Ergonomics: An uncharted route to improved overall systems performance in shipping

CECILIA ÖSTERMAN

Department of Shipping and Marine Technology
Division of Ship Work Environment and Safety
Human Factors
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2010
Ergonomics: An uncharted route to improved overall systems performance in shipping

CECILIA ÖSTERMAN

cecilia.osterman@chalmers.se

© Cecilia Österman

Report no 10:119

ISSN 1652-9189

Published and distributed by:
Department of Shipping and Marine Technology
Division of Ship Work Environment and Safety
Human Factors
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone +46 (0)31 772 1000

Printed by:
Reproservice at Chalmers University of Technology
Göteborg, Sweden, 2010
ABSTRACT

Continuously, improved design of hull, propulsion and cargo handling systems has increased speed, capacity and reliability of sea transports. Simultaneously, efforts have been made to perfect crew size and composition in order to optimize operations costs. Mechanization, automation and communications technology has made many manual tasks redundant, enabling ship operations with a minimum of manpower. However, there is an area of potential yet uncharted: occupational ergonomics and the interface between human and technology. As technological systems increase in complexity, the gap between the operator and the system tend to increase as well, causing inefficient operations, as well as maritime and occupational accidents.

The purpose of the present thesis was to present how increased knowledge of ergonomics can contribute to improved overall systems performance and employee well-being in the shipping industry. Using a qualitative, exploratory research approach, three studies have been performed. The studies addressed the key issues of maritime economics, the strategic constituents of maritime economics and how a shipping company’s overall systems performance can be operationalized and linked to ergonomic principles.

It was found that there is a lack of knowledge within the Swedish shipping industry on the economic effects of ergonomics, indicating a need for suitable methods in this respect. Further, it was concluded that overall systems performance in terms of productive time, operational efficiency, quality and employee well-being in shipping would benefit from a ship design that allows not only for operability, but also takes into account the ship’s maintainability, working conditions, habitability and survivability for a safe and efficient ship operation over time.

Suggestions for further work include a quantitative study, investigating the availability of data as well as empirically validate the proposed theoretical links between ergonomics knowledge and systems performance.

Keywords: Ergonomics, human factors, shipping, productivity, efficiency, quality, safety.
I first came across *Konungs Skuggsjá* when I visited Iceland ten years ago. This ancient Norse writing is presented as a dialogue in which a father gives his son advice on how to live a good life, both in a moral and in a more practical sense. The writing starts with a talk on how to become a successful merchant and one passage especially made a great impression:

“Always buy shares in good vessels or in none at all. Keep your ship attractive, for then capable men will join you and it will be well manned.”

*(Konungs Skuggsjá, 1917:84)*

The statement seemed so obvious in all its simplicity. Why should this not be true of the merchant shipping of today? In 2008, when I was given the opportunity to join the Human Factors research group at the division of Ship Work Environment and Safety, I returned to this passage. With one degree in marine engineering, and one in ergonomics, I set out to investigate if knowledge of ergonomics principles can contribute in keeping a ship attractive and well manned to generate good business.

The academic journey has been different from any voyage I have made on the seven seas and I could never have done it without help. First and foremost, I want to thank the informants for kind and committed participation in my research work. I am also grateful to my main supervisor, examiner and head of department Professor Olle Rutgersson who together with Margareta Lützhöft enabled my embarking on this journey. Thank you, Margareta Ljung, Linda Rose and Anna-Lisa Osvalder for being such inspirational co-authors and contributing to my scientific training. Thank you also Paula Liukkonen for daring to take this engineer under your wings and introducing me not only to the field of economics and management, but also to Russian shipbuilding, leadership and courage. I have truly treasured our meetings in Stockholm! Thank you, Lars-Ola Bligård for valuable comments and much appreciated encouragement. Many wonderful colleagues at Chalmers, too numerous to mention, have provided a stimulating and supportive work environment, made me laugh and made me run. Thank you! At last, thank you Peter.

*Cecilia Österman*

Göteborg, May 2010
LIST OF APPENDED PAPERS

Exploring Maritime Ergonomics from a Bottom Line Perspective.
Submitted for approval to WMU Journal of Maritime Affairs

Who Cares and Who Pays? The Stakeholders of Maritime Human Factors

Using Ergonomics to Improve Productivity, Efficiency and Quality in Shipping
Submitted for approval to Maritime Policy & Management

Distribution of work:
Österman has performed and analysed the literature studies, interviews and stakeholder analysis. The papers have been written jointly by all authors, with Österman having the main responsibility for the work.
TABLE OF CONTENTS

ABSTRACT.......................................................................................................................... iii
PREFACE AND ACKNOWLEDGEMENT ........................................................................ v
LIST OF APPENDED PAPERS.......................................................................................... vii
1.  INTRODUCTION............................................................................................................. 11
  1.1.  Background............................................................................................................. 11
  1.2.  Purpose and research questions ........................................................................ 13
  1.3.  Delimitations ....................................................................................................... 14
  1.4.  Outline of thesis .................................................................................................. 14
  1.5.  Abbreviations, acronyms and terminology ....................................................... 16
2.  THEORETICAL FRAME OF REFERENCE ................................................................. 19
  2.1.  Systems theory and the socio-technical system .............................................. 19
  2.2.  Ergonomics, human factors and the human element ...................................... 21
  2.3.  Maritime economics .......................................................................................... 23
  2.4.  The regulatory framework of maritime economics ......................................... 25
3.  METHODOLOGICAL FRAME OF REFERENCE ...................................................... 29
  3.1.  General research approach ............................................................................... 29
  3.2.  Research tools ................................................................................................... 31
  3.3.  Research activities ............................................................................................. 33
4.  RESULTS FROM STUDIES........................................................................................ 39
  4.1.  Key issues in maritime ergonomics .................................................................... 39
  4.2.  The stakeholders of maritime ergonomics ...................................................... 40
  4.3.  Operative measurements in maritime economics ............................................ 43
5.  ANALYSIS AND SYNTHESIS.................................................................................... 45
  5.1.  Key issues in maritime ergonomics .................................................................... 45
  5.2.  Stakeholders of maritime ergonomics ............................................................... 47
  5.3.  Operative measurements in maritime economics ............................................ 49
  5.4.  Relation between good ergonomics and good economics in shipping – tying the knot .... 54
6.  DISCUSSION.................................................................................................................. 61
7.  CONCLUSIONS.......................................................................................................... 63
8.  FURTHER WORK ........................................................................................................ 65
REFERENCES .................................................................................................................... 67
APPENDED PAPERS
FIGURES

Figure 1. General dimensions of ergonomics................................................................. 21
Figure 2. Profit making potential in shipping ................................................................. 25
Figure 3. An outline of the basic elements in the research process................................. 30
Figure 4. The stakeholders of maritime ergonomics through a ship’s lifecycle.................. 41
Figure 5. Conceptual model of productivity, efficiency and quality in shipping ............. 44

TABLES

Table 1. Composition of the informants and their organizational affiliation.................... 35
Table 2. Ergonomic issues and their effects in a shipping perspective............................ 56
Table 3. Indicators for personnel, productivity, efficiency, and quality in shipping .......... 58
1. INTRODUCTION

This chapter gives an overview of the background to the present research. Purpose, goal and research questions are formulated and delimitations accounted for. The chapter ends with an outline of the thesis and an explanation of occurring abbreviations, acronyms and terminology.

1.1. Background

Adventure and a will to engage in foreign trade has stimulated and advanced the building of ships from time immemorial. Continuously, improved design of hull, propulsion and cargo handling systems has increased speed, capacity and reliability of sea transports. It has been stated that a ship’s earnings potential is determined by three factors: cargo carrying capacity, speed and versatility, and that these factors are determined by certain technical characteristics of the ship (Veenstra & Ludema, 2006). Simultaneously, efforts have been made to perfect crew size and composition in order to optimize operations costs (Ding & Liang, 2005; Stopford, 2009). Mechanization, automation and communications technology has made many manual tasks redundant, enabling ship operations with a minimum of manpower. A striking example of the technology development is the world’s largest container vessel, the Emma Maersk, which is 397 meters long, can carry over 15 000 twenty-foot containers, and is normally operated by a crew of only 13 people (Maersk, 2010).

However, there is yet an area of potential to develop in the effort to improve ship operations: occupational ergonomics and the interface between human and technology in the shipboard man-machine system. As technological systems increase in complexity, the gap between the operator and the system tend to increase as well. Operators have difficulties in understanding what the technological systems does and correctly detect and assess problems (Osvalder & Ulfvengren, 2008). This gap between human and machine has led to a number of incidents and accidents over the years. Two recent and similar examples are the container vessel Savannah Express’ collision with linkspan in Southampton Docks in 2005 after an engine failure (MAIB, 2006), and the loss of control of the product tanker
Prospero that lead to heavy contact with a jetty in Milford haven, in 2006 (SHK, 2007). Both incidents resulted in material damages only.

Additionally, the area for potential improvements of ship operations is also shown in the fact that despite significant changes in work tasks onboard, towards more monitoring and administrative work, shipping still suffer from a high level of occupational accidents (Bloor, Thomas, & Lane, 2000; Hansen, Nielsen, & Frydenberg, 2002). Occupational mortality and morbidity rates for seafarers remain among the highest for all occupations (Roberts & Marlow, 2005). The maritime work environment has a high incidence of physiological and psychological stressors (Comperatore, Rivera, & Kingsley, 2005). A constantly moving surface and whole-body vibrations induced by sea and machinery cause accidents, musculoskeletal disorders (Törner, Almström, Karlsson, & Kadefors, 1994) and fatigue (Lützhöft, Thorslund, Kircher, & Gillberg, 2007). With seafarers of different national and cultural background working together onboard, there is a social and intercultural dimension. Life onboard is to a great extent characterized by high demand and low control (Carter, 2005), a combination well known to cause stress (Cooper & Marshall, 1976; Karasek & Theorell, 1990). Divided by department, rank and nationality there is a risk that seafarers feel isolated and a sense of inequality between crew members with different working hours and different wages for the same job (Carter, 2005).

Deficiencies in the work environment can have adverse effects on the individual. However, since shortcomings in the work environment are not always recognised as production problems, money spent on improvements or interventions risks being regarded as a cost rather than an investment. On the other hand, many ergonomists and work environment specialists believe that what is good for the work environment is also good for business. Several studies on workplaces ashore support a relationship between work environment improvements and performance in terms of increased production (Abrahamsson, 2000; De Greef & Van den Broek, 2004; Niemelä, Rautio, Hannula, & Reijula, 2002), less quality deficits (Axelsson, 2000; Eklund, 1995), and reductions in work-related musculoskeletal disorders, personnel turnover and absenteeism (Goggins, Spielholz, & Nothstein, 2008; Mathiassen, Winkel, Liukkonen, Bao, & Björing, 1996).

Poor working conditions lead to negative monetary and other effects for individuals, companies and for the society as a whole (De Greef & Van den Broek, 2004; Leigh,
Markowitz, Fahs, & Landrigan, 2000). In order to achieve better communication between ergonomists and company management, efforts have to be made towards an increased use and understanding of the relationship between commercial value generation and ergonomics. An ergonomic intervention that can be presented in business terms with economic benefits as well as the benefits for the quality of working life is thought to increase the chance of rising necessary funding (Hendrick, 2003). In order to be able to find economic incentives for a comprehensive and systematic work with ergonomic issues in shipping, it is therefore required to investigate the relationships between ergonomic issues and factors strongly linked to a company’s financial results.

1.2. Purpose and research questions

The work presented in this thesis focuses on the relation between good ergonomics and good economics in shipping. The purpose was to present how increased knowledge of ergonomics can contribute to improved overall systems performance and employee well-being in the shipping industry.

The research questions were:

RQ1 Which are the key issues in maritime ergonomics?
RQ2 Which are the stakeholders of maritime ergonomics?
RQ3 How can a shipping company’s overall systems performance be operationalized and linked to ergonomic principles?

In order to answer the research questions, three studies have been performed:

Study 1 explored the concept of ergonomics and examined which major issues that has been addressed in previous maritime ergonomics research and which ergonomic factors that are considered important by the shipping industry itself. It also included a review of models and methods for estimating the cost-benefit of ergonomics in other domains as well as a short survey among Swedish ship owners to investigate to which extent the economics of ergonomics is known in the shipping industry.
Study 2 consisted of a stakeholder analysis to identify the constituency of maritime ergonomics. In short, the study investigated who cares, who pays and who benefits from maritime ergonomics.

Study 3 explored the concepts that make up the bottom line in a shipping company and investigated how productivity, efficiency and quality in shipping can be defined, measured and possibly linked to ergonomics factors.

1.3. Delimitations

The studies in this thesis was limited to comprise merchant ships of 500 Gross Tonnage and above, covered by the mandatory International Safety Management (ISM) Code (IMO, 2002). Naval ships, fishing vessels, training ships and so called traditional ships are not included.

Moreover, the studies were limited to the economics of ship operations in the freight market (Stopford, 2009), and does not consider sale and purchase of ships, asset play or operations strictly related to cargo handling operations in port.

1.4. Outline of thesis

Introduction – gives an overview of the background to this research. Purpose, goal and research questions are formulated and the delimitations accounted for. The chapter concludes with an outline of the thesis and an explanation of occurring abbreviations, acronyms and terminology.

Theoretical frame of reference – presents the thesis’ theoretical foundation. It is initiated with a section on general systems theory, followed by a description of the concepts of ergonomics, human factors and human element. Finally, the economic and regulatory framework of the shipping industry is explored.

Methodological frame of reference – describes the researchers’ journey, beginning with the general research approach, continuing with a description of the research tools used, before ending with a description of the research activities performed in each study. The intention of the chapter is to enable the reader to follow the research process and to form an opinion about the trustworthiness of the findings.
Results from studies – presents the results from the three studies and reflects the evolution of the thesis work.

Analysis and synthesis – presents the analyses of the results in the three studies respectively, followed by a comprehensive analysis and synthesis of the results in relation to the purpose of the thesis, tying the knot between good ergonomics and good economics in shipping.

Discussion – in this chapter the purpose of the thesis is discussed in relation to the quality of the research and the main findings.

Conclusions – summarizes the most important findings from the thesis work.

Further work – presents suggestions for further work and complementary studies.
1.5. Abbreviations, acronyms and terminology

Abbreviations and acronyms

FoC  Flag of Convenience. The country where the vessel is registered differs from the nationality of the owner. The country of registration determines the laws under which the ship is required to operate.

IACS  International Association of Classification Societies

ILO  International Labour Organization.

IMO  International Maritime Organization. The UN agency that deals with maritime affairs.

ISM  The International Safety Management code adopted by the IMO. Objectives are to ensure safety at sea, the prevention of human injury or loss of life, and the avoidance of damage to the environment and property.

PSC  Port State Control. An inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with international regulations and that the ship is manned and operated in compliance with these rules.

PSCO  Port State Control Officer. A person authorized to carry out Port State Control inspections by the maritime authority of the port State and acts under its responsibility.

ro-ro  Roll on, roll off vessels are equipped with one or more ramps, allowing all cargo to be rolled on and off

SMS  Safety Management System.

SOLAS  The IMO International Convention for the Safety of Life at Sea.
## Terminology

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ballast</strong></td>
<td>Sea water pumped into ballast tanks or cargo spaces when the ship is not carrying cargo, to lower the ship in the water.</td>
</tr>
<tr>
<td><strong>Charterer</strong></td>
<td>A person or firm who enters into a contract with a shipowner for the transportation of cargo or passengers for a stipulated period of time, <em>i.e.</em> a shipowner's customer.</td>
</tr>
<tr>
<td><strong>Classification society</strong></td>
<td>An organisation which establishes and maintains proper technical standards for the construction and classification of ships, supervises their construction and carries out regular surveys of ships in service to ensure continued seaworthiness and compliance with safety standards.</td>
</tr>
<tr>
<td><strong>Dry bulk</strong></td>
<td>Coal, grain, minerals, ore, wood products, dry chemicals, edibles etc. transported unpackaged in large quantities in cargo holds.</td>
</tr>
<tr>
<td><strong>Liquid bulk</strong></td>
<td>Crude oil, liquified natural gas (LNG), petroleum, gasoline, liquid chemicals, vegetable oil etc. transported in large quantities in tanks.</td>
</tr>
<tr>
<td><strong>Master</strong></td>
<td>Captain commanding onboard a vessel.</td>
</tr>
<tr>
<td><strong>Off hire</strong></td>
<td>Period of time during which a vessel under time charter is unable to meet the requirements agreed between the charterer and shipowner due to reasons within the control of the shipowner, <em>e.g.</em> machinery breakdown. During this time, the charterer is not required to pay hire money.</td>
</tr>
<tr>
<td><strong>Ship operator</strong></td>
<td>Owner or other operator of ships who enter into a contract with the shipper for the transportation of goods.</td>
</tr>
<tr>
<td><strong>Ton miles</strong></td>
<td>The tonnage of cargo shipped multiplied by the distance it is transported.</td>
</tr>
</tbody>
</table>
2. THEORETICAL FRAME OF REFERENCE

In this chapter, the thesis’ theoretical foundation is presented. The chapter is initiated with a section on general systems theory, followed by a description of the concepts of ergonomics, human factors and human element. Finally, the economic and regulatory framework of the shipping industry is explored.

2.1. Systems theory and the socio-technical system

The systems theory was well framed by the influential philosopher of the systems movement West Churchman (1968, p. 2):

“How can we design improvement in large systems without understanding the whole system, and if the answer is that we cannot, how is it possible to understand the whole system?”

The systems view constitutes an established analytical view with some definite characteristics. A common core is that a system consists of a number of parts that are coordinated to achieve certain goals. According to Churchman (1968), five fundamental aspects must be considered in order to be able to understand and analyse a system:

- The tasks and goals that the system is to achieve
- The environment in which the system operates
- The system’s resources that can be used to fulfil the tasks
- The system’s parts, activities, goals and functional validity. What do the parts contribute with to the system as a whole?
- The management and coordination in the system, and how it is effected.

The essence is not to know all there is about the studied system, but rather to understand the possible implications of our lack of comprehensive knowledge. It is because we never know enough that understanding and critical judgment becomes essential, from an intellectual as well as a moral point of view (Churchman, 1968).
Systems theory has been traced back to Aristotle’s reference to *holon*, the whole, as opposed to the *pan*, the multiplicity; in stating that the whole is characterized not only by its parts, but by the relations between the parts as well (Ropohl, 1999). However, it was the Austrian biologist Ludwig van Bertalanffy that first introduced the term of general system theory and its underlying principles in 1937 (von Bertalanffy, 1968). As a biologist, von Bertalanffy realized that the closed systems studied by physicists, where it is assumed that everything that affects the system are included in the model, is not feasible for most practical phenomena. Conversely, an open system continuously interacts with other systems outside of themselves. This interaction has two components: input, that what enters the system from the outside, and output, that what leaves the system for the environment. Von Bertalanffy called general system theory a general science of “wholeness” applicable to the various empirical sciences (1968, p. 37), and argued that it was not sufficient to understand only the elements in a system, but also their interrelations as well. In each case it is necessary to consider what is encompassed in the studied system, and the boundaries towards the environment.

A major component of many systems is people, acting as users, operators, maintainers and so forth. Even a highly automated system requires people – in any case to start, stop, and monitor the system. Often, users and operators also perform service and maintenance on the machines.

The term socio-technical system refers to the interrelatedness of social and technical aspects when viewing an organization as an open system. The approach was developed largely at the Tavistock Institute of Human Relations and their studies from British coal mines (Emery & Trist, 1960). The point of departure for a socio-technical systems theory is a lack of mutual understanding of the technical society. Engineers are said to ignore the social concerns of their work, and social scientists to ignore technology. In this respect, a systems model can be a tool to bring both sides together and portray both social and technical phenomena; the technization of society and the socialization of technology (Ropohl, 1999).
2.2. Ergonomics, human factors and the human element

Ergonomics is a science of designing for human use, with the purpose to fit systems, tools, machines, and environments to the physical and mental abilities and limitations of people (Chapanis, 1996). As illustrated in figure 1, ergonomics is a multi-disciplinary science, including a variety of dimensions such as social needs, theory, practice and education, management, design, and technology/environment (Karwowski, 2005).

![Diagram of general dimensions of ergonomics](image)

**Figure 1. General dimensions of ergonomics. From Karwowski (2005).**

The word ergonomics derives from the Greek *ergos* (work) and *nomos* (law, or system) and can be translated as the science of work. Ergonomics as a scientific discipline was first introduced in 1857 by the Polish scientist Wojciech Jastrzebowksi (Karwowski, 2005), who proposed a broad scope of human activity, including labour, entertainment, reasoning and dedication (Jastrzebowski, 2006). Contemporary ergonomics has fused from the North American human factors and engineering psychology developed from military problems during World War II, and the European industrial applications for design of workstations and industrial processes (Helander, 1997).

