails that the catering crew has to participate in the evacuation process. This implies, for the vast majority of the crew on board a passenger ship, major changes in demands of the tasks to be solved. The adaption towards these demands are most likely easiest for the deck end engine room crew as these two groups are accustomed with the operation of the ship in their normal routines. These different occupational groups, deck, engine and catering department, on board have different qualifications and prerequisites to adapt to their assigned role in the safety organisation. The basic safety training, which is compulsory and common for all sea farers, contains the minimum standards of competence in personal survival techniques, is equal for all occupational groups on board (IMO, 1996b). Study II has drawbacks that are addressed, but the safety organization, the ability to perform the tasks, the handling of life vests and communication, are all areas of interest when evaluating the evacuation of passengers. The evacuation analysis calculated in the IMO declaration (IMO, 2007) is based on time. The results found in study II represent different important constituents all which are present during an evacuation. These constituents risk adding extra time to the evacuation process which should be accounted for in the analysis of the ship's evacuation. The uncertainty in handling the evacuation equipment seen in study II suggests that the training and education, which prepares the individual crew member for the challenges involved in an evacuation, could benefit from taking the different occupational groups´ previous knowledge into consideration when determining the syllabus of the basic safety training course. This could indicate a need for different basic safety training for different occupational groups to facilitate the crew's ability to adapt towards their role in the safety organisation.

The result in study III indicated an adaption towards a technological context. The participants describe a physical environment that lacks the support to the tasks to be performed, as also was the case of the physical environment in relation to safety, as found in study II. This also coincides with the workstations and their suggested mutual layout in the ECR given in study I. The purpose of the suggested lay-out of the work areas was to create a surrounding that could support the work in the ECR by providing an overview governed by the tasks performed at each work station. The importance of retaining overview while changing from analogous to digital equipment in the ECR was stressed in study III and has also been discussed in previous studies and in shore based industries (Grundevik, 2008; Veland & Eikås, 2007).

Study III also indicates that the engine officers appreciate the introduction of computers in the ECR. Recent research confirms that a majority of seafarers have a constructive attitude towards technology in general (Allen, 2009). The technological development and the introduction of computers have implied changes in the demands of the work role. The result of study IV suggests that the engine officers experience a role conflict. The engine officers appear to be in favour of the technological development but their knowledge could be falling behind. Taken together, this could indicate that the training and education of the engine officers needs to be further investigated to certify that the officers on board are provided with relevant knowledge to be able to adapt to the new technology and comply with the new demands. This is also recognised by the IMO as the international minimum requirements of the education, certification and watch keeping for seafarers as stipulated in the STCW Code (IMO, 1996a), which is currently being revised.

Further, results from study III illustrate the need for taking the organisation into consideration while designing ships system. Study III indicates that the engineers now apprehend the alarm systems as being sub-optimized and incomprehensive to use. The work in the engine department implies periods of single-handed work (Olofsson, 1995) and for the alarm system to support this organisational situation it needs to be more flexible. Slave panels in the engine room and/or pagers which can manage alarms facilitate the management of the alarms and support the engine officers during periods of single-handed work. The need for a more flexible management of the alarm system on board has been described in previous research (Grundevik, 2008). The research performed in other process and industrial settings can be helpful when designing alarm systems for ships. Thunberg and Osvalder (2009) concludes in their research that alarm handling can be made more effective if the operator is supported by, i.e., alarm prioritization and suppression of irrelevant alarms. The work conditions in the ECR on board are slightly different from the work in a shore based control room with round-the-clock manning. The ECR on board is not always manned which further stresses the importance of the conclusions made by Thunberg and Osvalder (2009).

The logistics is mentioned, in study III, as one of the most important characteristics of the ER. A result which is supported by the previous study of (Ivergård, et al., 1978). As the number of crew members has been further reduced the more important it is that the work in the ER is supported by the design. The fewer "hands" in the ER, the more important it is that sufficient lifting aids are available, likewise appropriate gratings, platforms and ladders. The consequences of the adaption here, when the hull and technology fails to support the tasks to be performed, increases the risk of injuries while performing maintenance and repair work. Slip, trips and falls are a substantial risk of injuries on board and the cleaning of engine parts is one of the situations where the risk of being exposed to harmful substances is at its largest (Forsell, et al., 2007, 2008; Jensen, et al., 2005).