Most professionals in the discipline regard ergonomics and human factors as equivalent (Chapanis, 1996), an equivalence that is manifested in the International Ergonomics Association (IEA) definition of ergonomics:

---

21
"Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance" (IEA, 2009).

With this definition, IEA call attention to a holistic and systems-oriented approach embracing every aspects of human work. The definition indicates both a social aim (human well-being) and an economic aim (overall system performance). Thus, ergonomics can be seen as a way to ensure goals of improved system effectiveness, productivity, safety, ease of performance and the contribution to overall human well-being and quality of life (Karwowski, 2005).

The various specializations within ergonomics are principally grouped in physical, cognitive and organizational ergonomics. As the name indicates, physical ergonomics refers to the humans’ physical work activities including working postures, work related musculoskeletal disorders, workplace layout and health and safety. Cognitive ergonomics is concerned with mental processes and how they can affect interactions between humans. For example topics like decision-making, work stress and training. Within organisational ergonomics lays the design of socio-technical systems including communication, resource management, design of working times, teamwork etcetera (IEA, 2009).

Shipping literature often uses the term human element, defined by the International Maritime Organization (IMO) as:

"a complex multi-dimensional issue that affects maritime safety and marine environmental protection. It involves the entire spectrum of human activities performed by ships’ crews, shore based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties, all of whom need to cooperate to address human element issues effectively" (IMO, 1997).

Crew performance is viewed as a function of individual capabilities, management policies, cultural factors, experience, training, job skills and work environment factors (IMO, 1997).

Hence, the terms ergonomics, human factors and human element can be used more or less indiscriminately. The present thesis predominantly uses the term ergonomics, the exception
being the second appended paper. Since the paper was written for a conference called “Human Factors in Ship Design and Operation”, it was considered appropriate to use the term human factors.

2.3. Maritime economics

The primary task of the shipping industry is to transport goods and people around the world. The main assets, the ships, vary in size and type, and carry a variety of goods over deep seas and along inland waterways. Today, international merchant shipping is responsible for more than 90 per cent of the global trade (IMO, 2009a), seven billion tons of cargo was transported between 160 countries in 2005 (Stopford, 2009). In addition, the shipping industry is an important employer, onboard and onshore. In Europe, which has the world’s largest merchant fleet, five million jobs are provided by the shipping industry (Weber & Nevala, 2006).

The first seafarers to actually pursue sea transport service, trading with other merchant’s cargo, were the Venetians that dominated the seas for more than a millennium during medieval and renaissance times (Martin, 2001). In the 18th century, the trade with West and East India increased and the world was opened up. The industrialization brought substantial changes to shipping, as to the rest of the society. Expansion of the world fleet ultimately depends on changes in world trade and vessel speed, and this time in history saw both. Extensive industrial developments and the population growth provided plentiful employment for shipping. Only in Britain, the population doubled between 1801 and 1851 and almost doubled again between 1851 and 1901 (Sturmey, 1962).

Gradually, the market was taken over by iron steamships that increased the cargo capacity in the world fleet and were less dependent on weather and wind. Liner companies could now operate on a fixed time scheduled on fixed routes (Pollard & Robertson, 1979), and the arrival of speculative capital allowed shipowners to opt for more advanced ships than previously (Sturmey, 1962).

The technological advancements have naturally continued. The introduction of the diesel engines reduced the need for fuel storage and increased cargo capacity, automation systems further reduced the crew size, and improved cargo operations such as containerization and
specialized shipping (car carriers, chemical parcel tankers, etc.) has lead to decreased turnaround time in port.

Maritime economics as a branch of economic theory has developed through the study of transport economics, and as for business in general, maritime economics is about supply and demand. Principally, the level of demand depends on the following variables: the world economy, commodity trades, average distance, political events and transport costs, whereas supply depends on the size of the world fleet, productivity, shipbuilding production, scrapping of ships and freight rates (Stopford, 2009). In the short run, supply can be influenced by laying up vessels or by a change in vessel speed. In the longer run, supply can be influenced by putting newbuildings into service, or breaking up old vessels. Supply can also be altered by technological change and changes in the cost of key inputs such as fuel prices.

Classic examples of how external factors can affect demand and supply in shipping are the closures of the Suez Canal in 1956 and 1967. With the canal closed, ships had to be rerouted around Cape of Good Hope, implying a significant increase in ton miles and thus a shortage of supply. Since there was not enough tonnage to accommodate for the demand the freight rates rose, and sea transport buyers even signed contracts for transports with ships that were not yet built. During the strong market times, many newbuildings were ordered, which lead to an oversupply and falling freight rates when the Canal was reopened again (Stopford, 2009). Cycles like this are significant for shipping market and since the demand for ship changes faster than the supply, freight cycles are generally irregular. Because troughs generally last longer in time than peaks, there is a strong focus on cost-cutting rather than revenue in maritime economics.

Veenstra & Ludema (2006) investigated the relationship between technical specifications of ships and their economic performance. They concluded that the earnings potential is determined by three factors: cargo carrying capacity, speed and versatility. These factors, it is argued, are determined by several technical characteristics of the ship that in the design stage are open to the shipowners to decide on.

Central to the profit making potential in shipping is the roundtrip frequency (Laine & Vepsäläinen, 1994), which depends on the optimum of loaded days at sea, and the time spent in port, ballast, or off-hire. Figure 2 illustrates how the roundtrip frequency can be
increased by some direct investments in shipping technology. According to this model, the investments can be made either to decrease the time in port, by investing in cargo handling systems, or by investing in technology to optimize ship propulsion and design (Laine, 2005; Laine & Vepsäläinen, 1994).

![Figure 2. Profit making potential in shipping. From Laine and Vepsäläinen (1994).](image)

Shipping is a capital intensive business, especially in relation to the size of company staff. The operational costs are fixed and independent of the level of output, and cover the costs that enable a ship to sail, such as crew costs, maintenance, insurance, stores and victualling (provisions). Crew costs are a vital part of the operational costs, constituting about 33 and 50 per cent of the operational costs (Willingale, 1998). It is also said to be the most flexible cost (Leggate & McConville, 2002).

### 2.4. The regulatory framework of maritime economics

The shipping industry has been viewed by economists as the model of perfect competition since the days of the Dutch philosopher Hugo Grotius and the publication of *Mare Liberum* (The Free Sea), in 1609. This apparent freedom of action does, however, bring some problem-potentials. The fragmentation of the shipping industry, and the range of
organizations and decision-making structures involved, can be illustrated by the typical example of a Norwegian owned ship, flying Liberian Flag, manned by British officers and Filipino crew, carrying Iranian crude oil to Japan. The ship can be certified by an American classification society, have her hull and machinery insurance placed in London and her cargo insurance in Paris (Thorstensen & Shield, 1998). With such a multitude of stakeholders of different nationalities, the regulation of the shipping industry is inevitably complex with intra- and inter-organizational relationships within and among various members of the global maritime community. These intermediary organizations interact to form both systems of self-governance, and private systems of governance. These systems often overlap, relying in part on the same organizations (Furger, 1997).

Principally, three main regulatory regimes create rules and have the means to enforce them: the Classification societies, the coastal states and the flag states (Stopford, 2009). There are also international conventions on issues where it is considered especially important that all nations have the same laws. The three main United Nation (UN) bodies developing maritime conventions are the International Maritime Organization (IMO), the International Labour Committee (ILO) and the United Nations Conference on Trade and Development (UNCTAD).

**The classification societies**

The classification societies are the backbone of the system of self-regulation within the industry. Its history goes back to the 1800th century and started as a register grading ships for the London underwriters. Gradually the role of the societies has developed and the importance of the contemporary classification certificate has dilated beyond the insurers. The classification societies of today have unfolded into a major technical adviser to both shipowners and governments, and they develop and implement rules and standards regarding the design, manufacture, construction and maintenance of ships.

Eleven of the most prominent of the classification societies worldwide are members in the International Association of Classification Societies (IACS). The objectives of the association include harmonization of the different rule books and to constitute an interface to other rule-setting organizations, primarily the IMO where IACS has consultative status. Neither IACS nor the individual societies have any legal authority. Their power is a consequence of market forces. The sanction for non-compliance with classification rules is the loss of certificate of classification, which is the basis for charter parties and insurance. Without the
It is practically impossible to effect an insurance policy, and a vessel without an insurance policy is unable to attract any business.

**The coastal states**

With many ships spending their entire economic life travelling between different jurisdictions follows a need for common rules when settling questions on which nation’s law applies, and the rights of other nations over the ship. The UN Convention on the law of the sea (UNCLOS) entered into force in 1994. UNCLOS is one of the most comprehensive multilateral treaties ever concluded, limiting national jurisdiction over the seas and aiming at the protection and the preservation of the marine environment (Dixon, 2007). UNCLOS define the rights of the coastal states by dividing the sea into maritime zones; the territorial sea, the contiguous zone, the exclusive economic zone and the high seas. Coastal states have the right to pass legislation with reference to the ships that trade in their territorial waters.

**The flag states**

Every state has the right to register ships. The country where the vessel is registered is called the flag state and with registration follows that both owner and vessel must comply with that nation’s legislation. This liberty of choice has led to economical strategic decisions on ship registration. Shipowners can decide to fly a so called flag of convenience (FoC) depending on how requirements and economic terms offered by the various registers suits the owner, vessel and its trade. National registers are often open for registration for any owner fulfilling the requirements, but do not distinguish shipping from other business in the country. Open registers on the other hand are generally designed with the purpose to attract shipowners with favourable fiscal and legal terms. It often regards issues dealing with taxes, crewing, company law and safety standards.

**The IMO**

The International Maritime Organization (IMO) is the UN agency attending to maritime matters. The Organization and its 168 members and three associate members, have adopted more than 800 conventions, codes and recommendations concerning maritime safety, prevention of pollution and related affairs (IMO, 2010).

Several of the most important conventions have followed in the wake of maritime disasters. The Titanic initiated the international convention for the Safety of Lives at Sea (SOLAS) that is regarded as the most important treaty. SOLAS specify how ships shall be constructed to be
as safe as possible and covers all aspects, from stability and fire protection to the carriage of dangerous goods and port security. In 1967, the 120 000-tons crude oil tanker Torrey Canyon that ran aground off the Isles of Scilly originated the MARPOL convention of 1973 to tackle operational and accidental pollution. The Torrey Canyon disaster also initiated the Civil Liability Convention improving the system for compensation of victims of oil spill damage after an accident at sea. IMO also established the Marine Environment Protection Committee (MEPC) that handles environmental issues. In the wake of the capsizing of the ro-ro ferry Herald of Free Enterprise off Zeebrugge in 1987, IMO adopted the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code) that became mandatory in 1998. The objective was to ensure safety, to prevent human injury or loss of life, and to avoid damage to the environment. The ISM Code requires the implementation of a safety management system (SMS) on all ships over 300 gross tonnes. Ship operators must develop policies and procedures for a systematic and self-regulating management of occupational health and safety matters (IMO, 2002).

**The ILO**

The UN agency International Labour Organization (ILO) influences the occupational health and safety issues in the industry. Since the start in 1919 the organization has adopted more than 65 international labour standards related to seafarers. In 2006, ILO adopted the comprehensive Maritime Labour Convention (MLC) that after ratification will update and consolidate the earlier ILO conventions and recommendations. The new “super convention” set minimum requirements for seafarers and address conditions of employment, accommodation, recreational facilities, food, health and social security protection. It aims to be globally applicable and uniformly enforced (ILO, 2006).

**UNCTAD**

The United Nations Conference on Trade and Development (UNCTAD) is the principal organ dealing with trade, investment, and development issues. UNCTAD formulate policies relating to all aspects of development including trade, aid, transport, finance and technology. Annually, UNCTAD publishes *The Review of Maritime Transport*, reporting on the worldwide evolution of shipping, ports and multimodal transport related to the major traffics of liquid bulk, dry bulk and containers (UNCTAD, 2009).
3. METHODOLOGICAL FRAME OF REFERENCE

This chapter describes the researchers’ journey, beginning with the general research approach, continuing with a description of the research tools used, before ending with a description of the research activities performed in each study. The intention of the chapter is to enable the reader to follow the research process and to form an opinion about the trustworthiness of the findings.

3.1. General research approach

The purpose of the research was to present how increased knowledge of ergonomics can contribute to improved overall systems performance and employee well-being in the shipping industry. With such a broad scope both in input (ergonomics), and output (systems performance), a qualitative, exploratory research approach was considered appropriate in order to capture rich, detailed information on the nature of these concepts and their interrelatedness. A qualitative, exploratory research focuses on meanings rather than quantities (Denzin & Lincoln, 2008), and allow discovery of concepts not yet known during the investigation (Merkens, 2004).

In qualitative research it is important to account for the researchers pre-understandings when entering the research work. A researchers pre-understanding such as experience, knowledge and insights into a particular problem area or setting can influence the choice of research approach and methods (Olsson & Sörensen, 2001), and implies a certain attitude and a commitment on the part of the researcher (Gummesson, 2000). Relevant experiences, beliefs and values that has shaped the author of the present thesis emanates from academic studies in maritime engineering, work environment management and ergonomics. Important prior work experiences include working more than ten years at sea in the engine department, a position as shipyard safety engineer, and as inspector at the Swedish Work Environment Authority. Influential research and theories are accounted for in the theoretical framework chapter.
Figure 3. An outline of the basic elements in the research process.

An outline of the research process is illustrated in figure 3. It should be observed that the figure is schematic and that the process in reality was less linear, and more of an iterative process where each stage of the process provided new knowledge, reaching a different level of understanding. Figure 3 illustrates how the researcher’s preceding experiences initially
influenced the choice of main topic and formulation of research questions. The researcher has also been aware of, and has reflected on any potential influence of this pre-understanding, during the phase of analysis and synthesis of the research.

The research activities consist of four elements: the three studies that were designed to answer the three research questions respectively (reported in Paper I-III), and a comprehensive analysis and synthesis of the research as a whole. The comprehensive analysis and synthesis aims at tying the knot between the three studies and the thesis’ purpose – between ergonomics and systems performance in shipping.

### 3.2. Research tools

Tools for data collection in qualitative research are primarily concerned with the gathering of information in the form of words, rather than figures (Jacobsen, 2002). The research tools used in the present work includes literature studies, semi-structured qualitative interviews, structured interviews, and a stakeholder analysis. The tools are all commonly used within qualitative research and each technique is described in more detail below.

#### 3.2.1. Literature review

A literature review constitutes the foundation of knowledge necessary for the different phases in a research project (Williamson, 2002) and is a part of the academic development in understanding the topic and identifying previous research and key issues (Hart, 1998). For the present thesis, search for relevant scientific literature has been made continuously. A snowball strategy was adopted, where bibliographies and references of the retrieved, relevant studies were followed up and reviewed. All sources used in the present thesis work are original sources.

#### 3.2.2. Semi-structured qualitative interviews

Kvale (1997) describe the qualitative research interview as a conversation with a structure and a purpose. Two metaphors illustrate the different ways of viewing knowledge created through a research interview; the researcher as a miner or as a traveller. The miner is digging up nuggets of data, while the traveller creates knowledge during the voyage. Meeting people is claimed to lead to conversations that give insights and new understandings. It is
possible that both researcher and informant may change when reflecting over what has previously been seen as obvious (Kvale, 1997). The knowledge process in an interview is an interactive process; therefore it is important to continuously check that the interpretation of the said is accepted by the informant.

In a semi-structured interview, the researcher uses a thematic guide as framework, allowing for flexibility to probe for details or further discuss issues (Williamson, 2002). Since the questions follow the flow of the informant rather than being asked in the order of the guide, it is important that the interviewer is flexible and sensitive to the informant. By using semi-structured interviews, it is feasible to compare the answers from several interviews and, to a certain extent, make some generalizations.

3.2.3. Structured interviews

In a structured interview, the structure of questions, attendant questions, sequence and interview situation is designed in advance (Williamson, 2002). The informant is asked about one or more problem areas and leaves little room for discussion or probing for details. The results of several structured interviews are generally easy to evaluate and compare across the informants.

3.2.4. Stakeholder analysis

A stakeholder analysis is a systematic process of collecting and analysing qualitative information in order to determine the interested parties in a policy or project, and is commonly mapped in a power-interest matrix (Gardner, 1986).

Freeman (1984) defines a stakeholder as:

“any group or individual who can affect, or is affected by, the achievement of the organization’s objectives”

According to Freeman, an influential stakeholder that affects a policy or an organization does not necessarily get affected in return. It can work both ways or in one direction only. Adopting this view, stakeholders can consist of employees, customers, suppliers, stockholders, banks, environmentalists, government and other groups. The different rights, duties and expectations from the stakeholders can influence the processes of an organization and in extreme cases pose a threat to its projects.
3.2.5. Analysis and synthesis

The terms analysis and synthesis originates from ancient Greek and translates literally to *unloose* and *put together* respectively ("The Concise Oxford Dictionary of English Etymology," 1996). Generally, analysis can be defined as the process by which an intellectual or substantial whole are divided into parts or components (Ritchey, 1991). In qualitative research the dividing line between data collection and analysis is often vague (Jacobsen, 2002). Analysis of qualitative data is not purely an activity that happens on a conscious level after the data collection phase, but occurs also on an unconscious level throughout the research (Williamson, 2002). The conscious level of analysing and interpreting data is a process to bring structure, order and meaning to the data. In short, it is the process of making sense of the data. Although techniques for analysing qualitative data vary with methods, theoretical positions or topic areas, three elements are central: (1) a detailed description of the data, (2) the systematization, reduction and categorization of the data, and (3) the linking and connecting of data to look for meanings and causes (Jacobsen, 2002).

Every analysis requires a subsequent and complementing synthesis in order to verify and correct its results. Synthesis is generally defined as the opposite process to analysis and signifies a combination of the separate elements or components in order to form a coherent whole (Ritchey, 1991).

3.3. Research activities

The four main research activities were the study of: (1) the key issues in maritime ergonomics, (2) the stakeholders of maritime ergonomics, (3) the operative measurements in maritime economics, and (4) a comprehensive analysis and synthesis of the three studies as a whole in order to fulfil the purpose of the thesis.

3.3.1. Study 1 - Key issues in maritime ergonomics

The study included a literature review, nine semi-structured qualitative interviews with various stakeholders within the industry, and structured telephone interviews with ten HR managers, each representing a Swedish shipping company.
**Literature review**

The literature review had a twofold aim: searching for previous studies on the economics of maritime ergonomics, and to investigate the key ergonomic factors addressed in previous maritime ergonomic research. Peer-reviewed, scientific literature in English or any of the Scandinavian languages from the year 1998 and onwards was sought primarily in the academic databases Web of Knowledge, Scopus, Science Direct and PubMed. Search strings on the topic of ergonomics, economics and shipping were truncated and used in various combinations.

Studies on fishing and naval ships were excluded, as were articles with a limited focus on medical or other health care issues rather than a comprehensive ergonomic perspective. The reason for the time limitation is the implementation of the International Safety Management (ISM) Code in 1998, that signified a fundamental change to the systematic health and safety work at sea (IMO, 2002).

**Semi-structured interviews**

Nine informants representing active seafarers, ship owners, insurance companies, sea transport buyers, and classification societies were contacted for interviews (table 1). The informants were not randomly selected, but rather chosen and aimed at specific groups of persons with a background and experience from shipping.

Purposely, the informants’ experience, area of competence and interest differed, constituting a combination of width and depth of knowledge. Individual, semi-structured interviews were held, using a thematic interview guide as framework but allowing for flexibility to probe for details or further discuss issues.

The interviews were performed by one interviewer (the author of this thesis) with a solid knowledge of the domain, an important prerequisite to accomplish an explorative interview (Kvale, 1997). The questions were not necessarily asked in the order as they appear in the interview guide, but rather followed the flow of the informants. Additional questions were asked and answers probed on an individual basis during the interviews. Eight of the interviews were performed in Swedish and one in English. None of the approached participants declined to participate.
Table 1. Composition of the informants and their organizational affiliation

<table>
<thead>
<tr>
<th>Informant</th>
<th>Organizational affiliation</th>
<th>Profession</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>Classification Society</td>
<td>Manager</td>
</tr>
<tr>
<td>I2</td>
<td>Classification Society</td>
<td>Surveyor</td>
</tr>
<tr>
<td>I3</td>
<td>Marine Insurance Company</td>
<td>Manager</td>
</tr>
<tr>
<td>I4</td>
<td>Marine Insurance Company</td>
<td>Manager</td>
</tr>
<tr>
<td>I5</td>
<td>Shipping Company</td>
<td>2nd Officer</td>
</tr>
<tr>
<td>I6</td>
<td>Chemical Company (sea transport buyer)</td>
<td>Vetting Inspector</td>
</tr>
<tr>
<td>I7</td>
<td>Shipping Company</td>
<td>Technical Superintendent</td>
</tr>
<tr>
<td>I8</td>
<td>Shipping Company</td>
<td>Ship Manager</td>
</tr>
<tr>
<td>I9</td>
<td>Seamen’s Union</td>
<td>Union representative</td>
</tr>
</tbody>
</table>

Notes were taken by hand during the interviews and a clean copy was typed out as soon as possible afterwards, while having the interview experience fresh in mind. The answers from the interviews are documented and kept by the author, but is not attached of discretion to the informants.