Previous research describes areas of concern similar to those found in study III (Ekelin, 1977; Flising & Stefenson, 1977; Ivergård, et al., 1978; Svedung, 1977). The result of field studies performed on seven Swedish ships indicated that some of these areas had been improved, such as vibrations and noise in the ECR (Wagner, et al., 2008). However, other problems such as the logistic in the ER, awkward working postures and the risk of slip, trips and falls, identified in previous research of later date remain unsolved (Anderson, 1983; Ivergård, et al., 1978; Jensen, et al., 2005; Seif & Muftic, 2005; Wagner, et al., 2008; Veenstra & Ludema, 2006). The development in technology and the introduction of computers have implied that new problems has been added, e.g., lack of overview of operational values and status of equipment, problems which have not yet been comprehensively studied in the ECR (Wagner, et al., 2008).

The results in Study III, highlights the importance of the design of the engine department considering the organizational changes and how tasks are performed. Previous research has also stressed the importance of involving the end user into the design process (Bridger, 2009; Clegg, 2000; Ivergård & Hunt, 2009). The computerization and the increase in automation have increased the number of systems on board, which require new and different knowledge. The engine officers still need to have a sound knowledge in operational and maintenance work. In addition to this, the automatic control systems call for an increased knowledge about electric-, electronic equipment and control engineering. The contemporary work role of the engine officers has changed from mainly handling mechanical tasks to a role which also entails pronounced operational and surveillance skills. (Anderson, 1983; Andersson & Lützhöft, 2007; De Joode, Burdorf, & Verspuy, 1997; Jensen, et al., 2005). This can be regarded as arguments which further support Liberia's initiative to an overhaul of the exiting guidelines for the engine-room layout, design and arrangement (IMO, 2006a).

9.3 Research question IV

The work roles of the engineers have changed from operator to monitor which implies that the demands imposed on the engine officers due to the development of the automatization on board are different (Allen, 2009; Parasuraman, 1987). The result in study IV indicating that the engine officers perceived stress to a considerable extent, can be explained by a work role conflict which suggest that the engine officers are less satisfied with their situation as of today. The engine officers did not report any role ambiguity in study IV. This result is not surprising as the hierarchical structure of the crew implies that every role is well defined with regards to areas of responsibility. The organizational structure on board is hierarchical and each position is associated with a specific area of responsibility. It varies in details depending on type of ship, but in broad outline, the crew members are aware of what is expected of them when signing on a ship.

According to the results in study IV, the engineers also perceived elevated levels of stress compared to a multi-occupational British sample. There is a clear unanimity in the source of the elevated stress levels found on board (Agerberg & Passchier, 1998; Elo, 1985; Oldenburg, et al., 2009; Zeitlin, 1995). The results presented by Agerberg and Passchier (1998) supports the results in study IV which suggests that it is not the content of the work but rather the role conflict which is the cause to the perceived stress. The results also indicate an elevated stress level among the engine officers but no elevated risk of mental ill-health.

This, however, needs to be investigated further. Further, the generic established stress models cannot be expected to provide a specific root cause as these models aim at capturing those generic constituents important for the stress experience. More occupation-specific instruments need to be developed to better capture which work-related constituents that cause ill-health among seafarers.

9.4 Summary

Olofsson (1995) presented the ship from a sociotechnical perspective (figure 2). This perspective is chosen to further illustrate and explain the results found in this thesis. The model in its original form constitutes a foundation that aligns well with the results from the respective studies. Based on the results found in study I, II and III, the model has been extended to also include organizational issues and in the external environment emphasize regulatory issues (Figure 4).