Analysis of the interviews were been done through meaning condensation and categorization of the ergonomic factors distinguished by the participants (Kvale, 1997). Other information gathered during the interviews constitutes part of the data corpus.

**Structured interviews**
A structured interview schedule was developed and tested on three persons within the university’s administrative division considered typical for the intended informants. Ten
shipping companies were chosen across the different segments and sizes of Swedish shipowner with an in-house personnel department. Together, the chosen companies represented more than ten per cent of the members in the Swedish Shipowners’ Association (SRF, 2009), and operate oil and chemical tankers, roll-on/roll-off vessels, passenger ferries and general cargo ships.

The head of each personnel department was interviewed by telephone and was after a presentation of the project asked to answer the following questions:

(1) Are the costs for shortcomings in the work environment known within your company?
(2) Does your company make cost estimates for investments in the work environment?
(3) Does your company account for costs due to sick-leave?

The introduction and questions were read from a script and no additional questions were asked. The interviews were performed in Swedish and none of the contacted shipping companies declined to participate.

3.3.2. Study 2 - Stakeholders of maritime ergonomics

The stakeholder analysis included four major components, performed in an iterative process:

• Identifying key stakeholders
• Collecting and recording information
• Creating a stakeholder map
• Analysing the stakeholder map

Initially, a list of all possible stakeholders was developed including every potential actor that could have an interest in, or the power to influence maritime ergonomics. Through several steps the list was refined into a priority list of key stakeholders, seeking the thoughts of experts in the domain from the academy as well as industry. The analysis included stakeholder characteristics as knowledge, interest, position, and the ability to affect maritime ergonomics.
3.3.3. Study 3 – Maritime economics

A literature review aimed to examine how the concepts of productivity, efficiency and quality can be defined and delineated in a shipping context. Search for relevant literature was primarily conducted in the academic databases Business Source Premier, Web of Knowledge, Science Direct and Scopus. The following search criteria were used, truncated and in different combinations: shipping, maritime, productivity, effectiveness, efficiency and quality. Inclusion criteria for the literature study were peer-reviewed scientific literature reporting on studies from the maritime industry where productivity, efficiency or quality was defined. Studies only concerning port operations were excluded as were studies in other languages than English or any of the Scandinavian languages. The search for relevant literature was iterated until the data corpus was considered sufficient.

3.3.4. Analysis and synthesis – making sense of the data

The present thesis work is based on information acquired from verbal and non-verbal dialogues and texts by means of written and spoken words as well as body language during interviews. The gained understanding from each research activity has been reflected upon using multiple levels of abstraction during the research process. Each individual study has contributed in the search for an understanding of the overall principle on how the parts interplay. The change from analysis to synthesis was an iterative process with the direction of the process moving towards a creation of entirety and the fulfilment of the research purpose; linking ergonomics to systems performance in shipping.
4. RESULTS FROM STUDIES

This chapter presents the results from the three studies, reflecting the evolution of the thesis work.

4.1. Key issues in maritime ergonomics

Paper I addressed RQ 1, identifying the key issues in maritime ergonomics. Specifically, the objectives of the first study were to investigate if:

- any previous studies on the costs and benefits of ergonomic work have been carried out within the shipping industry,
- if models and methods developed within other domains can be applied in shipping,
- if Swedish shipowners calculate the economic effects of the work environment,
- which key ergonomic factors that have been addressed in previous maritime ergonomic research, and
- which ergonomic factors that are considered most important by the shipping industry itself.

The literature review, as it was designed, found no relevant studies on the economics of ergonomics within the shipping industry. There is however a number of models and methods to evaluate the economics of ergonomics developed for other industries. But, since most models emanated from typical production environments, the benefits were often expressed in terms of increased productivity, efficiency and quality. For these operative measurements to be readily applicable in the shipping industry, it is necessary to first define what these concepts means in a maritime context. Further, it was found that for the past ten years, maritime ergonomic research has focused primarily on issues regarding physical ergonomics and occupational health rather than a broad perspective of ergonomics.

The structured interviews with the ten Swedish HR managers showed that the costs for absence due to sickness were known by all informants in the study. But, only two informants stated that they estimate any other costs and benefits of ergonomics on a regular basis.
The semi-structured interviews showed a common concern about the global shortage of competent seafarers, especially officers, shared by all informants. Six factors were mentioned as being the most important to address in order to achieve a good work environment and safety onboard: leadership; knowledge; culture and values; the work of the Human Resources department; communication; and employee participation.

4.2. The stakeholders of maritime ergonomics

Paper II turned to RQ 2 and the strategic constituents. The aim was to identify the key stakeholders in maritime ergonomics and analyse in which way they might be interested in and able to influence ergonomic issues towards better safety, productivity and operator satisfaction in shipping. The stakeholders were presented with a vessel lifecycle perspective (figure 4), illustrating how the vessel and its crew interact with different stakeholders through the four shipping markets.

Eight key stakeholders were identified; crew, shipowner, shipbuilders, buyers of sea transport, shipbrokers, financiers, ship breakers, and the surrounding world sub-divided in insurance companies, legislators, classification societies and third party stakeholders.

The crew was identified as the stakeholder with the greatest interest. The power to influence was however seen as dependent of the circumstances of the employment. It was believed that the increased shortfall of manpower may have a positive effect on maritime ergonomics in the future, as a way to recruit and retain competent seafarers.

A shipowner’s or a ship operator’s interests in ergonomics were found to vary with corporate aim and ambitions. Financial margins govern the ability to invest in new equipment and improvement projects, and it can be difficult for a smaller owner to order a ship with special requirements for design and choice of equipment. However, the owner has the power to influence the working conditions in other respects. Company policies can affect the ergonomic issues less dependent on hardware, such as organization of work, leadership and communication.
In the present work, *shipbuilder’s* embrace shipyards, naval architects, marine equipment manufacturers, and other providers of service and knowledge. The largest stake was found to be in the design and construction of ships. The design of the physical conditions in the work environment can contribute to greater flexibility in the organization of work, improved maintainability, usability, habitability and crew well-being.

**Figure 4.** The stakeholders of maritime ergonomics through a ship’s lifecycle.

The *buyers of sea transport services* are found in various industrial sectors. Primarily, buyers of liquid bulk transports, but increasingly also in other industries, use independent or own vetting regimes to ensure that vessels are maintained and operated according to international and company rules. Traditionally, there has been economic incentive for charterers and cargo owners to see the continued existence of low quality ships, as
eliminating these would imply increased freight rates, but this is likely to change due to increased customer demands for sustainable transport services.

Shipbrokers and agents were found to have no direct stake in the ergonomic issues, but in their role as providers of knowledge and competence to both cargo owners and shipowners, they have a possibility to influence decision-making in all four shipping markets. On a practical level, ship agents can be influential in their interactions with the vessel and its crew. Quality speed-boats, safe and efficient crew changes, and deference to work and rest hours were small, yet important, examples of measures that could be taken.

Ship financiers were assumed to have a minimal interest in the design and operation of the vessel from an ergonomics perspective. The power to influence maritime ergonomics was limited to accept or deny business proposals from prospective buyers.

The shipbreakers stake was assumed to increase with the implementation of the so called Green Passport concept, an inventory of all hazardous materials that has ever been introduced to the ship. Although introduced to protect the employees at the shipbreaking yards, the passport is thought to become a valuable source of information also beneficial for the crew when planning work and doing risk assessments onboard.

Marine insurers’ bear many of the costs associated with low-quality ships and were thought to have a clear interest in lowering the costs for incidents caused by poor ergonomics. Since a ship without adequate insurance has no commercial value, marine insurers have the power to influence maritime ergonomics with both stick and carrot. A sound operation and maintenance of the ship could be encouraged by linking the insurance premium to previous claims history and the ship’s value.

Shipping is regulated by national, supra-national and international legislative regimes. The flag state must ensure that the ships flying their flag are operated and maintained with a minimal risk to seafarers, environment and cargo. In various parts of the world, regional cooperation groups among the coastal states have been founded in which Port State Control Officers are authorized to inspect and under certain circumstances detain ships. On an international level, the UN agencies IMO and ILO are the major regulatory regimes.
Although classification societies have no legal authority, they have power to influence as a consequence of market forces. Without a classification certificate the ship will not get insurance, and without insurance it will not get any business. Since many maritime administrations have delegated the certification of ships according to IMO conventions and codes to the classification societies, they have an important stake in maritime ergonomics.

The public and the media were found to be increasingly important third party stakeholders. However, the public interest and subsequent power varies greatly between the various segments of shipping. The interest in maritime ergonomics can also be contradicted by the end consumers’ demands for cheap goods.

### 4.3. Operative measurements in maritime economics

Paper III addressed RQ 3 and returned to the development needs identified in the first study; the detailed modelling of the operative measurements of productivity, efficiency and quality in shipping. The purpose was to define and delineate productivity, efficiency and quality in shipping, and theoretically explore how these terms can be operationalized and related to maritime ergonomics.

No exclusive definitions of productivity, efficiency and quality in shipping were found. However, cargo and crew emerged as central elements in all three concepts. A conceptual model (figure 5) was outlined of how productivity, efficiency and quality as determinants of the financial performance of a shipping company are influenced by the design of the socio-technical system in the larger perspective. The model proposed that the productive time at sea, as well as efficiency and quality of operations, can be increased by means of proper design of both technical and organization systems.

Productivity in shipping could be improved by addressing the ergonomic factors contributing to a minimum of unproductive days due to maritime accidents, personal injuries, operational disturbances of machinery and equipment, time consuming inspections and potential subsequent detentions or loss of business opportunities.

Efficiency in shipping could be improved by addressing the organizational ergonomic factors contributing to crew efficiency such as organizational and managerial structures,
communication, design of working times, and knowledge creating processes. Technically, operational efficiency could benefit from a ship design that allow for more than just operability, but also take into account the ship's maintainability, usability, habitability and survivability for a safe and efficient ship operation over time.

![Diagram of productivity, efficiency and quality in shipping.](image)

**Figure 5. Conceptual model of productivity, efficiency and quality in shipping.**

Quality in shipping was largely equated with safety and dependant on both quality of the vessel and how it is operated. It was assumed that the self-regulating quality management systems will continue to develop. It was further assumed that the public awareness and pressure on shipping to deal with environmental issues will expand to encompass social and ethical issues such as fair working conditions.
5. ANALYSIS AND SYNTHESIS

This chapter presents the analyses of the results in the three studies respectively, followed by a comprehensive analysis and synthesis of the results in relation to the purpose of the thesis, tying the knot between good ergonomics and good economics in shipping.

5.1. Key issues in maritime ergonomics

The key issues in maritime ergonomics were investigated from two perspectives. The theoretical perspective turned to the scientific literature to examine which major issues that has been addressed in previous research; and the practical turned to the industry to examine if the economics of ergonomics was known in the industry and which ergonomic issues were considered important.

The review of literature on maritime ergonomics indicated a focus on physical ergonomic and occupational health issues from a medicinal perspective. An explanation to the emphasis on physical ergonomics is undoubtedly that seafaring is a hazardous occupation with high number of accidents and illnesses compared to many other industries (Bloor, et al., 2000; Hansen, et al., 2002). Few studies report on organizational and psychosocial ergonomic factors, indicating that the systems view of humans at work is scarce in maritime ergonomic research. However, a reason for the limited number of studies can be due to practical difficulties in designing and carrying out studies on the maritime domain. Especially to arrange visits to the ships and meet the people working onboard in their daily working situation and not only meet the shore based part of the organization. Field studies might be difficult to plan since ship schedules are known to change with short notice, and is further complicated by the restricted possibility for a ship to accommodate visitors due to a limited number of cabins onboard.

The costs for absence due to sickness were known by all shipping companies included in this study, but only two informants stated that they estimate other costs and benefits of ergonomics on a regular basis. Considering the composition of the informants, it is assumed
that this result is representative for Swedish shipowners and hence that the economics of ergonomics is not widely known in the Swedish shipping industry.

The ergonomic factors that emerged from the interviews were all organizational issues. Well managed, the informants consider these issues to yield fewer maritime accidents, personal injuries and damaged equipment, or as an informant put it: “fewer surprises”. A motivated, skilled crew is thought to do a better job operating and maintaining the vessel, and if an accident happens, be better prepared for mitigation; thus limiting costs and time off hire. In a longer perspective, it can be argued that a well maintained ship result in less costly mandatory periodical surveys and a better price on the second-hand market.

Several of the informants use the expression “fire fighting” when describing safety and ergonomics work; the personnel have to give priority to the very necessary tasks as they appear. There is not sufficient time to work proactively. According to Hollnagel and Woods (2005), responding to what happens is not sufficient to ensure control, since this limits a system to a purely reactive behaviour. The conditions that characterise how well an organization performs, and when and how the organization loses control, are consistent with the six ergonomic factors found from the interviews. Conditions include defective leadership leading to unattainable demands, inadequate or overoptimistic planning, or a lack of foresight; lack of knowledge and of competence; and lack of resources (Hollnagel & Woods, 2005).

When comparing the answers from the informants with the results of the literature review, there seems to be a gap between what is being studied by researchers and what is considered important by the stakeholders. While most research seems to be concerned about physical ergonomic issues, it seems that a shift towards organizational factors should be appropriate to meet the needs of the industry. The technical and organizational design of the shipping companies of tomorrow must be shaped to encourage the retention of competent seafarers already in the business, as well as facilitate the recruitment of new qualified employees. Since contemporary shipping suffers from a global manning crisis that is expected to continue (Drewry, 2009), ergonomic factors such as job satisfaction, motivation and leadership might have an increasing economic significance in the recruiting and retention of a competent workforce. It is fair to assume that high turnover rates of
officers and ratings, and the level of experience diminishing, might have a negative impact on safety at sea. A stimulating work environment can definitely be a competitive element.

It was concluded that beyond the costs for absence due to sickness, there is a lack of knowledge within the Swedish shipping industry on the economic effects of ergonomics. Further, due to the global shortfall of seafarers, recruiting and retention of competent seafarers was a common concern among all informants. Regarding the key issues in maritime ergonomics, it seems the focus on physical ergonomic and health and safety issues in scientific literature did not fully match the interest of the informants which pointed more towards a focus on organizational issues.

5.2. Stakeholders of maritime ergonomics

The ship system acts in a social, political and economic environment affected by a multitude of actors. Adapting a systems perspective on the stakeholders of maritime ergonomics, a complex web of formal and informal structures, processes, and policies emerge.

An important part of the system are the legal structures; regulations, procedures, routines and responsibilities; that are designed and implemented by regulatory regimes on a national, supra-national and international level (Stopford, 2009). The designs of these structures strongly influence strategic operational decisions which affect the level of expenditure on issues related to maritime ergonomics. Since not all countries ratify or effectively ensure the enforcement of the conventions, ships registered in such countries are, in principle, able to operate outside the convention. It is also easy, and comparatively cheap, to provide an effective cover to the identities of beneficial owners who seek anonymity (OECD, 2003). In this way, competitive advantages can actually be created by some shipowners by not adhering to international rules and standards (OECD, 1996), at the expense of quality operators who do.

On an industry level, additional layers of regulating structures are found in various self-regulating systems. Traditionally, there has been an economic incentive for charterers and cargo owners to see the continued existence of low quality ships, as these provide a cheaper carriage of their cargoes and eliminating such vessels imply increased freight rates (OECD, 2001), but this is likely to change. Independent or own vetting inspectors are used by an
increasing number of sea transport buyers to ensure that the chartered vessels are maintained and operated according to international and company rules. These vetting inspections are performed in addition to the inspections required by law. Unfortunately, for a parcel-tanker loaded with 40 different chemicals for as many different owners, the frequent inspections can have a significant impact on the crew’s workload and administrative burden.

Both the interest in and the power to influence ergonomic issues were found to be much differentiated. This is largely depending on the disparity in the business as a whole and even within the same segments. The diversity of the industry was shown also in the social and ethnic multiplicity of crew, with varying professional standards, terms of employment and power to influence. For an effective target oriented communication in ergonomic projects or interventions it is necessary to do an individual stakeholder analysis for each specific case, rather than a generic approach such as this.

Crew was identified as the stakeholder with the greatest interest while the power to influence was dependent of the circumstances of employment. The safety engagement and well-being of the crew is considered to be proportional with the perceived respect for the personal experience and judgment (Knudsen, 2005). This signifies the importance of leadership and the relations between the master and decision-makers ashore; and the relations between the master and the crew. Fear of being blacklisted might curb the will to convey any complaints or put forward proposals of improvements.

Due to the global shortage of manpower in shipping (Drewry, 2009), sought-after personnel are more or less ‘poached’ by other prospective employers. Retention is an important issue; the considerable turnover of seagoing personnel affects the safety through loss of knowledge and an increase in unsafe practices (Quinlan, Mayhew, & Bohle, 2001). In a similar fashion, disabling injuries are strongly correlated with job experience. New employees, regardless of age, befall a high and disproportionate number of injuries and accidents (Leigh, et al., 2000).

It was concluded that both the interest in, and the power to influence maritime ergonomics was much differentiated. This was largely due to the disparity in the business as a whole, but also within the same segments. For an effective target oriented communication in ergonomic projects or interventions, it is necessary to perform individual stakeholder
analyses. Crew was identified as the stakeholder with the greatest interest. Influence was dependent of the circumstances, but in general it is believed that the scarcity of manpower may lead to an improvement, not only in monetary terms. An increased public interest in sustainability has already affected the environmental work in the industry. Growing societal pressure from consumers on manufacturers was assumed to disseminate along the supply chain, leading to increased demands on shipping from the buyers of sea transport services.

The main contribution of this paper was descriptive, illustrating the complexity of the ship system and indicating a need for ergonomic issues to be addressed on several inter- and intra organizational levels.

5.3. Operative measurements in maritime economics

In Study 1, development needs were identified as detailed modelling of productivity, efficiency and quality in shipping, and how these terms can be operationalized and linked to ergonomic issues. These operative performance measurements influence a company’s bottom line and constitute the foundation of business decisions. They can also carry information, signalling a need for remedial measures, ergonomic or other.

Assuming that a ship’s productive time is the time it spends loaded at sea (Laine & Vepsäläinen, 1994; Stopford, 2009), it would hence be desired to keep all other time at a minimum. It is acknowledged that unproductive time can be caused by events outside the control of the ship operator (e.g. force majeure, strike or war). In this context; given that cargo operations is beyond the scope for the present thesis; three main causes for lost productive time were identified: (1) accidents or injuries, (2) operational disturbances of machinery and equipment, and (3) inspections and potential subsequent detentions. All of which are to a large extent considered to be under the control of the ship operator.

*Accidents and injuries* are always likely to have a disruptive effect on operations, both at the time of the accident or injury, and in the aftermath with potential subsequent investigations, repairs, replacement of personnel, training and familiarization of new personnel. According to the European Maritime Safety Agency, loss of life, and the number and cost of accidents remain significantly higher than 3-5 years ago. During 2008, 754 vessels were involved in 670 accidents, and 82 seafarers lost their lives on ships operating and in and around EU waters.
(EMSA, 2009). The high occurrence of occupational injuries compared to other industries (Bloor, et al., 2000; Hansen, et al., 2002; Jensen, et al., 2005; Jensen, et al., 2004) and the high costs for incidents involving crew members suffering from mental ill-health (NEPIA, 2006) implicate a high potential for improvements in this area.

Leading stakeholders within the industry have stated that eroding knowledge and competence across the industry is a major cause for increasing accident tolls (Richardsen, 2008; Spencer, 2009). Supposedly, reasons for insufficiently educated and trained seafarers are that competence is sacrificed for less expensive labour, but also a lack of suitable mechanism to ensure a globally implemented minimum standard for maritime training and control of competence (Ding & Liang, 2005).

Lower manning levels do not pose a problem in itself. However, in addition to the worldwide shortage of competent seafarers, estimates suggest a shortfall of 33 000 in 2009 (Drewry, 2009), there is a risk that subsequent lower retention and faster promotion results in a eroded level of experience onboard. At the same time, new technical solutions have been introduced which might have increased the complexity and reduced the transparency of operations onboard. Complacency, automation induced errors, out-of-the-loop unfamiliarity, behavioural adaptation and loss of skills are but a few commonly described problems with automation in the literature on ergonomics (Lee, 2006). These problems and its effect on safety have also been observed within the maritime domain (Lützhöft, 2004).