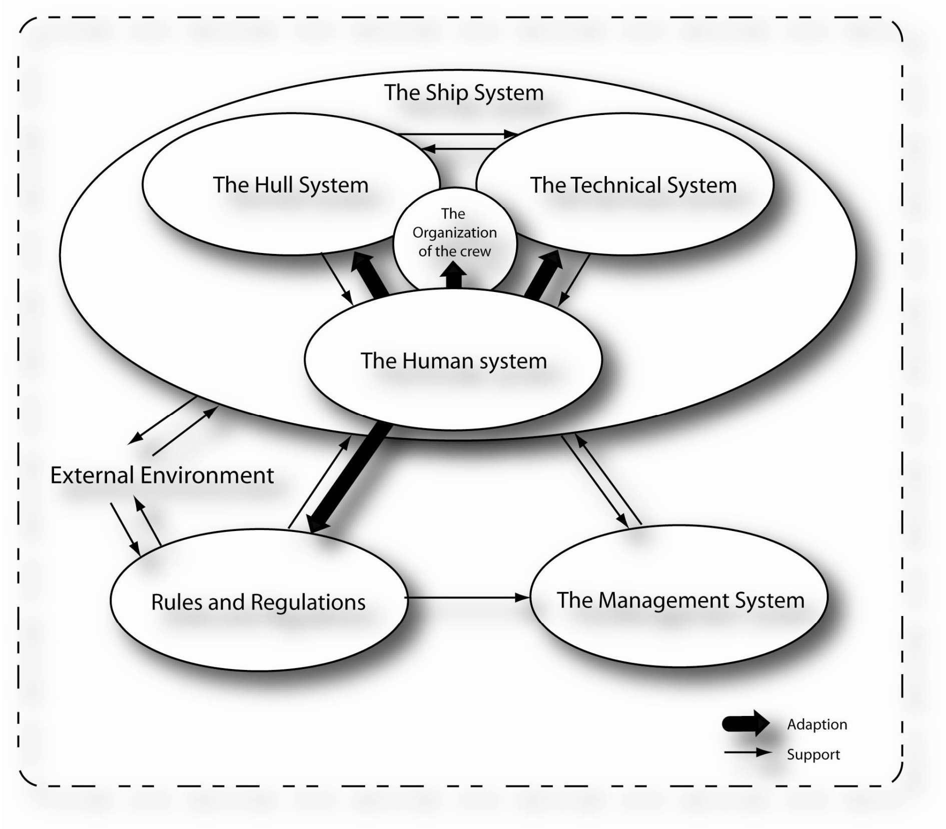

Figure 4 The ship in a system approach elaborated from figure 2 by (Olofsson, 1995).

The demands put on the seafarer have changed over the past years as described in study I and III in particular. This is demonstrated in study IV, which reveals that the engine officers are not satisfied with their work role on board as they experience a role conflict and elevated levels of daily stress. This is partly ascribed to the separation from the family but this does not fully explain the role conflict alone. Study II and III reveal that the crew lacks the prerequisites needed to manage and facilitate their work.

The framing of the physical context of the ship, hull and technical systems in the engine department are determined by SOLAS and the guidelines for the design of the engine department (IMO, 1998, 2001). The existing guidelines concerning the engine department admit and generate sub-optimal design solutions which the crew has to adapt to, as supported by the result in study II and III. Further, the results found in study III also stresses the importance of taking the organizational issues on board into consideration while designing ships. The fewer people on board the ship that can contribute, the more important it is that the design is supporting the work of the crew rather than forcing them to adapt and find alternative ways to perform their tasks.

The effectiveness of an organization are from the social technical system's perspective dependent on how well the technical and social systems are designed with respect to each other and to the demands of the external environment (Pasmore, 1988). As of today, the crew has been forced to adapt towards the existing context and conditions. The prevailing rules and regulations imply a physical context and technology which does not support the work of the crew. The reduced manning on board has not been proceeded by any changes in the hierarchical structure which leaves the crew having to adapt towards fewer hands available to manage the operation of the ship. Clearly, the technical and social systems are not designed with respect to each other or to the demands of the external environment. Future design of ships should provide an environment which is designed and integrated with both the organization onboard and the work that is performed. Given the results and as shown in figure 3, the only way to ensure and facilitate this work is if this presented research can constitute a basis for further improvement and development of current rules and regulations that originates from the crews physical and psychosocial wellbeing.