Other important ergonomic factors known to cause accidents and injuries at sea include fatigue, situation awareness, communication, decision making, team work, health and stress (Hetherington, Flin, & Mearns, 2006).

Operational disturbances of machinery and equipment due to unplanned maintenance or breakdowns are costly both in direct costs for repairs and loss of productive time for ship, crew and technical and administrative support ashore. According to the International Union of Marine Insurance (IUMI), machinery damage remains the primary cause for major partial losses, accounting for 35.5 per cent between 2004 and 2008 (IUMI, 2009). The Hanseatic Marine Underwriters state that the value of machinery claims doubled between 2004 and 2009 although the number of insured ships was stagnant (Fairplay, 2009). Among insurers, the causes for this trend include poor fuel quality, crew skills deficiencies, neglect of
technical inspection by owners and managers, and the complexity of modern onboard systems that are not always fully understood, maintained or repaired.

*Inspections* by various constituents are frequent occurrences in shipping operations. Depending on executor, a failed inspection can result in the ship, or ship operator, being disqualified for certain business opportunities, detention of ship, conditions or withdrawal of class, or a ban to enter certain ports. Coastal states around the world have founded regional co-operation groups in which Port State Control Officers (PSCO) are authorized to inspect and under certain circumstances detain ships, for instance the Paris and Tokyo Memorandum of Understanding (MoU). During an inspection, a ship’s various certificates are examined, but also the general condition of the ship, its engine room, accommodation and hygienic conditions (EU, 1995). It is further controlled that operations and procedures are conducted safely and in accordance with the various IMO Conventions; that the crew demonstrates sufficient proficiency and are familiar with critical procedures; and that crew members are able to communicate with each other and with other persons onboard (ParisMoU, 2010). Deficiencies hazardous to safety, health or the environment can cause a ship to be detained, or only be permitted to proceed to the nearest repair yard until the deficiencies are rectified. In 2008, deficiencies were reported in 58 per cent of the inspections within the Paris MoU, and the detention rate amounted to 4.95 per cent. A major category of deficiencies were related to working and living conditions, representing almost 12 per cent of the deficiencies (ParisMoU, 2009). Detention has significant cost implications for the shipowner, not only in possible loss of revenue and schedule disturbances, but also because unplanned work undertaken at short notice is more expensive. Deficiencies and detentions within the Paris MoU are regularly made public in the web information system Equasis. Thus, even when the ship is not actually delayed, a failed port state control can reflect poorly on both ship and companies involved and can have commercial consequences for future employment for the ship. Ships with deficiencies get an increased Target Factor, which in turn leads to increased likelihood for future inspections. Potential charterers can assess the likelihood of the ship being inspected during their charter, and assess the cost of possible delay. Likewise a sub-standard ship may have difficulties obtaining insurance cover (ParisMoU, 2010).
Efficiency in shipping could be described as a function of costs, time, and customer satisfaction. Given that crew costs are a significant (Willingale, 1998), and perhaps the most flexible (Leggate & McConville, 2002) part of the operating costs, it was presumed that strategies to improve crew efficiency, as defined by Ding and Liang (2005), is high on any shipping company’s agenda. Knowledge, skills, and structures for communication are internal determinants of efficiency depending on the managerial functions (Barthwal, 2000), and as such related to organizational ergonomics and the design of the socio-technical system. The seafarers of today are knowledge-workers operating in an increasingly complex socio-technical system. Generally, in what is referred to as the speed-accuracy trade-off (Wickens & Hollands, 2000), an operator has a choice between increased speed or increased accuracy. By reducing operator errors, it is however, possible to improve safety and efficiency at the same time (Helander, 2006).

The impact of the technical, functional and image quality dimensions respectively were found to vary in the different segments of sea transport services. Roughly, the technical quality of a ship depends on the quality of its design and build, along with the maintenance it has received since construction. The functional quality is how the transport service is executed and how reliable it is. Large shipping companies have developed beyond the pure sea transport service to become a one-stop shop for logistics solutions. Over the years, the public response to maritime accidents and pollution indicates a public interest in the environmental and safety policies of companies. Consumer awareness can be turned into a powerful marketing tool for ship operators, contributing towards the quality of shipping. When it comes to environmental issues there are already mechanisms in place. The Clean Shipping Index is used by over 20 of Sweden’s largest cargo owners in their procurement processes in order to evaluate the environmental performance of shipping companies (CleanShippingProject, 2010). However, transferring quality costs to the freight rate is not always feasible. The end consumer is often unaware of sea transport costs that are included in the price paid in the shops. The situation is different for the segment transporting oil, chemicals and gases where the companies shipping and receiving the goods have been leading in developing self-regulation standards and systems as a consequence of an economic interest (Korteland, 1998).
Since ergonomic issues tend to be disconnected from the day-to-day operations and strategic decision-making in a company, the work with ergonomics has not been as coherent and effective as it potentially could have been. As a consequence, it can be difficult for the operating management to obtain a strategic understanding of ergonomics in order to identify and prioritize the most important issues to address. With decisions to suspend or postpone short-term costs associated with ergonomics interventions or improvements follows a risk for losing the long-term objectives that in turn could induce yet greater direct and indirect costs and lost opportunities.

When a ship is delivered, owners tend to take the operating costs as a given, and it is often not acknowledged that some important costs are determined by important design choices that the owners have made consciously or unconsciously (Veenstra & Ludema, 2006). Productivity, efficiency and quality as determinants of the financial performance of a shipping company are influenced not only of technical development opportunities regarding hull and propulsion, but by the design of the socio-technical system in the larger perspective. The productive time at sea, as well as efficiency and quality of operations, can be increased by means of proper design of both technical and organization systems. The significance of technical systems regarding hull and propulsion for improved fuel economy is acknowledged, but not elaborated further in the present thesis. There are however room for improvements of the human-machine interface when it comes to the physical design of the operational and critical systems for machinery, navigation, and cargo operations onboard (Andersson & Lützhöft, 2007; Lützhöft, 2004). An interface design that takes the human characteristics, abilities and limitations into account would most likely minimize the risk for usability problems and use error.

Considering the volatile nature of shipping, the design of the organizational systems must aim towards building a resilient organization that over time is capable to adjust to the impact of internal and external events and stresses (Sundström & Hollnagel, 2006), and is able to avert situations that can lead to potential disturbances of operations.

In using the same framework that direct the core business processes, ergonomics is recognised as an investment rather than a cost, a strategy for creating value towards competitive advantage. The value-creating processes and the outcome of the operations in terms of overall systems performance and well-being are naturally affected by the
organization as such. Planning and execution of the operational processes are dependent on the design of the organization. Formal and informal structures, interactions, corporate culture, development, and use of human, technological and capital resources enables strategic processes such as problem-solving, decision-making, communications, knowledge formation, planning, co-ordination, co-operation and follow-up. The operational processes are then performed in a physical and social environment, taking into account the physical and psychosocial stressors in the work environment, and how members in the organization identify with corporate and operational goals.

It was concluded that the overall systems performance in shipping can be operationalized and measured in terms of productivity, efficiency and quality. Productivity can be improved by addressing ergonomic issues that contribute to a minimum of unproductive days. Efficiency can be improved by addressing issues contributing to crew efficiency. Quality in shipping was found to be largely equated with safety and depending on both quality of the vessel and how it is operated.

5.4. Relation between good ergonomics and good economics in shipping – tying the knot

The purpose of the present thesis was to investigate how an increased knowledge of ergonomics can contribute to improved overall systems performance and well-being in shipping; an outcome consistent with the aim of ergonomics (IEA, 2009). Managing a multiplicity of ergonomic factors in an equally complex environment such as shipping requires a systems approach that identifies the individual elements and determines how the elements individually and collectively affect overall performance.

The overall systems performance in shipping has in the present thesis been operationalized as a function of productivity, efficiency and quality. These operative quantities should be measured together to make sure that improvements in one area has not occurred at the expense of another. Although there is no generally agreed definition of employee well-being, theory and research has focused on topics such as physical and mental health, job satisfaction, employee morale, stress, motivation, organizational commitment, and climate (Grawitch, Gottschalk, & Munz, 2006).
**Ergonomic issues**

Table 2 illustrates a compilation of a number of ergonomic issues relevant for the shipping industry, and how they can affect the outcome in terms of maritime and occupational accidents, injuries, operational disturbances and employee well-being. However, the analysis does not pose as an absolute account, nor are the issues ranked in order of importance.

An inherent potential for improvements can be found within the work place layout and the technical design of the ship system as a whole. Many ergonomic issues regarding the physical environment and physical load are believed to be best solved if addressed already in the planning and design phase of a vessel, ensuring that the workplace design match the tasks, capabilities and limitations of the expected users. Slips, trips and falls, are common causes of occupational accidents believed to be caused largely due to poor design of ladders and stairways with steep and various angles (Anderson, 1983; Hansen, et al., 2002; Jensen, et al., 2005).

Noise-induced hearing loss is one of the most recognised occupational diseases in the European Union (EU-OSHA, 2005), as well as in seafaring (Kaerlev, et al., 2008), and these rates have not declined over time. Importantly, noise is further known to cause non-auditory health effects, interfering with sleep, communication, and mental tasks that require attention and concentration (EU-OSHA, 2005; Kjellberg, 1990). However, regulations for noise levels only take the auditory health affects into account, neglecting the change in work tasks that has taken place in shipping. Similarly, whole-body vibrations caused by wind, sea, and propulsion are known to cause fatigue in both humans and ship structures, musculoskeletal disorders and reduced cognitive performance (Dobie, 2000; Törner, et al., 1994).

Seafarers of today are undoubtedly more knowledge workers than manual workers, demanding a high level of concentrating during planning, operation, monitoring and administration of work. With long working hours and composition of watch systems with few hours of rest follows a need for good quality sleep in order to recuperate. A systematic work towards reduced noise and vibration levels in working and living quarters onboard is here believed to yield less personal injuries, but also contribute to efficient operation with less risk for use errors and accidents by stressed or fatigued operators lacking of concentration.
Table 2. Ergonomic issues and their effects in a shipping perspective.

<table>
<thead>
<tr>
<th>ERGONOMIC ISSUES</th>
<th>CAUSES AND EFFECTS</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical environment</td>
<td>Chemicals: Exposure to toxic and carcinogenic materials causing deaths, and acute and chronic illnesses.</td>
<td>+</td>
</tr>
<tr>
<td>Physical environment</td>
<td>Noise: Noise-induced hearing loss. Non-auditory health effects interfering with sleep, communication and mental tasks requiring attention and concentration.</td>
<td>+</td>
</tr>
<tr>
<td>Physical environment</td>
<td>Work place layout: Poor design common cause of STF.</td>
<td>+</td>
</tr>
<tr>
<td>Physical load</td>
<td>Work postures: Strenuous working postures, manual handling, etc, causing MSD.</td>
<td>+</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Automation: Complex technology leading to increased attentional and cognitive demands. Over reliance on machines leading to less effective monitoring. Poor judgement in use of technological aids contributes to maritime accidents.</td>
<td>+</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Mental health: Psychosocial factors contributing to poor performance, accidents and mental disorders. Suicide rates found high for seafarers.</td>
<td>+</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Work stress: Work at sea associated with considerable stress; especially regarding relationships with others and the home/work interface. Many female seafarers experience sexual harassments and feel unsafe.</td>
<td>+</td>
</tr>
<tr>
<td>Organizational</td>
<td>Communication: Lack of situation awareness and poor team working. Social relationships, onboard and ship-shore. Language problems. Lack of common language can contribute to feelings of isolation.</td>
<td>+</td>
</tr>
<tr>
<td>Organizational</td>
<td>Work experience: Inadequate training and short term contracts contribute to operational disturbances and high accident rates.</td>
<td>+</td>
</tr>
<tr>
<td>Organizational</td>
<td>Work organization: Poor organization of work and rest hours causing fatigue and alone work tasks.</td>
<td>+</td>
</tr>
</tbody>
</table>
The increased use of complex shipboard technology for automation, navigation and communication has brought new cognitive and attentional demands for the human operators onboard. Studies from aviation suggest that poorly designed automation may reduce workload under routine conditions, but can actually increase workload during stressful operations (Wiener, 1989). This phenomenon has also been seen in shipping where poor judgement in use of technological aids has contributed to several maritime accidents (MAIB, 2006; Perrow, 1984; SHK, 2007). Over reliance on machines can lead to less effective monitoring on the bridge (Lützhöft & Dekker, 2002), and poor design of some advanced radars may even have increased the likelihood of certain collisions (Lee & Sanquist, 2000).

Stable crews returning to the same ship show reduced risk for accidents (Bailey, 2006; Carter, 2005; Hansen, et al., 2002), and these findings are consistent with research from other domains (Quinlan, et al., 2001). Negative effects of poor work organization and crew composition include work stress, fatigue, mental ill-health, and a sense of social inequality that in turn can lead to increased risk for accidents, reduced performance and well-being (Carter, 2005; Hetherington, et al.,, 2006; Lützhöft, et al., 2007; Parker, Hubinger, Green, Sargent, & Boyd, 2002). Essentially, most positions and work tasks at sea can be seen as safety critical. Hence, poor performance, irrespective of cause, can lead to increased risks for seafarers, environment, cargo and ship.

**Economic outcomes**

As illustrated in the proposed conceptual model (figure 5), the technical and organizational systems design is believed to affect both costs and revenues. Costs traceable to ergonomic issues include direct costs accrued from maritime and occupational accidents or injuries, such as medical costs, compensation payments, and fines. In addition, there are also indirect costs related to damage to environment, cargo, or equipment; overtime; training and supervision of new tasks or new staff; employee turnover; rework; and lost production time due to cautiousness and time spent discussing the accident with other employees. Conversely, revenues are believed to be positively affected by increased knowledge of the interplay between the human operator and the technical systems. In addition to the augmentation of the productive time that would follow a decrease in accidents and injuries, there is also a potential for increased efficiency of operations in terms of resource usage measurable in work hours, fuel, equipment and spares, etc.
It is believed that substantial savings may be gained through proper design for maintenance of technological systems since as much as 80 per cent of a maintainer’s time may be spent in diagnosing a difficulty (Chapanis, 1996).

Table 3. Indicators for personnel, productivity, efficiency, and quality in shipping.

<table>
<thead>
<tr>
<th>AREA</th>
<th>EXAMPLES OF INDICATORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>Personnel composition; age, education, certification, form of employment, length in service in company and in profession</td>
</tr>
<tr>
<td></td>
<td>Working hours, overtime hours</td>
</tr>
<tr>
<td></td>
<td>Personnel turnover</td>
</tr>
<tr>
<td></td>
<td>Absence from work</td>
</tr>
<tr>
<td></td>
<td>Work related accidents and diseases</td>
</tr>
<tr>
<td></td>
<td>Sick leave</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation cases</td>
</tr>
<tr>
<td></td>
<td>Employees who has not been ill for a long period of time</td>
</tr>
<tr>
<td></td>
<td>Training</td>
</tr>
<tr>
<td></td>
<td>Job satisfaction, motivation</td>
</tr>
<tr>
<td></td>
<td>Work environment</td>
</tr>
<tr>
<td>Productivity</td>
<td>Maritime and occupational accidents</td>
</tr>
<tr>
<td></td>
<td>Incidents</td>
</tr>
<tr>
<td></td>
<td>Operational disturbances, breakdowns</td>
</tr>
<tr>
<td></td>
<td>Inspections</td>
</tr>
<tr>
<td></td>
<td>Deficiencies</td>
</tr>
<tr>
<td></td>
<td>Detentions</td>
</tr>
<tr>
<td></td>
<td>Ban from port</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Quantity (how much gets done)</td>
</tr>
<tr>
<td></td>
<td>Quality (how well it gets done)</td>
</tr>
<tr>
<td></td>
<td>Timeliness</td>
</tr>
<tr>
<td></td>
<td>Multiple priorities (how many things can be done at once)</td>
</tr>
<tr>
<td>Quality</td>
<td>Customer satisfaction</td>
</tr>
<tr>
<td></td>
<td>Damage to cargo</td>
</tr>
<tr>
<td></td>
<td>Damage to vessel</td>
</tr>
<tr>
<td></td>
<td>Corporate image</td>
</tr>
</tbody>
</table>
Table 3 exemplify measurable indicators in the suggested areas of personnel, productivity, efficiency and quality in shipping. The suggested indicators can be further subdivided into quantifiable dimensions of absolute or relative numbers, percentage, time, or value. But, also in qualitatively terms for e.g. perceived job or customer satisfaction, work environment or corporate image. Operationalized performance indicators such as these act as evaluation tools, information bearers and can signal a need for remedial measures, ergonomic or other, and constitute the foundation of business decisions.

In conclusion, a systems approach to the design of the ship system is coveted. It is believed that knowledge of ergonomic principles incorporated already at the design and planning stage enables a technical and organizational ship design that ensures operability, usability, maintainability, habitability and survivability. The outcome could be measured in terms of individual, organizational and societal benefits. Individual benefits include reduced risk for occupational injuries, improved physical and mental health, and job satisfaction. Organizational benefits include improved productivity, efficiency, quality; personnel concerns such as recruiting and retaining, reduced absenteeism and labour turnover; and liabilities. On a societal level, benefits include reduced costs for ill-health and accidents, and on a larger perspective a contribution towards an economically, environmentally and socially sustainable transport system and society as a whole.
6. DISCUSSION

In this chapter the purpose of the thesis is discussed in relation to the quality of the research and the main findings.

The purpose of this thesis was to present how an increased knowledge of ergonomics can contribute to improved overall systems performance and well-being in the shipping industry. In order to fulfil this purpose, three research questions were formulated representing the three subsections respectively: the field of maritime ergonomics, the shipping industry, and the operationalization of the overall systems performance in shipping.

Primarily, it is acknowledged that the research approach and tools to some extent have been influenced by the researchers pre-understanding. On a general side, a certain amount of pre-understanding entering a research project can be timesaving since the researcher doesn’t have to read up on structures, procedures and other peculiarities of a certain company or industry. It is also said to simplify acquisition of institutional knowledge, such as informal hierarchies, cultural values, social interactions and patterns that can otherwise be difficult to access (Gummesson, 2000). However, there is a risk that pre-understanding leads to preconceptions that can block new information, create bias and hamper creativity and innovation. This has been thoroughly acknowledged. Throughout the present thesis work, the researcher has been aware of, and reflected on the subjects of pre-conceptions, the risk for selective perception and personal defence mechanisms, values and beliefs.

By explicitly accounting for relevant experiences significant for the pre-understanding, and striving for a detailed documentation of the analysis process and line of argumentation, the researcher has aimed for a transparent research process that enables the reader to form an opinion of the quality and trustworthiness of the present research.

In interviews, there is a possibility that the informants might offer answers and reflections that put themselves and/or the companies they represent in a good spot. This possibility was considered and reflected upon both during the actual interview and later when the data was analysed, consciously seeking a critical approach. The competence and experience of the
informants’ differ, but that is seen as an advantage rather than a disadvantage. Collectively, the informants had the necessary combination of width and depth of knowledge to answer the questions. As far as possible the thematic questions were put to all informants in the same way, if not necessarily in the same order since that was decided by the turn of discussions. The questions were not formulated as leading questions, but open ended, enabling the respondent to reflect and reply from their own experiences. By performing a less structured interview the study might have lost in the possibilities for a generalisation of the results, and admittedly the interviews occasionally drifted to topics slightly outside the scope. However, a generalisation of results was not the primary aim of this research. The principal achievement from the investigation is finding patterns and tendencies, thus each individual answer is of less importance.

To the extent that qualitative research results at all can be generalised, the thesis work deliberately included different stakeholders with various responsibilities within shipping. The informants represent diverse views and perspectives to ergonomics in the maritime domain and the level of experience and competence vary. The fact that the informants agree on the salient ergonomic factors to such a large degree does at least point in a certain direction.

A weakness of the present research approach is the lack of a complementary quantitative study to empirically test the proposed theoretical links between ergonomics and economics in shipping. However, that is seen as a natural next step where the present thesis work constitutes a solid base for the design of future studies in knowing what to measure and how. Furthermore, in order to encourage improvement actions there is a need to complement the rather dismal focus on accidents and injuries with models of good practice.

The main findings of the thesis work has indicated that an increased knowledge of ergonomics can contribute to improved overall systems performance and employee well-being in the shipping industry, implying a fulfilment of the thesis’ purpose.
7. CONCLUSIONS

This chapter summarizes the most important findings from the thesis work.

The focus of the present thesis has been the relation between good ergonomics and good economics in shipping, and specifically how increased knowledge of ergonomics can contribute to improved overall systems performance and employee well-being in shipping.