9.5 Method

The approach to the research questions has guided the choice of methods used in this thesis. Each research approach has their strengths and weaknesses. Further, the choice between these two research paradigms, i.e., qualitative and quantitative methods, implies a trade off between depth and breadth (Patton, 2002). Discriminating between qualitative and quantitative research methods is, however, not always straight forward. Researchers have discussed this distinction and claim that all research, independent of the choice of method includes qualitative as well as quantitative features (Allwood & Erikson, 1999; Patton, 2002). The two research fractions can also be regarded as complementary (Hammersley, 1996; Patton, 2002; Thurén, 2003). Patton (2002) argues that quantitative methods can be utilized for identifying areas of focus while the qualitative methods give substance to those areas. But this can also be regarded vice versa; it is possible for qualitative data to point out areas of focus, quantitative data can then give an apprehension of the magnitude of the area in focus (Barbour, 1998). The overall purpose of this thesis was to create knowledge to improve work conditions on board. To achieve this goal and to find both important focus areas, evaluate the presence and magnitude of the areas in focus, a combination of methodological approaches had to be applied.

9.6 Qualitative and quantitative methods in research

Qualitative and quantitative research represent two different paradigms and is the subject of discussion of how to evaluate the quality within each paradigm. On the discussion of qualitative versus quantitative research paradigm Hoepfl (1997 p. 48) states that "Where quantitative researchers seek casual determination, prediction and generalization of findings, qualitative researchers seek instead illumination, understanding and exploration of similar situations". The two research paradigm thus result in different kinds of knowledge which call for alternative sets of criteria for judging the quality of each work (Patton, 2002).

The evaluation of quality in quantitative studies is determined by the fulfilment of validity and reliability. In order to obtain reliability and validity in study IV, established scales were used. However, the ecological validity can be questioned as the specific work conditions which are present on board ships were not included in the scales.

The definition of quality within the qualitative paradigm is, however, the subject of discussion. Stenbacka (2001) argues that reliability, as used traditionally, has no relevance in qualitative studies. Corbin and Strauss (2008) prefer the term "credibility" in front of validity and reliability, as each method deserves its own set of judgement criteria, which reflects one of many possible and plausible explanations derived from the data. While Eneroth (1984) dismisses the discussion about, e.g., validity as a problem adherent to quantitative method. Alternative criteria or a re-definition of the existing criteria, validity, reliability and generalizability, need to be considered for judging the quality of qualitative work (Golafshani, 2003; Lincoln & Guba, 1985; Maxwell, 1992; Patton, 2002; Stenbacka, 2001).

When reflecting upon quality concepts in qualitative research, it is stated that the most basic insight is that the researcher is always a part of the study (Lützhöft, 2004; Stenbacka, 2001). A qualitative researcher must reflect upon and make visible his/hers possible pre-understanding (Stenbacka, 2001). Grounded Theory as developed by Corbin and Strauss (2008) provides the researcher with a thorough description of the different steps in the analysis. Given this, the definition of quality by Stenbacka (2001), and with regards to my own background, I choose to use the method as it makes the different steps in the analysis visible for scrutiny. This decision was made albeit the critique that Corbin and Strauss' urge for a systematic method risk being too "forcing" (Stenbacka, 2001).

9.7 The participants

The participants in the observations performed during the full-scale trials in study II were all recruited by the shipping companies who were responsible for the planning of the trials. The shipping company also informed the participants about the research that was conducted on board. In two of the five trials, the participants consisted of mainly students from the School of Navigation and people from the Sea Rescue Service which all could be expected to have previous experience of evacuation equipment and life vests. On another occasions, the participants were mainly senior citizens. The two remaining trials had a mix of participants but no elderly or children. Common for all five trials were that there were no participants with disabilities and the participants' middle age was estimated to mid/late thirties with the exception of the trial with senior citizens. None of the senior citizens were disabled or required extra assistance from the crew. All participants were able to follow the crews' instructions. Nor were there any disturbances such as family members becoming separated or people hesitating to evacuate. Compared to realistic circumstances, the conditions under which the evacuation trials were very favourable with regards to weather etc., which most likely affected the results. However, taking all five trials into consideration, the sample represented an age and gender distribution which can be regarded as a representative sample.