The following conclusions were drawn regarding the key issues in maritime ergonomics:

- Beyond the costs for absence due to sickness, there is a lack of knowledge within the Swedish shipping industry on the economic effects of ergonomics, indicating a need for suitable methods in this respect.
- Due to the global shortfall of seafarers, especially officers, recruiting and retention of competent seafarers is a common concern among all informants.
- Six organizational ergonomic issues are mentioned by the informants as the most important: leadership; knowledge; culture and values; the work of the Human Resources department; communication; and employee participation.

Further, the following conclusions were drawn regarding the stakeholders of maritime ergonomics:

- The stakeholder’s interest in and power to influence the maritime ergonomics is much differentiated due to the disparity in the business. For effective and target oriented communication of ergonomics projects and interventions it can be useful to perform a stakeholder analysis to gain support and to identify possible threats to the project.
- An increased public interest in sustainable transports implying increased demands from cargo owners and shippers has begun to affect the environmental work in the industry. It is fair to assume that the sustainability concerns in time will evolve to encompass also the socio-ethical part of the sea transport service.
The following conclusions were drawn on how a shipping company’s overall systems performance can be operationalized and linked to ergonomic principles:

- The overall systems performance in shipping can be operationalized in terms of productivity, efficiency and quality.
- Productivity in shipping can be improved by addressing the ergonomic issues that contribute to a minimum of unproductive days due to maritime accidents, personal injuries, operational disturbances of machinery and equipment, time consuming inspections and potential subsequent detentions or loss of business opportunities.
- Efficiency in shipping can be improved by addressing the organizational ergonomic factors that contribute to crew efficiency such as organizational and managerial structures, communication, design of working times, and knowledge creating processes.
- Quality in shipping is largely equated with safety and depends on both quality of the vessel and how it is operated. It is assumed that the self-regulating quality management systems in place today, especially within the liquid bulk segment, will continue to develop within other shipping markets.

Finally, the following conclusions were drawn on how an increased knowledge of ergonomics can contribute to overall systems performance and employee well-being in shipping:

- The knowledge and application of ergonomic principles from a holistic perspective are vital for the adequate technical and organizational design of the ship system.
- The overall systems performance and employee well-being in shipping would benefit from a ship design that allows not only for operability, but also takes into account the ship’s maintainability, working conditions, habitability and survivability for a safe and efficient ship operation over time.
8. FURTHER WORK

This chapter presents suggestions for further work and complementary studies.

The present thesis work has presented a theoretical model of how good ergonomics can contribute to good economics in the shipping industry. Suggestions for further work include a complementary quantitative study, using a European shipping company as a prototype. The proposed study will investigate the availability of data within a representative shipping company as well as empirically validate the proposed theoretical links between ergonomics knowledge and systems performance. The envisioned result is a method suitable for shipping companies to assist in monitoring performance and estimating effects of ergonomic issues.

Complementary studies are also needed to investigate the feasibility in working pro-actively with the design of technical and organizational systems, preferably already on the design phase in a newbuilding project, turning to the approving authorities, shipbuilders or both.

Furthermore, in order to encourage improvement actions it is desirable to complement the reactive focus on accidents and injuries with a proactive stance and examples of best practise within the domain.
REFERENCES


Exploring Maritime Ergonomics from a Bottom Line Perspective

Manuscript version.

Submitted for approval to WMU Journal of Maritime Affairs
Exploring Maritime Ergonomics from a Bottom Line Perspective

Cecilia Österman¹, Linda Rose² and Anna-Lisa Osvalder³

¹Chalmers University of technology, Shipping and marine technology, SE-412-96 Gothenburg, Sweden
²KTH Royal Institute of technology, School of Technology and Health, SE- 141 52 Huddinge, Sweden
³Chalmers University of technology, Product and Production Development, SE-412-96 Gothenburg, Sweden

Abstract

The present paper reports an initial study exploring the economics of ergonomics in a shipping context. A literature review was made with the aim of identifying any previous studies on costs and benefits of ergonomics within the shipping industry. Furthermore, a survey investigated if Swedish shipowners calculate the economic effects of the work environment. In order to identify salient ergonomic factors, the concept of ergonomics was explored from researcher perspective through a review of literature, and from stakeholder perspective through qualitative interviews.

The results show that several models and methods have been developed to estimate costs and benefits of ergonomics in other industries, but no studies of this kind was found from the shipping industry. The survey among 10 Swedish shipowners showed that beyond the costs of sick-leave, other calculations on the economic effects of ergonomics were not done on a regular basis.

The results from the review of contemporary maritime ergonomic literature showed a focus on physical ergonomic and health and safety issues. This focus did not fully match the interview results which indicated an organizational focus. Leadership, knowledge, culture and values, crewing, communication, and employee participation was stated as the most important ergonomic factors.

Key words: Maritime ergonomics, organization, work environment, economics, shipping industry.

1 Introduction

A ship at sea can be a hazardous workplace. In addition to the ergonomic challenges of any industry, the maritime work environment also includes some domain specific difficulties. It is known as an accident prone working place (Bloor, Thomas, and Lane 2000; Hansen, Nielsen, and Frydenberg 2002), and long working hours on a constantly moving work place cause not only accidents, but also musculoskeletal disorders and fatigue (Törner et al. 1994; Lützhöft et al. 2007). Moreover, the ship is a social and intercultural environment where crew of mixed nationalities and cultures besides work, also live, eat, and socialize together.

It is always costly for a ship operator when a ship has to go off-hire and be taken out of service due to accidents, investigations, detentions, or unplanned maintenance. Besides the direct costs involved, it can also affect the insurance premium that often is linked to the previous course of events. Nevertheless, deficiencies in the work environment are not always recognised as production problems that could have an influence on the company’s bottom line. Thus, ergonomics risks being regarded as a field where money is spent with little or no return on investment, a cost rather than an investment.

However, many ergonomists and work environment specialists trust that what is good for the work environment is also good for business, and several studies support this opinion. Research on workplaces ashore show a strong relationship between a number of ergonomic issues and performance by way of increased production, higher quality, less cassation and less personnel turnover (Abrahamsson 2000; Axelsson 2000; Eklund et al. 2006; Goggins, Spielholz, and Nothstein 2008).

1 Corresponding author.
The present paper reports an initial study which is described in more detail in Österman (2009). This study is a part of an ongoing PhD-project examining the economics of ergonomics within the shipping industry. Specifically, the objective of this paper is to address the following questions:

- Are there any previous studies on the costs and benefits of ergonomic work in the shipping industry? If not, can models and methods developed within other domains be applied in shipping?
- Do Swedish shipowners calculate the economic effects of the work environment?
- Which key ergonomic factors are addressed in previous maritime ergonomic research?
- Which ergonomic factors are considered the most important by the shipping industry itself?

2 Methodology

2.1 Literature Review

The aim with the literature review was twofold; to search for any previous studies on the economics of maritime ergonomics, and to ascertain the key ergonomic factors addressed in previous maritime ergonomic research. Literature in English from the year 1998 to present date was sought in the academic databases Web of Knowledge, Scopus and PubMed. Search strings on the topic of ergonomics, economics and shipping were truncated and used in various combinations. The reason for the time limitation is the implementation of the International Safety Management (ISM) Code in 1998, that signified a fundamental change to the systematic health and safety work at sea (IMO 2002). Studies on fishing and naval ships were excluded, as were articles with a focus limited on medical or other health care issues rather than a comprehensive ergonomic perspective.

2.2 Survey on the Awareness of Costs and Benefits of Ergonomics

10 Swedish shipping companies with an in-house personnel department were chosen across the different segments and sizes of Swedish shipowners. The 10 shipping companies represent more than 10 % of the members in the Swedish Shipowners’ Association (SRF 2009). Together, the informants operate oil and chemical tankers, roll-on/roll-off vessels, passenger ferries and general cargo ships.

The head of each personnel department was asked to answer three questions:

- Are the costs for shortcomings in the work environment known within your company?
- Does your company make cost estimates for investments in the work environment?
- Does your company account for costs due to sick-leave?

2.3 Semi-structured Qualitative Interviews on Maritime Ergonomic Factors

With the purpose to identify which ergonomic factors that the shipping industry consider important, nine stakeholders within the maritime cluster were interviewed. In order to get a representative distribution of stakeholders, informants were not randomly selected, but chosen among shipowners, seafarers, insurers, classification societies and sea transport buyers. Purposely, the informants’ experience, area of competence and interest differ, thus constituting a combination of width and depth of knowledge.

Individual semi-structured interviews were held, using a thematic interview guide as framework, but allowing for flexibility to probe for details or further discuss issues. The analysis of answers and comments was made through meaning condensation and categorization of the ergonomic factors distinguished by the participants (Kvale 1996).

3 Ergonomics, Human Factors and the Human Element

The contemporary concepts of ergonomics and human factors include every aspect of human work in an organizational context. The various specializations within ergonomics and human factors include
physical, cognitive and organizational ergonomics. As the name indicates, physical ergonomics refers to the humans’ physical work activities including working postures, work related musculoskeletal disorders, workplace layout, and health and safety. Cognitive ergonomics is concerned with mental processes and how they can affect interactions between humans. For example topics like mental performance, decision-making, work stress and training. Within organizational ergonomics lays the design of socio-technical systems including communication, resource management, design of working times, teamwork etc. (Wilson 2005).

In November 1997, the International Maritime Organization (IMO) Assembly adopted a resolution acknowledging the human element as a complex multi-dimensional issue that affects maritime safety and marine environmental protection (IMO 2009). According to IMO, the human element involves every human activity performed by ships' crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties.

The terms ergonomics, human factors and human element can thus be used more or less indiscriminately. However, throughout the present study the concept of ergonomics is used, and it is used in its widest sense. The point of departure for this study is that ergonomics is not a goal in itself, but also a way to optimise human well-being and overall system performance (IEA 2009).

4 Literature Results

The literature search, as it was designed, found no relevant studies on the economics of ergonomics within the shipping industry. Therefore, the review solely reports briefly on related studies from other domains. The second part of the review reports on the key ergonomic factors addressed in maritime ergonomics for the past ten years.

4.1 Economics of Ergonomics

Generally speaking, poor working conditions annually lead to negative monetary and other effects for individuals, companies and for the society as a whole. At society level, Leigh, Markowitz et al. (2000) estimated the direct and indirect costs associated with injuries and illnesses that occurred at American work places in 1992 to a total of USD 155 billion, nearly 3 % of the US gross domestic product.

At company level, numerous examples of profitable improvements of working environments exist (Abrahamsson 2000; Oxenburgh, Marlow, and Oxenburgh 2004). The profitability mainly originates from improvements in productivity and quality (De Greef and Van den Broek 2004) while the economic consequences of sick-leave are a small part of the total economic effects of the working environment (Rose and Ortenius 2000; Abrahamsson 2000). The greatest proportion of indirect costs associated with injuries and illnesses in the workplace include overtime, productivity losses and quality deficiencies (Rose and Orrenius 2007). At an employee level, poor working conditions can lead to accidents and illnesses that affect their income, lead to short term and long term costs such as treatments and rehabilitation and can affect their lifetime wages.

Dul and Neumann (2006) propose that ergonomics should be linked to a company’s business strategy. A suggested strategy, the cost strategy, is suitable for shipping. As a service provider rather than a manufacturer the shipping company is interested in cutting costs to offer a competitive pricing towards the customers. The ergonomic selling point in this case is that the cost-cutting would be achieved by e.g. an ergonomic workplace and system design, and elimination of inefficient and unhealthy tasks. This notion is supported by Axelsson (2000) who found that ergonomic working conditions lead to 10 times less quality deficits.

4.1.1 Measuring the Effects of Ergonomic Work

In a review of studies on the effects of work-environment improvements, Eklund et al. (2006) focused on two categories; health promotive interventions against musculoskeletal disorders (MSD), and systematic work environment work and economic consequences. In the case of experimental or quasi-experimental studies there was no definite evidence of improved health after MSD interventions. However, many case studies and studies in so called grey literature (semi-published material such as reports, internal documents, theses etc.) showed positive effects of MSD interventions. Regarding
health promotive actions it was clear that interventions that encourage workers to an increased physical activity are favourable and can reduce back pain.

In studies on the economy of systematic work environment work, monetary benefits primarily originated from improved productivity and quality (Eklund et al. 2006). There are nevertheless methodological issues at stake. The much wished for comprehensive approach to ergonomics makes it difficult to evaluate and determine causality when investigating the effects of an intervention.

4.1.2  **Available Methods to Relate Ergonomics to Business**

There are a variety of models and methods developed to relate the work environment to terms of business results. Rose and Orrenius (2007) selected and evaluated 10 different methods and categorised them into three groups:

- methods to identify risks and analyse and assess the economic impact of risks in the work environment,
- methods to develop and evaluate a suggested ergonomic intervention in combination with an investment analysis, and
- methods that only incorporate investment analysis.

Some of the selected methods are tailored for Swedish conditions whereas other methods are more broad and general in their use. In order to encourage the usage of the methods, Rose and Orrenius (2007) recommend more detailed application guidance, especially on how to estimate the costs associated with productivity and quality deficiencies, but also case studies showing suitable types of work situations and industrial areas. They also suggest further development of methodology in the field, with emphasis on quality and productivity aspects.

4.1.3  **The Economics of Accident Prevention**

Maudgalya, Genaidy, and Shell (2008) reviewed 18 case studies of safety initiatives and the effect on productivity. On average, the case studies reported an increase of 66% in productivity, 44% in quality and 71% in cost-benefits. However, this study still claims that fewer accidents as the only argument are not sufficient as an incentive for companies to spend money on workplace safety and injury prevention. Safety should rather be viewed as a goal for operational sustainability, balancing business costs versus social costs. Case studies of organizations that had incorporated safety culture in line with other business goals reported on benefits originating from increased worker participation, decreased employee turnover and a more efficient identification and elimination of safety hazards and production problems (Maudgalya, Genaidy, and Shell 2008).

4.2  **Contemporary Maritime Ergonomic Research**

Bloor, Thomas, and Lane (2000) discuss the changes in contemporary shipping from a globalization perspective to illustrate the impact of globalization on seafarers’ health and safety. The growth in trade during late 1960s and early 1970s resulted in major investments in new ships. When the trend turned and the high oil prices halted the world trade, the industry engaged on a battle to cut costs. Labour costs were reduced by turning to the developing world for cheap crew substitution and by reducing the number of crew onboard. Even though an increased level of automation has removed a lot of manual tasks there are fewer people onboard to deal with breakdowns and emergencies. Typically, this must be accomplished having considerable physical and geographical distance to the management (Bailey 2006). There are also concerns that fewer people onboard also may have an impact on the psychosocial work environment (Bloor, Thomas, and Lane 2000).

Carter (2005) compare a seafarers working life to the restricted world of a prison. Divided by department, rank and nationality the seafarers can experience considerable isolation and the frequent call for adaption to and integration of new crew-members can be a significant stressor. Other important stressors are the experience of time pressure, depending of trade and port calls, perception of inequality between crew members when it comes to differences in employment security and the
right to health care, the length of the tour and working hours and different wages for the same job (Carter 2005).

Jensen et al. (2004) conducted a questionnaire study among seafarers in eleven countries. The study shows high rates of injuries in the shipping industry, and that the youngest seafarers, ratings and engine room personnel have the highest risk of injury. 9% of all seafarers reported that they were injured during their latest tour of duty and 4% were unable to work for at least one day. The self-reported injuries were more numerous than the accidents reported to the Maritime Authorities. The authors suggest that this might be due to under-reporting to the authorities, a suggestion readily acceptable and also mentioned by Hansen, Nielsen and Frydenberg (2002).

In Jensen et al (2005) it is concluded that 43% of the self-reported injuries were related to a slip, trip or fall incident. 43% constitute a higher proportion than previously estimated for seafaring and the relative risk for slips, trips and falls is estimated by Jensen et al to be three times higher than in shore-based industries.

Hansen, Tüchsen, and Hennerz (2005) and Kaerlev et al. (2007) report of an elevated risk of hospitalization for lifestyle-related diseases among Danish seafarers. Despite the mandatory health examination before the first employment and a biannual follow-up examination for all seafarers, a large proportion of the Danish seafarers suffered from poor health. Both studies suggest that the total impact of the working environment is likely to be small and that poor health is mainly caused by lifestyle related factors (Hansen, Tüchsen, and Hannenr 2005), and that tobacco smoking, dietary factors and sedentary habits are factors necessary to address (Kaerlev et al. 2007). Considering that the ship is a social environment as well as a working environment these statements could be subjected to discussion. The onboard personnel have limited options beyond eating what is served and with the development towards increasingly sedentary occupations in modern life onboard and ashore, it is necessary that opportunities and equipment for exercise are available onboard.

In summary, contemporary maritime ergonomic research address a wide range of topics, but focus is mainly on physical ergonomics and occupational health.

5 Results

5.1 Results from Survey on the Awareness of Costs and Benefits of Ergonomics

During the interviews, all representatives for the ten Swedish shipping companies stated that cost and benefit estimates of ergonomics is difficult to perform. Seven of 10 companies do not know how much shortcomings in the work environment cost. The other three companies state that they know the costs to a certain extent, but that no special methods are used for calculating these.

Six of 10 companies do not make calculations or cost estimates for investments in the work environment. One of these company representatives claims that doing so would be wrong since it is not possible to describe the human value in monetary terms. Two informants state that their companies regularly make calculations or cost estimates for work environment investments, while the remaining two state that this is done occasionally.

The third question on sick-leave costs was answered unanimously. All 10 informants stated that they calculate and account for the costs of absence due to illness.

5.2 Results from Qualitative Interviews

The factors brought up by the informants as being the most important in the maritime work environment are categorised into six dimensions: leadership, knowledge, culture, human resources/crewing, communication and participation.

5.2.1 Leadership

All of the informants mentioned leadership as being one of the most important ergonomic factors in the shipping industry. The impact of leadership was discussed on several levels, from owner and executive management perspective, as well as the role of the onboard management. Two informants
representing different insurance companies both claimed that visible owners have fewer occurrences in the claims statistics. An important part of the leadership was said to be the social skills of the officers onboard. One shipping company representative claimed that a captain’s social skills are just as important or perhaps more important than his or her professional skills.

5.2.2 Knowledge

Knowledge was brought up by the informants on several levels; the professional knowledge and skills among the crew, as well as knowledge within the onshore organization in order to create an understanding for the conditions onboard.

Shortcomings in the professional knowledge and skills of the crew are on one hand considered to be a common cause of accidents. On the other hand, knowledge is also seen as an asset worth to look after and keep within the company. Knowledge is seen as a prerequisite for a functioning interaction and communication between ship and shore. Onboard, there must be sufficient knowledge to understand and know how to work the different safety, economy, quality and environment management systems. Additionally, the shore-based part of the organization must have sufficient knowledge to correctly assess the working situation onboard when implementing systems, equipment and work procedures.

5.2.3 Culture and Values

Culture was discussed by the informants in terms of both safety (or organizational) culture, as well as culture and values stemming from differences in nationality, age or personal background.

One informant states the organizational culture, defining it as “the way we do things here”, is the most important factor to affect the work environment. The prevailing onboard-culture is thought to influence the working conditions and the willingness to take risk during normal operation at sea, e.g. on how close you let another ship pass.

Issues regarding mixed crew, made up of several nationalities, were also brought up as a cultural dimension that can influence both safety and well-being of the crew. One shipowner representative claimed that it is important to consider the composition of the crew in order to minimise the feeling of isolation that can occur on any vessel during long tours of duty.

5.2.4 Human Resources - Crewing

All informants mention the global shortage of competent seafarers and the importance of recruiting and retaining personnel. The Human Resources (HR) department is mentioned by both seafarer and insurer informants as a major player when it comes to attract, retain and support crew. The HR department is often the link between the employee and the company, and handles most personnel matters such as working schedules, training courses, travels and other administrative concerns.

5.2.5 Communication

Good communication on all organizational levels is believed to be of great significance both in the day-to-day life onboard and in different situations between ship and shore. Communication is claimed to be further complicated by cultural barriers and language problems, either due to a mix of nationalities onboard or because the vessel is operating in international waters. However, several examples were given on communication problems between deck and engine department onboard, and between the ship and the shore-based organization, even with a homogenous crew sharing nationality and language.

5.2.6 Employee Participation

The value of employee participation was brought up in issues ranging from the feeling of being appreciated and listened to, until having means and possibilities to influence business operations. An informant now representing a sea transport buyer, but with an extensive personal seagoing experience, claimed that participation as a way to increase crew morale and get the crew to feel seen was the most important ergonomic factor. In all, five informants suggested that participation should be included in
the company culture and include more than the day-to-day work and the ship specific issues. The aim with this should be that all employees should know how the company performs. Three of the informants, all with seagoing experience stated that participation in the purchasing process is important.

6 Discussion

6.1 Economics of Ergonomics in Other Domains
There are many similarities between work places ashore and onboard regarding cost savings originating from personnel factors such as absenteeism from accidents and diseases, personnel turnover and competence investments. However, there are differences in sick-leave reporting, since a seafarer remains onboard, unless he or she is seriously ill. In addition, employment contracts vary for different groups of seafarers resulting in an inevitable personnel turnover on ships where seafarers work for a longer time than they have time off.

Despite the lack of studies on economics of maritime ergonomics, there is no shortage of models developed for shore-based industries. However, with most studies coming from typical production environments, the benefits are often expressed in terms of increased productivity, quality and effectiveness. For these operative measurements to be readily applicable in the shipping industry, it is necessary to first define what these concepts means in a maritime context.

6.2 Is the Economics of Ergonomics Known in Swedish Shipping Industry?
It is a human truism that what gets measured gets done, but there is undoubtedly a challenge in finding the right performance indicators and creating an economic value for ergonomics. Beyond the costs of sick-leave there is not much calculation and evaluation of ergonomic issues among the 10 Swedish shipping companies that were interviewed in this study. Considering the composition of the informants, it is assumed that this result is representative for Swedish shipowners.

Physical factors have a tendency to dominate the work environment discussions since they are easy to identify and assess. Psychosocial and organizational factors are more elusive. No question on how the respondents’ defined work environment was included in the study. However, it is assumed that any conceptual differences among the respondents have a minor impact on the result of the survey and that the costs and benefits are equally unknown, irrespective of ergonomic specialization.

Rather than measuring performance indicators regarding production rate and quality, which can be found in other areas, shipping has to be examined in terms of ability to provide the right sort of vessel and deliver the cargo in the right condition, to the right place and to the right price. To be able to fulfil this service, the crew on their part must be able to run and maintain the ship to a reasonable cost and avoid discrepancies of any kind.

The global manning crisis that the shipping industry suffers from today has lead to high turnover rates for both officers and ratings, and the level of experience is diminishing. There is an obvious risk that this might have a negative impact on safety at sea (Pålsson and Bengtsson 2008). Previous studies on shore-based industries show that precarious employment is associated with poor knowledge of occupational health and safety, and an increased risk for injuries and hazard exposures (Quinlan, Mayhew, and Bohle 2001). New employees, regardless of age and industry, represent a high and disproportionate number of disabling injuries and accidents (Leigh et al. 2000).

6.3 Issues in Maritime Ergonomic Research
The review of literature on maritime ergonomics indicated a focus on physical ergonomic and occupational health issues. An explanation to the emphasis on physical ergonomics is undoubtedly that seafaring is a hazardous occupation with high number of accidents and illnesses compared to many other industries (Bloor, Thomas, and Lane 2000; Hansen, Nielsen, and Frydenberg 2002).

Undeniably, it is difficult to carry out studies on the maritime domain, especially to perform visits to the ships and meet the people working onboard in their daily working situation, and not only meet the
shore-based part of the organization. Studies might be difficult to plan since ship schedules are known to change with short notice. A field study onboard is further complicated by the restricted possibility for a ship to accommodate visitors due to a limited number of cabins onboard.

Few studies report on organizational and psychosocial ergonomic factors, indicating that the system view of humans at work is missing in maritime ergonomic research.

6.4 Important Ergonomic Factors

All six ergonomic factors that emerged from the nine qualitative stakeholder interviews were organizational issues. Well managed, the informants consider these issues to yield fewer maritime accidents, personal injuries and damaged equipment, or as an informant put it: “Fewer surprises”. A motivated, skilled crew is thought to do a better job operating and maintaining the vessel, and if an accident happens, be better prepared for mitigation; thus limiting costs and time off hire. In a longer perspective, it can be argued that a well maintained ship result in less costly mandatory periodical surveys and a better price on the second-hand market.

Several of the respondents use the expression “fire fighting” when describing safety and work environment work; the personnel have to give priority to the very necessary tasks as they appear. There is not sufficient time to work proactively. According to Hollnagel and Woods (2005), responding to what happens is not sufficient to ensure control, since this limits a system to a purely reactive behaviour. The conditions that characterise how well an organization performs, and when and how the organization loses control, are consistent with the six ergonomic factors found from the interviews. Conditions include defective leadership leading to unattainable demands, inadequate or overoptimistic planning, or a lack of foresight; lack of knowledge and of competence; and lack of resources (Hollnagel and Woods 2005).

Since contemporary shipping suffers from a global manning crisis that is expected to continue, ergonomic factors such as job satisfaction, motivation and leadership might have an increasing economic significance in the recruiting and retention of a competent workforce. It is fair to assume that high turnover rates of officers and ratings, and the level of experience diminishing, might have a negative impact on safety at sea.

When comparing the answers from the informants with the results of the literature review, there seems to be a gap between what is being studied by researchers and what is considered important by the stakeholders. While most research seems to be concerned about physical ergonomic issues, it seems that a shift towards organizational factors should be appropriate to meet the needs of the industry. The organizational cultures within the shipping companies of tomorrow should be designed to encourage the retention of competent seafarers already in the business as well as facilitate the recruitment of new qualified employees. A stimulating work environment can definitely be a competitive element.

6.5 Methodology Discussion

This study is limited by its small sample and only cover merchant ships of 500 Gross Tonnage and above covered by the mandatory ISM Code (IMO 2002).

In interviews, there is a possibility that informants offer answers and reflections that put themselves and/or the companies they represent in a good spot. This risk has been considered and the study has strived for a critical approach in the analysis of the empirical data. Far from all possible stakeholders have been approached in the present study, there are for instance no respondents from the governmental authorities such as the Maritime Administration or Work Environment Authority. This is mainly due to the limited time frame of the study.

In the survey, as well as in the interviews, the definition and meaning of the concept of work environment may have differed among the individual informants. However, even with this potentially wide conceptual range, the results point in same direction. A generalisation of the results was not the primary aim of this study. The principal achievement from the investigation was to find patterns and tendencies, thus each individual informant’s answer is of less importance. The fact that the informants
agree of the importance of organizational ergonomic factors to such a large degree indicates the importance of these factors.

7 Conclusions
The literature review found no studies on the economics of ergonomic conducted within the shipping industry. There is however a number of methods for evaluation and calculation developed for other industries. Whether these methods can be readily adapted to the shipping industry has to be investigated further.

Shipping is generally an under-researched domain when it comes to ergonomic research. The ergonomic research for the past ten years is predominantly focused on physical ergonomic and occupational health issues and does not take the broad perspective of ergonomics into account.

The costs for absence due to sickness are known by all 10 contacted Swedish shipowners included in the study. Only two respondents state that they estimate other costs and benefits of ergonomics on a regular basis.

Common for all interview respondents included in the study is the concern about the global shortage of competent seafarers, especially officers. Six factors, mainly organizational are mentioned by the respondents as being the most important: leadership; knowledge; culture and values; the work of the Human Resources department; communication; and employee participation.

8 Further Research
Further research regarding ergonomics and economics in shipping includes defining and delineating the concepts of productivity, effectiveness and quality. These operative measurements strongly influence a company’s bottom line and constitute the foundation of all business decisions including the working environment. It is necessary to investigate where costs and revenues can be found in order to be able to prioritize between investments, ergonomic and others. It is desirable to take a proactive stance and link the systematic ergonomic work to examples of best practise within the domain. Further research in this area would be beneficial for seafarers, as well as for the industry as a whole, and in a large perspective the society.

References


Who Cares and Who Pays? The Stakeholders of Maritime Human Factors

Paper presented at RINA Conference on Human factors in ship design and operation,
WHO CARES AND WHO PAYS?
THE STAKEHOLDERS OF MARITIME HUMAN FACTORS

C Österman, M Ljung and M Lützhöft, Chalmers University of Technology, Sweden.

SUMMARY

This paper aims at identifying the key stakeholders in maritime human factors and analyse their interest in, and power to influence the human factors issues. A stakeholder analysis is done and a model displays eight stakeholders from a vessel lifecycle perspective. It is concluded that the interest and the power to influence is much differentiated, largely due to the nature of shipping. An increased public interest in environmental, economic and socio-political sustainability has affected the environmental work in the industry and it is believed that pressure from consumers will lead to increased demands on shipping. It is further concluded that well operated shipping contribute to greater overall efficiency and economy and should offset higher unit freight costs resulting by the use of better maintained and managed ships.

1. INTRODUCTION

Specialists in human factors and ergonomics explicitly state that good ergonomics is good business and the relationship between ergonomics and increased productivity and quality has been shown in a number of scientific studies within shorebased industries. This paper is part of a larger study intending to investigate the economics of ergonomics within the maritime domain and hopefully be able to identify economic incentives for a systematic and comprehensive approach to human factors. The overall aim is that these incentives presented to the right stakeholder will lead to improved working conditions at sea. This paper explores the concept of stakeholders and uses stakeholder mapping to identify and analyse the key stakeholders and their interest of, and influence on human factors in the shipping industry. In short; who cares, who pays and who benefits?

1.1 BACKGROUND

In addition to the human factors challenges of any industry, the maritime work environment also includes some domain specific difficulties. It is known as an accident prone working place [1, 2] and the constantly moving surface and whole-body vibrations cause not only accidents but also musculoskeletal disorders and fatigue [3, 4]. With an increase in automation and removal of a lot of manual tasks there are fewer people onboard to deal with unplanned maintenance, breakdowns and emergencies. Typically, this must be accomplished having considerable physical and geographical distance to the management [5]. Moreover, with seafarers of different national and cultural background working together onboard, there is a social and intercultural dimension. Life onboard is to a great extent characterized by high demand and low control, a combination well known to cause stress. Divided by department, rank and nationality the seafarers can feel considerable isolation. Other significant stressors are the experience of time pressure and the perception of inequality between crew members with different working hours and different wages for the same job [6].

Inadequate and outright hazardous working conditions are not only found in backward sectors in the industry but can be found in more prosperous segments as well. The conditions for present-day seafarers are to a large extent depending on the separate owners and operators and the disparity between the best and the worst practice is very wide.

A prevailing management focus on productivity, quality and economic profitability sometimes overrides the human factors issues disguising them first and foremost as health and safety problems rather than production problems. Thus, it risks being regarded as an area where money is spent with little or no return on investment, a cost rather than an investment. However, research on workplaces ashore show a strong relationship between a number of issues related to human factors and performance by way of increased production, higher quality, less cassation and less personnel turnover [7].

Poor working conditions lead to negative monetary and other effects for individuals, companies and for the society as a whole. It is necessary to develop an economic base for a systematic work with human factors and justify health and safety issues as production improvements and loss prevention topics. And a human factors project or an ergonomic intervention that can be presented in business terms with economic benefits as well as the benefits for the quality of work life is thought to increase the chance of rising necessary funding [8].

The maritime work environment is relatively underresearched. There is a need for readily accessible knowledge on applied human factors to support the various stakeholders in their decision-making, adapted to their respective roles and needs. That said, the question is which stakeholders to include and how.

1.1 AIM OF THIS PAPER

During any ship’s lifecycle; from blueprint, design and construction through manning and operation to the
dismantling and recycling of the vessel, there are a number of stakeholders involved. The aim of this paper is to address the three following questions:

- Who are the key stakeholders in maritime human factors?
- What is their interest in the human factors issues?
- Do they have power to influence these issues?

The result of the analysis can be used towards a more efficient interaction with key stakeholders. An increased knowledge and support for human factors issues, is believed to improve the safety, effectiveness, efficiency and well-being at sea.

2. METHODOLOGY

The stakeholder analysis includes four major components in an iterative process:

- Identifying key stakeholders
- Collecting and recording information
- Creating a stakeholder map
- Analysing the stakeholder map

Initially, a list of all possible stakeholders was developed including every potential actor that could have a possible interest in or influence on maritime human factors. Through several steps the list was refined into a priority list of key stakeholders, seeking the thoughts of experts in the domain from the academy as well as industry.

In order to collect data and provide an up-to-date picture of contemporary shipping the weekly trade journals TradeWinds and Fairplay were systematically scanned during October to December, 2008. Articles considered relevant to the study were read and saved.

In a pilot study, nine stakeholders have been interviewed on their views on the importance and economics of maritime human factors. The informants were not randomly selected but rather chosen for their background and experience from shipping. Individual semi-structured interviews were held, allowing for flexibility to probe for details or further discuss issues. The pilot interviews and data gathered from the trade journals, supplemented with scientific literature on the topic constitute the main data corpus in the analysis of the stakeholder model and the individual stakeholders.

3. WHO IS A STAKEHOLDER AND WHAT IS AT STAKE?

3.1 STAKEHOLDER ANALYSIS

Stakeholder analysis is a common, systematic process of collecting and analysing qualitative information in order to determine the interested parties in a policy or project. The analysis includes stakeholder characteristics as knowledge, interest, position, and ability to affect the maritime human factors. First of all, we must understand who the stakeholders are and, secondly, what the perceived stakes are.

3.2 WHO IS A STAKEHOLDER?

The trend in society towards greater participation in decision-making is paralleled with a trend towards a wider view of people with an interest or stake in organizations – the stakeholders. This paper finds Freeman’s wide definition of a stakeholder suitable: “A stakeholder is any group or individual who can affect, or is affected by, the achievement of the organization’s objectives” [9]. This inclusive definition leaves the door open to anyone and any group, regardless of formal contracts. Freeman’s definition signifies that an influential stakeholder that can affect a policy or an organization not necessarily gets affected in return. It can work both ways or in one direction only. Thus, the stakeholders can include employees, customers, suppliers, stockholders, banks, environmentalists, government and other groups. The different rights, duties and expectations from the stakeholders can influence the processes of an organization and in extreme cases pose a threat to its projects.

3.3 WHAT IS AT STAKE?

The stake in maritime human factors is multi-dimensional, and cannot be measured solely in dollar terms. It includes every specialization within the discipline of ergonomics and human factors; physical, cognitive and organizational ergonomics. Physical ergonomics refers to the humans’ physical work activities including working postures, workplace layout and health and safety. Cognitive ergonomics is concerned with mental processes and how they can affect interactions between humans e.g. decision-making, work stress and training. Within organizational ergonomics lies the design of sociotechnical systems including communication, resource management, working schedules, teamwork etcetera.

Despite the extraordinarily technological development, the human element is still a valuable part in any work system. We are matchless when it comes to adaptability and flexibility but yet vulnerable to factors in our work environment that can impair our work performance. The effect of a human factors project or an intervention can thus be found on the individual level as well as on the organisational level. The outcome parameters can be quality, productivity and economy; the risk for accidents and injuries; self-perceived health and well-being from psychosocial point of view. For this paper, the starting point is that human factors is not a goal in itself but rather a methodology in order to achieve safety, productivity and operator satisfaction [10].
3.3 (a) Safety

Maritime safety receives a high level of national, European and international attention. Poor safety standards regarding design, construction and operation of ships and their equipment can lead to loss of life, damage to the environment and considerable financial costs. It is a human truism that ‘what gets measured gets done’ but since safety is an absence of a discrepancy rather than the existence of something [11], there is a challenge in creating an economic value for safety.

3.3 (b) Productivity

The primary task of the shipping industry is to transport cargo around the world and as for business in general, maritime economics is about supply and demand. Rather than measuring key indicators regarding production rate and quality as found in other domains, shipping has to be examined in terms of ability to provide the right sort of vessel and deliver the cargo in the right condition, to the right place and to the right price. The aim of the customer is better and cheaper transport from origin to end destination. Speed and reliability is vital for contemporary “just-in-time” production systems where a shipper may be prepared to pay more for a guaranteed service. Even if lost or damaged goods are insurable, a customer might be willing to pay more to be spared the hassle. To be able to fulfil this service, the crew on their part must be able to run and maintain the ship to a reasonable cost, doing their best to avoid discrepancies of any kind. Time off-hire (the time that is lost when a vessel is taken out of service) on account of accidents, appendant inquiries and investigations, detentions, and unplanned maintenance is always costly for the shipoperator.

3.3 (c) Operator satisfaction

The shipping industry suffers from a global shortage of competent seafarers, especially officers, and the shortage is expected to worsen despite the current state of the market. Recent estimates [12] suggest a shortfall of over 80,000 by 2012. The high turnover rates of seafarers and the level of experience erosion might have a negative impact on safety at sea, and the industry as a whole agrees on the urgency on the matter. To increase the attractiveness of the work, continuous efforts are needed where existing qualities of a working life in shipping are better displayed and other qualities must be realized and enforced [13]. It is fair to assume that that ergonomics factors such as job satisfaction, motivation and leadership will have increasing economic significance in recruiting and retention of a competent workforce.

4. THE STAKEHOLDERS OF MARITIME HUMAN FACTORS

Since the tradition of seafaring is a truly international undertaking by nature, the stakeholders are found nationally, regionally and globally. Stakeholder analyses are commonly mapped in a power-interest matrix [14]. However, the heterogeneity in shipping as an industry is reflected in the stakeholders that are so differentiated that it is not purposeful to do a general matrix for the industry as a whole. A power-interest matrix would be more suitable for a clearly defined project or company.

A vessel lifecycle perspective was adopted as a framework when identifying the stakeholders, as shown in figure 1, with the obvious centre point being the vessel itself with its crew. During this lifecycle a merchant ship trades in the four markets of shipping [15]; the newbuilding market where the ship is ordered; the freight market where the ship is operated; the sale and purchase market is the second-hand market for ships; and ultimately, the demolition market, the unglamorous end station yet an important beginning in the recycling process. Furthermore, the vessel and its crew operate in a surrounding world where they are affected by regulatory regimes, insurance companies, classification societies, and third party stakeholders such as the public interest and media.

Figure 1. The stakeholders through a ship’s lifecycle.

4.1 CREW

The crew is represented in the center of the proposed model as a ubiquitous stakeholder all through the lifecycle. At best, crewmembers are appointed and given consultative status already at the design stage of a newbuilding. The input from end-users can hopefully result in a more user-friendly work-place taking operation, maintainability and habitability of the vessel into account. The crew is the stakeholder that has the most obvious interest in human factors since they are affected for better and for worse by the physical, social and organizational circumstances.

With a business as globalized as shipping the crew is by nature far from homogenous. An owner or manager can recruit seafaring personnel from any STCW approved manning nation in the world and labour costs can be
decreased considerably by looking to the developing world for crew. Hence, the working conditions vary from quality operated state of the art vessels with a well-educated crew with a fixed relieving system, job security and health care benefits and so forth; to worst-case circumstances where vessels of questionable seaworthiness are manned with underpaid crew with no job security. Double book-keeping is occasionally unmasked concealing violations of agreed working hours and remuneration from an inspection, and crew have been abandoned by owners on vessels without water and provisions, and with no means to get home. Even a modern, structurally sound ship can be hazardous if incorrectly operated.

The diversified conditions for seafarers result in equally divergent levels of knowledge of, and power to influence the maritime human factors. The crew’s safety engagement and well-being is considered to be proportional with the perceived respect for the personal experience and judgment. This signifies the importance of leadership and the relations between the master and decision-makers ashore; and the relations between the master and the crew. Seafarers’ subjected to discrimination and poor working conditions may adopt an evasive ‘another day, another dollar’- mindset. As mercenaries of the sea, life onboard is reduced to a question of toughing it out and provide for the family back home. Fear of blackballing might curb the will to convey any complaints or put forward proposals of improvements [16].

Due to the shortage of manpower sought-after personnel are more or less ‘poached’ by other prospective employers. Retention is an important issue; the considerable turnover of seagoing personnel affects the safety through loss of knowledge and an increase in unsafe practices [17]. In a similar fashion, disabling injuries are strongly correlated with job experience. New employees, regardless of age, befall a high and disproportionate number of injuries and accidents [18].

Crewmembers have the power to influence the human factors either through participation, given the necessary resources, or simply by ‘voting with their feet’ when in a position to do so. The scarcity of manpower may possibly lead to the crew obtaining more influence over the human factors, improving the lot of the seafarers not just in pure remuneration terms.

4.2 SHIPOWNER

A challenge for a study like this is the range of company organisations and decision-making structures within and between the different segments in the industry. A shipowner can be a small family-run company with only one ship and it can also be a multinational company employing a 100,000 people on hundreds of ships. There is also industrial shipping where a division within the primary industry operate their own ships, state-owned shipping companies and companies set up for the sole purpose of owning one specific ship. Almost all registered owners of ships flying a flag-of-convenience are such one-ship shell companies that often are owned by another company. This structure entails a lack of transparency that makes it possible for a shipowner so inclined to avoid any accountability which may arise through owning the ship [19]. Since the ship is the only asset of the company, the liabilities of the company can be limited to the value of the ship.

Depending on size and commercial aims the owner has the ship management, technical, purchasing, insurance and human resources department either in house or outsourced.