The selection of participants for study III was in accordance with the chosen method of analysis, Grounded Theory, and followed the principles of theoretical sampling (Corbin & Strauss, 2008; Patton, 2002; Pidgeon, 1996). The sample size was determined by saturation at a level where the development of categories in terms of properties and dimensions ceased (Corbin & Strauss, 2008). The number of participants in study III was in total 20 and consisted of 15 officers and 5 ratings. The predominance of officers in general and chief engineers in particular (9 chief engineers participated) was due to the decision of having participants who could provide the most variation with regards to previous knowledge and experience of the work in the engine department. The participants had experience from different types of ships; tankers, Ro-Ro ships, ferries, cruise ships container ships ranging from being built in the sixties to being a couple of years old. The chief engineers represent the engine crew which has experience from every position in the engine department.

In study IV the whole population of engineers affiliated to the Merchant Marine Officers' Association was approached. The questionnaire was sent to a total of 1383 engine officers. The total number of engine officers in Sweden during the time of the data collection mounted to 1397 which implies that 99% of the population was reached (Transportstyrelsen, 2009a).

9.8 Data collection

Direct observations were used in the field studies in study II. The method is labour intensive but takes the reader to the setting that was observed (Eneroth, 1984; Patton, 2002). Direct observations allows the researcher to become alienated from the participants being observed (Eneroth, 1984). However, an influence on the participants due to the presence of the researcher cannot be disregarded as this can bias the behaviour of the participants. The data obtained by observations provides the researcher with information with regards to the behaviour of the participants, but it does not give any explanation to the behaviour (Eneroth, 1984). The field studies performed during the full scale trials contained only observations and it is possible that a follow up study, with complementary interviews could have provided a deeper understanding for, and an explanation of, the observed behaviour. A questionnaire based on the result of the observations could have been another possible complementary method, which could have contributed to the results.

With regards to the situation during these full scale trials, getting access to participants for additional investigations was difficult. The trials were planned by the shipping company together with the other participating units, e.g., the Maritime Rescue Coordination Centre (MRCC), the sea rescue service, the police, the coast guard and medical service etc. The main purposes of these trials were to test the safety organisation on board and the coordination between the ship and the other participating organisations. The research is thus to be conducted on "borrowed time", taking advantage of occurring pre-planned events, not interfering with the tasks of the participants. Nor is it financially possible for a research organisation to carry the costs of these kinds of trials despite the clear advantage of being given the opportunity to plan and organise it from a research perspective.

The data collection in study III was performed through combined interview approach. The participants were presented to themes and were asked to elaborate on the work environment. Back-up questions were prepared to ensure all participants covered the same areas within the engine room. The participants were interviewed both on board and ashore. This was due to practical reasons dependent on the character of the participants' work schedules. The location of the interviews was not considered important for the outcome of the results since none of the questions required the on board equipment or was contextually dependent. The interviews that took place ashore were only preceded by e-mail contact and/or telephone call to determine time and place while the researcher stayed on board for the interviews performed on board. When the ship is in port, the engine officers are busy and thus, finding time for longer interviews is difficult. However, on those occasions where the researcher stayed on board, the participants had the opportunity to relate to the researcher, which gives the interviews different prerequisites. An interviewer effect may also be present as the respondents on board became aware of the interweaver's background as a marine engineer (Denscombe, 2000).

An alternative approach could have been to use focus groups (Wibeck, 2003). It was, however, decided against using focus groups due to practical reasons. The size of the engine room crew is relatively small, especially as the studies did not include crew members outside Scandinavia. Furthermore, they were all well acquainted with each other after having worked together on board. It is also difficult to gather the crew members while on leave as they can have their residence all over Sweden.

In study IV, a questionnaire was used to collect data. The seafarers are spread out all over Sweden and spend half of the year away from home. Questionnaires are thus frequently used in studies performed on a seafaring population as it reaches a large sample providing representative data.

9.9 Analysis

9.9.1 The observations

The research team did not have any contact with the participants prior to the full scale trials. The lack of opportunity to participate in the planning of the trials made the planning of the observations difficult. There were however some known facts like type of ship and means of evacuation. The observation log was based mainly on the type of equipment which was of current interest for each trial. The observers were, prior to the trials, given the available information and were instructed to observe the crews' interaction with the technical equipment and with the passenger group. After each trial the observers met and accounted for their observations. Notes were taken and used in the analysis when all trials were completed.

Previous research that has focused on observing large scale exercises have used computer based systems that handles distributed sources of information, from different actors involved together with trained observers (Morin, Jenvald, & Thorstensson, 2000). If a computer based reporting tool had been available a more systematic and complete approach would probably have been possible.

9.9.2 The interviews

Grounded Theory (GT) according to Corbin and Strauss (2008) was used for the analysis of the interviews. This method aims at a broad description of the different qualities associated with the phenomenon of interest (Corbin & Strauss, 2008; Eneroth, 1984; Miles & Huberman, 1994; Patton, 2002; Smith, 2008). The qualitative data is very rich and in order to be able to overlook the raw data, the number of participants is relatively small (Eneroth, 1984).

Corbin and Strauss (2008) regard previous professional experience as a way of enhancing the sensitivity. Experience can however also prevent analysts from reading data correctly, which is why the researcher should be careful not to impose his/her own previous experience on the data. The experience should rather be used to bring up alternative possibilities of meaning (Corbin & Strauss, 2008).Given my background I felt it very difficult to refrain from my previous experience and wanted instead to try and make use of it. Albeit given it careful consideration to any potential bias which it could have led to. The decision to use the work by Corbin and Strauss (2008) was based mainly on the possibility to use of prior knowledge in the research process.

9.9.3 The questionnaire

These generic models aim at sorting out the complex relations by identifying and measuring basic features which by the authors are considered as having an effect on health. The Role conflict and ambiguity scale study chronic role stress and the DC/S model have low control and high demands, especially in combination with low support as key components.

The questionnaire is originally in English and was translated to Swedish. Both versions were used in the survey. Prior to the distribution of the questionnaires a pilot study was performed to ensure complete comprehension between the two versions of the questionnaire. The reason for using the questionnaire in both English and Swedish was to ensure complete comprehension of the questions presented to the participants.

The result in study IV was partly contradictory. The participants reported higher stress levels but also higher control and lower demands than the British sample. According to the DC/S model high control and low demands should contribute to a lower level of stress.

The result in study IV indicates a role conflict but does not specify what the role conflict consist of. The development of more a more work specific instrument might give additional explanation of the perceived role conflict as well as contributing to a better understanding of the work related causes to mental strain among the engine officers.

10 Conclusions

- When compared, the bridge and the ECR show similarities in design and work characteristics of the workstation e.g. overview, development of alarms and introduction of computers.
- The safety organisation proved to be less than optimal in several described ways, which is not taken into consideration when the analysis of the evacuation of passenger ships is calculated and further not supported by current regulations.
- Many of the issues regarding the work environment in the engine department raised some 30 years ago remain unsolved.
- The prevailing knowledge in human factors/ergonomics is not being fully utilized in the design of the engine department. The consequences are a less favourable behaviour which enhances the risk of injuries and implies a less effective accomplishment of the tasks.

- The engine officers report an elevated level of stress and role conflict but no elevated levels of mental ill-health.

- It seems like the job content or qualification levels are not the main source of work stress. Rather, as indicated by the highly elevated of role conflict, the often contradictory requirements raised on the shipping operation seem to often create conflicts. The engine officers are expected to live up to their professional standards on shipping and at the same time be able to operate the ship with reduced crew numbers and high speed to satisfy the requirements for profitability.

11 Future work

The development of future guidelines, rules and regulation of the design of the engine department need not only to take the end users and the tasks to be performed into consideration. The organization of the crew members also needs to be taken into account. The reduced manning and the development of the technology on board has enhanced the need for a design that facilitates the work of the crew rather than force the crewmembers to adapt to less well suited solutions.

The future work within ship design needs to focus on providing input to the process of the revision of the guidelines for the design of the engine department. The shipping industry is highly exposed to competition. Therefore, the continuing work also needs to focus on the development of the guidelines governing the design of the engine department towards a mandatory regulation.

The work situation onboard differs from many shore based occupations with regards to such things as isolation, time spent away from home and not being able to move away from the work place. Future strategies on stress among sea farers need to develop models which aim to investigate the work specific components present on board, i.e., leadership, periods of service and leave, opportunities to improve competence, and organizational development.

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