As can be understood from the description of the differentiated company structures, an owner’s or manager’s interests in human factors vary with corporate aim and ambitions. Substantial economic benefits can be made by operators choosing to ignore international rules while penalties for poor vessel operations are relatively low compared to the economic advantages gained [20].

Financial margins govern the ability to invest in new equipment and improvement projects. In times of bulging shipbuilding orderbooks it can also be difficult for a smaller owner to order a ship with special requirements for design and choice of equipment. However, the owner has the power to influence the working conditions in other respects. Company policies can affect the human factors less dependent on hardware such as organisation of work, leadership and communication.

4.3 SHIPBUILDER

In this paper, the concept of shipbuilders encompasses shipyards, naval architects, marine equipment manufacturers and other providers of service and knowledge. The shipbuilder has an important stake in the designing and construction of the ships, most notably in the designing of the physical conditions in the work environment. That can in turn lead to greater flexibility in the organisation of work and also an improved habitability and crew well-being. For example, the design of the propeller and stern hull have an impact on noise and vibration levels onboard, and that affect the comfort as well as the safety at the risk of both seafarer fatigue and material fatigue with subsequent damages on propeller and rudder.

4.4 BUYERS OF SEA TRANSPORT SERVICE

Shipping is derived demand and is greatly affected by the world economic activity. The buyers of sea transport services are found in the energy sector with transports of oil products and other fuel sources; agricultural and forest trades and metal and other industries. Due to their share in value, the manufacturers of textiles, vehicles,
capital goods, etcetera, have a considerably larger impact on the shipping industry than the tonnage suggests [16]. Major buyers of liquid bulk transport use independent or own vetting inspectors to ensure that vessels are maintained and operated according to international and company rules. The vetting is performed in addition to the inspections done by the classification societies or port state controls. Unfortunately, for a parcel-tanker loaded with 40 different chemicals for as many different owners, it means a significant impact on the crew’s workload and administrative burden.

Traditionally, there is economic incentive for charterers and cargo owners to see the continued existence of low quality ships, as these provide a cheaper carriage of their cargoes and eliminating such vessels implies increased freight rates [21] but this is likely to change. Today, there is a notable call among customers for sustainable transport services. Increased awareness among the end-consumers on the need for a sustainable development including environmental, economic and socio-political sustainability, has trickled along the line and now encompasses all links in the production chain. Today many consumers want to make sure that products are not made by child labour. Tomorrow, this concern might well include fair and safe working conditions for those transporting the goods as well.

4.5 SHIPBREAKER

Shipbrokers and agents are involved in many dealings in all shipping markets. Shipbrokers act as intermediaries between shipowners and charterers or the buyers and sellers of ships and also provide their clients with market intelligence and specialist advice.

The agents have no obvious interest in the human factors issues but can be influential in their interactions with the vessel and its crew. Quality speed-boat, safe and efficient crew changes, and deference to work and rest hours are small yet important examples of measures that can be taken.

4.6 FINANCIER

Ship finance, like everything else in shipping, moves with the times. Financing is made through money markets, the capital markets and the stock market [15]. Investors are attracted by the volatility of shipping and prospect of great gains even if the return of investment is lower in shipping than other industries. Ships are regularly built on speculation and newbuilding orders are placed by people who have no intention of ever operate the ships. As long as they are passive lenders, banks are not liable if a defective ship on which they have provided a mortgage undergoes a casualty. In the past, some were willing to lend on ships of questionable quality and there are still some over-aged, low-quality vessels trading.

Generally, financiers are assumed to have a minimal interest in the design and operation of the vessel from a human factors perspective. Power is limited to accepting or denying business proposals from prospective buyers.

4.7 SHIP BREAKERS

Ship breaking is negatively correlated to the freight rates, high rates make it less economically advantageous for owners to sell their vessels to scrapyards. In less prosperous time there is an increase in ship breaking and the average age of the ships drop. The buying is often done by cash speculators who buy the ships for cash and sell them on to demolition yards, or at times, to a developing country.

Most of the world’s recycling capacity is found in India, China and Bangladesh, countries with low labour costs and lax environmental, health and safety regulations. Traditionally, the ship breakers would not be expected to have any interest or power in the human factors issues before the vessel reach the end station. However, in the draft ship recycling convention the IMO has introduced a ‘green passport’ concept. The passport will stay with the ship and contain an inventory of all materials potentially hazardous to health or to the environment ever introduced to the ship. The passport will make it easier for the ship breaker to take necessary precautions but will naturally serve the same purpose for the crew onboard, being a valuable source of information when planning work and doing risk assessments.

As the industry comes under increasing pressure from an environmental point of view, the ship recycling convention is likely to become mandatory and a number of classification societies are already offering guidance on the creation and maintenance of green passports.

4.8 THE SURROUNDING WORLD

4.8 (a) Insurance companies

A ship without adequate insurance has no commercial value. The Hull and Machinery (H&M) insurance, protecting the owner against physical loss or damage, and the Protection and Indemnity (P&I) insurance that covers third party liabilities, make up the largest proportion of the insurance costs for an owner. After some years of a slow decline, statistics show that the losses rose in 2007, with collisions and groundings at the top of the list [22], and also that costs for mental ill-health among crew are rising.

Marine insurance and P&I clubs bear many of the costs associated with low-quality ships and should have a clear interest in lowering the costs for incidents caused by poor ergonomics. The insurance companies also have power to influence the human factors work with both stick and carrot by linking the insurance premium to previous
claims history and the ship’s value, thus encouraging a sound operation and maintenance of the ship.

4.8 (b) Legislators

A merchant ship travels between different countries and jurisdictions and can be registered, owned, managed and operated from different corners in the world. Hence, shipping is regulated by a complex web of national, supra-national and international legislation

Every state has the right to register ships. National registers are often open for any owner fulfilling the requirements but do not distinguish shipping from other business in the country. Open registers on the other hand are by and large designed to attract shipowners with favourable fiscal and legal terms. It often regards issues dealing with taxes, crewing, company law and safety standards. This liberty of choice has led to economical strategic decisions on ship registration depending on how requirements and economical terms offered by the flag state suits the owner, vessel and its trade. The largest flags of registration are Panama and Liberia [23] but also so disparate nations as the landlocked Mongolia and the small island nation of Kiribati, with a land area half the size of greater London, offer ship registers.

The flag state is primarily responsible for ensuring that its ships are operated and maintained with a minimal risk to seafarers, environment and cargo. However, marketing is often done upon the protection offered shipowners and the banks that provide mortgages rather than on human factors issues, making it unlikely to be a priority in the commercial world of ship registration.

The Paris and Tokyo Memorandum of Understanding (MoU) are regional co-operation groups in which Port State Control Officers are authorized to inspect and under certain circumstances detain ships. Detention has significant cost implications for the shipowner, not only in possible loss of revenue and schedule disturbances, but also because unplanned work undertaken at short notice is more expensive. Even when the ship is not actually delayed, the detention reflects poorly on both ship and the reputation of the companies involved and can have commercial consequences for future employment. In a sense, these consequences can create an incentive for parties to do something about it.

In the wake of the accidents with oil tankers Erika and Prestige the European Union has intensified its role in maritime safety. The European Maritime Safety Agency has been set up to develop and implement EU legislation on maritime safety, pollution and security. Recently, the EU presented its Maritime Transport Strategy for 2009-2018 proposing inter alia a task force to examine ways of making the business more attractive to youngsters by improving the image of shipping and facilitate labour mobility.

On an international level, the United Nation agencies IMO and ILO are the major regulatory regimes. IMO has adopted more than 800 conventions, codes and recommendations on maritime safety, the prevention of pollution and related affairs. However, since not all countries ratify the conventions or effectively ensure the enforcement of them, ships registered in such countries are, in principle, able to operate outside the convention.

In 2006, the Maritime Labour Convention (MLC) was adopted by ILO, consolidating more than 65 international labour standards related to seafarers. The new convention address issues such as fatigue, occupational accidents, recruitment, employment opportunities and working and living conditions. The MLC is expected to come into force by 2012 on new and existing ships and aims to be globally applicable and uniformly enforced. PSC officers will be empowered to detain ships that have shown major non-compliance with the MLC.

4.8 (c) Classification societies

The classification societies are the backbone of the system of self-regulation within the industry. The societies have no legal authority; their power is a consequence of market forces. Since they depend on client revenue, the societies compete to attract members, leading to the anomaly that they are paid by the same shipowners on whom they impose financial penalties through their regulatory inspections. This has occasionally brought shipowners to re-class to a society with less exacting standards in order to avoid carrying out essential maintenance.

The classification societies develop and implement rules and standards regarding the design, manufacture, construction and maintenance of ships and since many administrations have delegated the certification of ships according to IMO conventions and codes to the classification societies, they have an important role in the safety of shipping.

4.8 (d) Third Party

The most important third party stakeholders are the public and the media. The development of mass communication and information technology has changed the role of media with regard to business and increased the importance for organisations to be aware of agendas of interest groups. Large organisations have their every action open to public scrutiny and for shipping this is especially true for the oil and cruise sector.

The surrounding environment consists of economic and socio-political forces. Isolating social issues as separate from the economic impact which they have would be to miss the mark both managerially and intellectually. Yet, the public interest and subsequent power not only differs between the various segments of shipping. It is also contradicted by the demands for cheap commodities and...
the wide selection of goods that only global trade can bring.

5. CONCLUSIONS

It was the aim of this paper to identify the key stakeholders in maritime human factors and analyse in which way they might be interested in and able to influence the human factors towards better safety, effectiveness, efficiency and well-being at sea.

A model is proposed (see figure 1) presenting the stakeholders with a vessel lifecycle perspective. The vessel and its crew travels through the four shipping markets interacting with the different stakeholders, each with their own interest in and power to influence the maritime human factors. Eight key stakeholders were identified: crew, shipowner, shipbuilders, buyers of sea transport, shipbrokers, financiers, ship breakers and the surrounding world that here is divided in insurance companies, legislators, classification societies and third party stakeholders.

When analysing the model, it can be concluded that both the interest in, and the power to influence the maritime human factors is much differentiated. This is largely depending on the disparity in the business as a whole and even within the same segments. For an effective target oriented communication in human factors projects or interventions it is necessary to do an individual stakeholder analysis.

Crew was identified as the stakeholder with the greatest interest. Influence is dependent of the circumstances but in general it is believed that the scarcity of manpower may lead to an improvement, not only in monetary terms.

An increased public interest in sustainability has already affected the environmental work in the industry. The pressure from consumers on manufacturers leads to increased demands on shipping from the buyers of sea transport services.

It should also be recognised that well operated and managed shipping does not necessarily translate into higher transportation costs. Safer ships should contribute to greater overall efficiency and economy resulting in savings through reduced costs for damage, reduced insurance premiums and shorter turnaround times.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the informants and consulted experts that have participated in the study, and thank all involved for their time. The study has been financed with help from VINNOVA and Region Västra Götaland.

7. REFERENCES

16. KNUDSEN, F., ‘Seamanship and Anthropoship – reflecting on practice’, University of Southern Denmark, Report No. 11, 2005


8. AUTHORS BIOGRAPHY

Cecilia Österman is a PhD-student at the Department of Shipping and Marine Technology at Chalmers University of Technology. She is a Marine Engineer and previous experience includes 12 years at sea, a position as a Safety Engineer at a naval shipyard safety and as an inspector at the Swedish Work Environment Authority.

Margareta Ljung holds the current position of Assistant Professor at Chalmers University of Technology and University West, Sweden. She is responsible for Human Factors research and lecturing. Her previous experience includes Function Based Manning in shipping.

Margareta Lützhöft holds the current position of Assistant Professor at the Department of Shipping and Marine Technology, Chalmers University in Göteborg, Sweden. She leads the Human Factors research group and is responsible for the thematic area Ergoship in the Lighthouse competence centre. She is a Master Mariner and has a PhD in Human-Machine Interaction.
Paper III: Österman, C. & Liukkonen, P.

Using Ergonomics to Improve Productivity, Efficiency and Quality in Shipping

Manuscript version.

Submitted for approval to Maritime Policy & Management
Using ergonomics to improve productivity, efficiency and quality in shipping

Cecilia Österman a and Paula Liukkonen b
a) Chalmers University of Technology, Gothenburg, Sweden
b) Stockholm University, Stockholm, Sweden

Abstract

Previous studies from workplaces ashore show a correlation between good ergonomics and good economics in terms of improved productivity, efficiency and quality. The present paper turns to the maritime domain with the purpose to define and delineate productivity, efficiency and quality in shipping, and theoretically explore how these terms can be operationalized and related to maritime ergonomics. A conceptual model is proposed illustrating how the productive time at sea, operational efficiency and service quality, is influenced by a design of technical and organization systems allowing for operability, maintainability, working conditions, habitability and survivability over time. Further work includes an empirical investigation to validate the conceptual model in a case study using a European shipping company as prototype.

Keywords: Ergonomics, shipping, productivity, efficiency, effectiveness, quality.

1. Introduction

Many ergonomists believe that what is good for the work environment is also good for business, and several studies support this opinion. At company level, the effects of ergonomics interventions and improvements are frequently evaluated in terms of productivity, efficiency and quality [1-4]. Specifically, Abrahamsson [5] studied the effects of a physical ergonomics intervention on the production in a Swedish steelworks. Mainly owing to fewer production disturbances and the elimination of major breakdowns, an investment of SEK 11.000.000 resulted in direct annual savings of SEK 5.000.000, showed a pay-off time of 2.2 years and an internal interest rate of 36 % [5]. Axelsson [6] reported that quality deficiencies could be reduced with 30-50 % with improved work postures, information handling, and workplace design. The impact of ergonomics on productivity, efficiency and quality has also been demonstrated in several European case studies [7].

A number of models and methods have been developed to estimate the economic effects of ergonomics on other industries [8, 9], but no previous research of this kind has been found within the shipping industry [10]. Whether these models and methods can be readily adapted to the shipping industry remains to be investigated further. Development needs are identified as detailed modelling of productivity, efficiency and quality in shipping, and how these terms can be operationalized and measured. These operative performance measurements influence a company’s bottom line and constitute the foundation of business decisions. They can also carry information, signalling a need for remedial measures, ergonomic or other.
It is necessary to investigate the relationships between ergonomic issues and factors strongly linked to a company’s financial results in order to be able to find the right economic incentives for a comprehensive and systematic work with ergonomic issues in shipping.

2. **Purpose, aim and delimitations**

The purpose of the present paper is to define and delineate the concepts of productivity, efficiency and quality in shipping, and theoretically explore how these terms can be operationalized and related to maritime ergonomics. The aim is to produce a deeper understanding on how ergonomic issues influence the overall systems performance.

During a vessel’s lifecycle, a merchant ship is said to trade in four shipping markets; newbuilding, freight, sale and purchase, and the demolition market [11]. The present paper is placed within the freight market where the actual sea transport service is taking place. It is further limited to a shipping company’s physical production processes of managing and operating one or more vessels, illustrated with dashed lines in figure 1. Thus, the present study does not consider the capital market, cash flow or the financing of ships.

![Figure 1. The economic delimitation of the study. Figure adapted and translated from Jyrkkö and Riistama [12].](image)

Although the present paper is limited to the economic effects of ergonomics on a firm level, ergonomics is an important part of the societal and ethical role of a company, and the human and societal value is duly acknowledged. Albeit difficult to measure in monetary terms; pain and suffering, reduced quality of life, and decreased lifespan are costs on the individual level. Societal costs include costs for medical care, social insurance, and loss of production capacity and purchasing power [7].

3. **Literature study**

Search for relevant literature was primarily conducted in the academic databases Business Source Premier, Science Direct and Scopus. The following search criteria have been used,
truncated and in different combinations: shipping, maritime, productivity, effectiveness, efficiency and quality. Inclusion criteria for the literature study were scientific literature reporting on studies from the maritime industry where productivity, efficiency or quality was defined. Studies only concerning port operations were excluded as were studies in other languages than English, or any of the Scandinavian languages. A snowball strategy was adopted where the bibliographies of the retrieved, relevant studies were followed up and reviewed. The search for relevant literature was iterated until the data corpus was considered sufficient. All data used in the study are original sources.

4. Ergonomics, human factors and human element

Traditionally, principal concerns of ergonomics and human factors were physical factors like noise, vibrations, workplace layout, and occupational health and safety, but during the second half of the 20th century a more holistic approach developed. The so called socio-technical systems theory, developed at large at the Tavistock Institute in London, is founded on the principles that all production systems include both a technical organization (consisting of machinery and other equipment) and a social organization (the humans), and that both dimensions must be taken into account in the design of any organization or work task [13]. This comprehensive view has evolved to include every aspect of human work; physical, cognitive and organizational [14]. According to the International Ergonomics Association, ergonomics (or human factors) is the:

scientific discipline concerned with the understanding of the interactions 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 [15].

The various specializations within ergonomics are principally grouped in physical, cognitive and organisational ergonomics. As the name indicates, physical ergonomics refers to the humans’ physical work activities including working postures, work related musculoskeletal disorders, workplace layout, and health and safety. Cognitive ergonomics is concerned with mental processes and how they can affect interactions between humans and includes topics like decision-making, work stress and training. Within organisational ergonomics lays the design of the organizational systems, such as structures, policies, and processes for knowledge generating and transfer, training, communication, crew resource management, design of work place and working times, work stress, and employee participation, to mention but a few [15].

In November 1997, the International Maritime Organization (IMO) Assembly adopted a resolution acknowledging the human element as a complex multi-dimensional issue that affects maritime safety and marine environmental protection. According to IMO, the human element involves every human activity performed by ships' crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties [16].

Thus, the terms ergonomics, human factors and human element can be used more or less indiscriminately. However, throughout the present paper, the term ergonomics is used.
5. Measuring systems performance for management control

In order for an organization to adequately plan operations, and identify and prioritize strategies for performance improvements, it is important to monitor performance and discern the impact of made decisions and the level of goal achievement. Traditionally, performance measurements for management control have been based on financial results measurements, which rather assess historical outcome than assist in predicting future outcomes or identify underlying causes to poor or high performance. In addition, financial performance measurements can often be affected by economic trends. In this context, it is necessary to find non-financial measurements for productivity, efficiency and quality to balance the financial measurements.

5.1. Productivity

Productivity, in general, is defined as the ratio of what comes out of a business to efforts and resources going in, and often refers to the total productivity encompassing all production factors:

\[ \text{Productivity} = \frac{\text{output}}{\text{input}} = \frac{\text{produced goods and services}}{\text{capital, labour, energy, material and services}} \]

When assessing the performance of a company, there are several approaches to measure productivity and the result can be displayed as an index or in physical or monetary terms (table 1). The choice of ratio is often a matter of convenience and available data.

<table>
<thead>
<tr>
<th>Railroad industry</th>
<th>The movement of a ton of freight one kilometre handled per employee in a given year ( \text{ton km employee year} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public services</td>
<td>Value added in 1000 EUR per employee ( \text{EUR employee} )</td>
</tr>
<tr>
<td>Steel industry</td>
<td>Average amount of working hours to produce a ton of steel ( \text{working hours ton} )</td>
</tr>
<tr>
<td>Research institutions</td>
<td>The Faculty Scholarly Productivity Index (FSPI) is based on statistical algorithms and measures publications; citations of journal publications; research funding; and awards and honours. ( \text{FSPI} )</td>
</tr>
</tbody>
</table>

In theory, the most simple productivity computation would be that of a company that produces a single output using only one input. In practice, it is necessary to consider multiple outputs in relation to equally numerous inputs. The total factor productivity is an aggregate involving all partial factors of production outputs and inputs, the quota of revenues and the total use of all resources. Increased total productivity reflects the effects of technological development, education and management organization.

Often, the wished for use of a more holistic and suitable productivity parameter must be balanced against the use of a cruder parameter that probably have fewer measurements errors.
A common example is the frequent use of labour productivity measurements instead of total productivity in empirical studies [19].

There are several reasons to measure productivity: to identify a ‘best practice’ to minimize technical and organizational inefficiencies; identify cost savings in production; benchmarking of production processes and factory-to-factory comparisons; and to assess living standards, often expressed as income per person [20].

It is important to consider and acknowledge the measurement problems that may occur when calculating total or partial productivity: data may not be available, or consistency and comparability problems with data can result in bias or inaccuracy when estimating the productivity.

5.2. Productivity outputs

Productivity outputs can be measured in physical units (tons, meters, numbers, etc.); in terms of value added; or as a standard unit such as the TEU (twenty-foot equivalent unit) used for measuring containerized cargo capacity. Physical output units can be reasonably straightforward to measure, but the output can also consist of more or less tangible services. In case of the latter, it is important to find output measures that reflect the role and function of the company. For transport service providers, the output can be measured using variables such as total volume or weight of freight; freight kilometres; number of passengers; or passenger kilometres per capita [21]. By using a value measure for output, not only the quantity of the product or service is expressed, but also the quality which is reflected in price variation of the output.

5.3. Productivity inputs

Partial measures of productivity, commonly involve five categories of inputs: capital, labour energy, material inputs and purchased services [22].

*Capital input*

The production capital input include real capital resources usually owned by the producer such as buildings; tools, machinery and office and computing equipment; vehicles; and the value of other assets in the business. Measuring the production capital can be problematic since both productive characteristics and depreciation vary greatly among the capital resources [19].

Technological advancements in production industries have meant an increased level of automation and more sophisticated tools and machinery. In practice, this means that the input of labour to a certain extent has been possible to substitute with capital [23]. The optimum combination would be when these two inputs are balanced so that the cost of production is at a minimum and the productivity is at the maximum level.

*Labour input*

Labour is an important input to any production. The division of labour and specialisation as a way to increase productivity was described in 1776 by Adam Smith in his famous passage on the pin factory [24]. But it is probably the originator of Scientific Management, Frederick W. Taylor that is most associated with systematic studies and observations of work. The time and
motions needed for every work operation was closely studied in the search for the one best way for organising work [25].

Labour productivity input is frequently measured by variables such as number of persons employed, actual or full-time equivalent, number of man-hours worked, overtime hours, or in wages [22]. These variables can be further broken down and distinguished in categories such as skilled and unskilled labour, blue and white collar workers, qualifications, certifications, and individual data for age, gender and education levels.

Organizations have moved from manual production to a more automated, knowledge-driven production, and contemporary labour productivity has moved beyond manual operations. The term ‘knowledge work’ was coined by Peter Drucker [26] to describe work that is performed primarily through mental processes rather than physical labour. Knowledge work tasks include planning, analysing, interpreting, and developing products and services, using data and ideas as the raw materials. Knowledge work can be both highly cognitive and social, allowing for time alone to think, converse, and for functional communication to check facts, supply information and ask questions. It can also include mundane tasks such as storing and retrieving information, planning and communicating [27].

Drucker argue that the knowledge owned by the knowledge-workers should be recognised as an enormous capital asset and that the ability to attract the best knowledge-workers should be an organizations’ most fundamental precondition for comparative advantage [28]. This view on knowledge as an intangible asset is often conceptualized as knowledge capital and alludes to both individual as well as collective or organizational abilities within a company [29]. However, since knowledge workers tasks are not fixed, have no production standard times, and can be performed differently by different workers, it can be difficult to observe and measure. Variables for measuring knowledge productivity are found in various dimensions of quantity, costs, quality, effectiveness and efficiency, timeliness, autonomy, project success, customer satisfaction, creativity, responsibility level, perception, and absenteeism [30].

Energy input
Besides early measurements of individual energy exerted by workers for different work tasks [25, 31], industrial energy productivity has traditionally been important within energy intense industries such as ironworks or agriculture. However, increased fuel prices, and the augmented focus on environmental issues imply that energy productivity is of interest for more or less all industries. The energy input can be measured in units for electrical power, fuel, wind or water etc.

Material input and purchased services
The input of materials, usually quantified in amount of or value of material used, and purchased services, are often aggregated. The importance of purchased services has increased over the years as it is more common that companies outsource services such as for instance cleaning, security and IT support.
5.4. Effectiveness and efficiency

To complement productivity measurements it is important to also measure effectiveness and efficiency. As illustrated in figure 2, effectiveness is a measure of how successful an organization is in producing a desired or intended result while efficiency describes the relation between the accomplished goals to the overall use of resources.

![Figure 2. The connection between productivity, effectiveness and efficiency.](image)

The core of any operational process transforming known inputs into some output would naturally be to do this with maximum possible effectiveness and efficiency. A company can be very productive, having a low resource consumption, but yet be very ineffective and inefficient if there are no clients to buy their products or services. In short, the company is doing things right, but is not doing the right things.

The management theorist Chester Barnard [32] claimed that for an organization to survive it needs to be either effective or efficient. However, for the organization to thrive, and not merely survive; it needs to be both effective and efficient. Focusing on the members in an organization, Barnard argues that an organization’s efficiency is its ability to motivate the individuals in the organization and stimulate their willingness to contribute [32]. This is accomplished by the executives whose role it is to communicate the values, missions and objectives of an organization. In his theory on managerial communication Barnard argue that attaining the information to the right people at the right time is vital in order to get the employees to participate in efficiency processes towards sustainable operational success.

Kreitner [17] adds a time dimension and defines organizational effectiveness as the ability to a) meet organizational objectives and societal expectations in the near future, b) adapt and develop in the intermediate future, and c) survive in the distant future (figure 3). When assessing the effectiveness of an organization, four main criteria should be considered: goal accomplishment, resource acquisition, internal processes and strategic constituencies satisfaction [33].
Goals to accomplish can range from system goals of profit maximization, to intermediate goals of productivity and quality improvements; minority recruiting; and keep-fit activities. Resource acquisition considers an organization’s ability to acquire human resources and necessary expertise, capital, energy and materials. Internal processes consider issues such as information flow, job satisfaction and commitment. Strategic constituencies’ satisfaction measures the satisfaction of individuals or groups with a stake in the organization, such as regulators, shareholders, customers or activist groups.

Determinants of efficiency can be categorized into internal and external forces [34]. The internal forces include all managerial functions of an organization such as communication of policies and goals, work planning, supervision; in sum providing adequate conditions for work. Thus, inefficiency in management will cause the entire operations to be inefficient, causing economic inefficiency in business. The external forces include the prevailing organizational or structural conditions in the industry as a whole, market fluctuations for input and outputs, trade union activities, government regulations, and so forth.

Efficiency or its components can be measured through physical indicators such as capital-output ratio, capital-labour ratio, etc. [34].

5.5. Quality

Quality is closely related to both productivity and efficiency and is largely concerned with meeting specified requirements or standards. In order to improve quality, a company can focus either on the product (or service) or on the production process.

Historically, the view of quality has evolved from inspections, quality control and continuous improvements to a systems view and the process thinking of Total Quality Management [35]. Juran defined quality as ‘fitness for use’, which places emphasis on the consumer needs and is valid as a definition for both quality of goods, and quality of service [36]. Deming stated that it is the role of the management to create a positive working climate where initiatives are encouraged and put to use. For support, Deming offered 14 key principles for management.
including the importance of understanding how individuals co-operate and communicate, and what motivates them [37]. Crosby defined quality as ‘conformance to requirements’; and a quality management system as ‘a systematic way of guaranteeing that organized activities happen the way they are planned’ [38].

Quality management is thoroughly addressed in the family of ISO 9000 standards. The international standard for quality management system requirements, ISO 9001:2008, defines quality as the degree to which a set of inherent characteristics fulfils requirements. The aim of the quality management system is for the organization to fulfil the customer's quality requirements, and applicable regulatory requirements, while aiming to enhance customer satisfaction, and achieve continual improvement of its performance in pursuit of these objectives [39].

Even though systematic approaches to quality management in goods manufacturing began to develop already in the 1920s, equivalent approaches in service quality took until the 1980s [40]. Service quality has several dimensions, many related to how the service is delivered and to the customer’s confidence in those providing the service, including access, communication, credibility, empathy, reliability, responsiveness [35]. Figure 4 shows service quality as a function of technical quality (what the customer gets), functional quality (how the customer gets it) and corporate image [41].

![Figure 4. Service quality as a function of technical quality, functional quality and corporate image [41].](image)

While the technical quality would be possible to evaluate in an objective way, functional quality is assessed in a subjective way. The perceived service is the result of the customer’s view of several both technical and functional service dimensions. When this perceived service is compared with the expected service, we get the perceived service quality. The corporate image, how the consumers perceive the firm, is an important quality dimension for most service providers. The corporate image is mainly built up by the technical and the functional quality of its services, but also on factors such as traditional marketing activities, ideology and word-of-mouth [41].

5.6. Strategies for creating value

In Porter’s (1985) classic generic model of how value is created in an organization, the value creating process is depicted as a linear value chain subdivided into primary and support
activities. Inputs are provided by suppliers, the company adds value to the inputs, before handing it over to the customer; which can be another business or the end consumer. The value chain concept has however been criticised for not sufficiently capturing the complexity of contemporary network economy. Instead a relation oriented value constellation [42], or value star [43], is proposed, shifting focus from Porter’s sequential value adding chain towards a continuous reconfiguration and integration of competencies. In the value creating constellation, suppliers, business partners and customers work together to co-produce value [42].

Wikström and Normann [43] perceive a company as a knowledge system, arguing that knowledge has become an increasingly important part of all industries and that also traditional blue-collar industries emphasize the highly qualified knowledge required by their operators. Assuming this perspective, a company is constantly generating and transforming knowledge through different types of bearer: people, machines, technical and administrative systems, documents, computer programs, and so forth.

Figure 5 illustrates how the value-creating processes in an organization occur in the intersection of three different modes of knowledge development: generative, representative and productive knowledge.

![Figure 5. Knowledge processes in the value creating system. From Wikström and Normann [43].](image)

In short, generative, new, knowledge is developed and created through joint activities involved with solving problems. Productive knowledge is developed through the production of goods and services, while representative knowledge is made available to customers’ and suppliers’ own value creating processes [43].

6. Measuring systems performance in a shipping context

The shipping industry operates in a business-to-business (B2B) context involving a number of service activities and some shipping companies have evolved beyond the mere sea transport service to offer a complete logistics solution, a one-stop-shop for their customers.

The first seafarers to actually pursue sea transport service, trading with other merchant’s cargo, were the Venetians that dominated the seas for more than a millennium during medieval and renaissance times [44]. Ships carrying as much as 500 tons were built, manned with up to 200 men. As an early example of labour and energy productivity, it can be noted that the contemporary ships trading in the North Sea were built in a different tradition. Without the
supply of slave labour as found around the Mediterranean, the northern ships are said to have
made better use of the wind to compensate for manpower [45].

In the 1800\textsuperscript{th} century a typical East Indiaman could be about 1000 deadweight tons manned
with a crew of a hundred men. However, on the outbound journeys from Europe, the manning
was larger than required to compensate for expected crew mortality from malnutrition, disease
and accidents. Performance mostly concerned freight volume rather than speed or time of
arrival, and ships were designed accordingly. Hence, the cost for labour was essential. A
shipowner’s main means of competition was to keep crew at a minimum and save on the
expenses for provisions [46].

Performance improved substantially during the 1900\textsuperscript{th} century. Improved harbour facilities and
steam powered tugs reduced time in port, and shipping costs were reduced by declining price
of metal steamships, which in turn lowered freight rates by nearly a half per cent annually [47].
Extensive development of coalfields and population growth during this time provided ample
employment for shipping. Only in Britain, the population doubled between 1801 and 1851 and
almost doubled again between 1851 and 1901 [48]. The population growth led to an expansion
of the emigrant traffic and an increased demand for food imports, which in turn was paid for in
exports of industrial products and coal [48]. With ships less dependent on weather and wind,
ship operators could now offer fixed routes with scheduled departures and arrivals. Further
technology developments towards reduced hull weight, and bigger steam engines with better
fuel efficiency meant larger ships with increased cargo capacity [49], and influx of speculative
capital allowed shipowners to opt for a more advanced ships than previously [48].

Major contributions to performance in modern-day shipping includes the introduction of the
diesel engines that reduced the need for fuel storage and increased cargo capacity, automation
systems that further reduced the crew size and improved cargo operations that reduced the
turnaround time in port.

6.1. Productivity in shipping

Examining the shipping industry with a lifecycle perspective; from construction through
operation and maintenance, to the scrapyard; there could be a number of productivity
measurements to consider. The present paper is however limited to the fleet productivity for
merchant ships during operation in the freight market [11].

Shipping productivity output

The literature on fleet productivity included in this paper is largely based on various output
parameters regarding the amount of transported cargo, such as value, weight or volume.
Freight rates and freight rate index can be seen as a ship’s income and is used as output for
several studies [47, 50-52]. Knauerhase [53] used average total port clearings as output in his
study of the effects of the compound steam engines on labour productivity. However, port
clearings as output variable was later questioned by Walton [54] claiming that it doesn’t take
the voyage distance into account.

Stopford [11] defines shipping productivity as ton miles of cargo per annum:

\[
P_{tm} = 24 \times S_{tm} \times LD_{tm} \times DWU_{tm}
\]
Where $S_{tm}$ is the speed per hour, $LD_{tm}$ loaded days at sea per year, and $DWU_{tm}$ deadweight utilization - a measure of actual cargo in relation to the maximum possible cargo. Deadweight (dwt) is considered to be the best general measure for transport capacity, however, for especially ferries and roll-on/roll-off ships, gross tonnage (gt) is claimed to be more suitable for measuring the output [55].

Laine and Vepsäläinen [56] make a distinction between the loaded days at sea, the productive time, and the unproductive time spent in port, in ballast, or off hire. The authors argue that the profit making potential in shipping lies in the roundtrip frequency and that both the productive and the unproductive time are equally important to increase the round trip frequency (figure 6). The roundtrip frequency, it is argued, can be increased by some direct investments in shipping technology, either in cargo handling systems or in ship propulsion and design [56, 57].

![Figure 6. Laine and Vepsäläinen’s [56] model for profit making potential in shipping.](image)

**Capital input**

Shipping is a capital intensive business, especially in relation to the size of company staff. The ships are often financed by banks that supply about 50 % of the capital needs [55]. Capital costs include payments of interests and loan principal, and the return on equity invested in the vessel. A shipping company also have costs for general overhead for marketing, advertising, banking costs, and so forth. Operational costs are fixed and independent of the level of output and cover the costs for operating the ship such as crew costs, maintenance, insurance, stores and provisions. Voyage costs are the costs related to the running of the ship, such as fuel, port fees and canal dues. Principally, only the costs for crew and maintenance are under the control of the shipowner. Since costs for crew are a significant element of the operating expenditure, attempts to improve shipboard productivity by crew reductions have been made frequently through history [11].
Along with crew reductions, investing in large ships with greater cargo capacity has been the traditional way of increasing productivity. However, an operational risk with economies of scale is the fluctuating demand. One way to increase cargo carrying capacity is to increase vessel speed, resulting in more roundtrips per year. This also means faster delivery time and responsiveness to customer service, alas a possibility to higher freight rates. However, drawbacks with increased ship speed are increased fuel consumption, increased risk for port congestions, and also that a shortened voyage time leads to more available tonnage, that in turn can disturb the balance of supply and demand and have negative effect on the freight rates.

**Labour input**

Crew costs such as wages, social security and provisions are a significant variable, independent of cargo utilization, and are said to constitute between 33-50% of the operational costs [58]. Since it is also claimed to be the most flexible cost, the manning-scale and investment in qualified and knowledgeable crew is a conscious decision by a ship-operator [59].

Common parameters for labour input when measuring fleet productivity are crew size and wages. However, using solely the onboard crew for labour input could imply an overestimation of the crew productivity since it ignores the contribution of shore-based labour for cargo operations, technical and administrative support at the operator’s office.

**Energy input**

The significance of energy costs in the sea transport production has changed over time; from galley slaves and wind, to coal, oil and gas. Contemporary energy productivity can be measured as the consumption of fuel for main and auxiliary engines, either in amount, or nominal value, of used fuel. The rising oil price in the 1970s was an important driver for the optimization of fuel consumption, and the interest is now reinforced by discussions on shipping’s impact on the environment and a possible need for stricter legislation.

**Material input and purchased services**

The input of materials and services purchased depend on the organizational structure of the shipping company. Costs for maintenance, repairs, insurance and port expenses are independent of the volume of cargo carried. Specifically, costs for preventive maintenance are an important element that is to a large extent decided by company policy. However, in the long-run, saving on maintenance works, materials and services can be contra-productive leading to breakdowns and the vessel to be taken out of service.

### 6.2. Effectiveness and efficiency in shipping

With a few exceptions, the terms effectiveness and efficiency were seldom operationalized or specified in the literature included in this study, but rather used as filler. In a study on Taiwanese’ shipowners preferences when employing seafarers [60], crew efficiency and competence was jointly described as a function of the seafarers’ knowledge, skills, ability to communicate, physical and psychological attitude, and medical fitness. In Jansson and Schneerson’s [61] study on the optimal ship size, efficiency was defined as the lowest total cost per cargo ton; both at sea, where a ship that carries a larger load is less costly per ton, and in port where higher port dues and longer time for cargo handling operations make a larger ship more costly.
6.3. Quality in shipping

To a large extent, the literature on quality in shipping equates quality with maritime safety. In Hawkins’ [62] study on quality shipping in the Asia Pacific region, seven mechanisms are claimed to be most effective in improving safety, and thus quality, of shipping in this area: port state control; ship vetting; ISM Code implementation; industry self regulation; government-industry partnerships; a regional approach; media coverage and information exchange. Better economic incentives to reward compliance and improving crew training, competence and welfare were pinpointed as especially important in order to improve quality [62].

The technical outcome in shipping constitutes the delivery of the goods being shipped, and success is claimed to depend largely on the quality of the ship [63], how the ship is operated, and on the maintenance it has received since construction, [64]. The functional outcome of quality in shipping deals largely with responsiveness and effectiveness towards the client [65].

A review of past practices in the maritime industry suggests that quality systems in the maritime industry have emerged principally from regulation, such as the ISM code, rather than from a firm-centric or product-based mindset [66]. In par with studies from other domains, the most important success factors of quality management in the shipping industry was identified as: top management commitment and participation; employee training and empowerment; quality information and performance measurement; and customer focus [67].

Over the years, various shipping sectors have initiated several self-regulating ship vetting systems to enhance quality driven by commercial interests. This is especially true for the liquid bulk market which is more sensible to the quality dimension of corporate image, possibly due to the high media profile of tanker accidents and associated public image repercussions for any well-known brand involved. Notorious examples are Exxon in the disastrous grounding of the Exxon Valdez in Alaska in 1989 and Total when the Erika broke in two and sank off Brittany in 1999. The clean-up costs alone are said to have cost Exxon USD 2.2 billion [68], and Total was recently ruled to pay EUR 200 million in compensation for damages by a French court [69].

The Oil Companies International Marine Forum (OCIMF) was formed in 1970, mainly in response to the grounding of the Torrey Canyon that caused 120 000 tons of crude oil to spread along the south coast of Britain [70]. With the objectives to promote safety and prevent pollution from tankers and at oil terminals, OCIMF produces technical and operational guidelines, many of which used as industry standards. In 1993, OCIMF introduced the Ship Inspection Report Exchange Programme (SIRE), promoting a uniform standard of common inspections among the oil companies. SIRE enables pooling and sharing ship inspection reports that measures tanker quality. The aim is to increase total number of vessels inspected and reduce the number of repeat inspections on the same vessel, thus reduce the burden on vessels’ personnel [71]. In 2004, OCIMF proceeded to implement the quality management system standard TMSA (Tanker Management and Self Assessment) to encourage vessel operators to measure and improve their safety management systems. Ship operators can compare their quality system against listed key performance indicators and obtain best practice guidance [72].

In the dry cargo market, similar market driven systems has been less prominent and has taken longer to develop. Possibly due to a perceived absence of economic incentives for endorsed
quality [73]. However, recently, several systems have been developed. RightShip is a ship vetting regime for dry bulk carriers and oil tankers based in Australia [74]. RightShip is owned by three major sea transport buyers representing mining and agriculture, aiming to raise standards across the industry and minimise commercial disadvantages of choosing quality ships [75]. Another example from the dry cargo segment is the 360 Quality Code developed especially for reefer cargoes [76]. The 360 Quality Code is based on the Six Sigma methods for improving quality and lays down requirements for reefer ships and terminals in order to eliminate handling damage.

7. Conceptual model linking systems performance to ergonomics in shipping

The result of the study indicated that there are no exclusive definitions of productivity, efficiency and quality in shipping that can be readily used in the models and methods to evaluate the economics of ergonomics developed for other domains. It is however believed that although these concepts derive from the production industry paradigm, they are still applicable as determinants for systems performance in shipping.

Originating from the notion of roundtrip frequency as central to the profit making potential in shipping [56], a conceptual model is proposed to illustrate how the productivity, efficiency and quality are influenced by the design of the technical and organizational systems in a shipping company (figure 7). The conceptual model, as is true of all models, simplifies reality, but is proposed to give tendencies.

![Figure 7. Proposed model of productivity, efficiency and quality in shipping.](image-url)
When a ship is delivered, owners tend to take the operation costs as given, and it is often not acknowledged that some important costs are determined by important design choices that the owners have made consciously or unconsciously [63]. The conceptual model proposes that the productive time at sea, as well as operational efficiency and service quality, can be increased by means of proper design of both technical and organization systems. The significance of technical systems regarding hull and propulsion for improved fuel economy is recognized, but not elaborated further in this study.

7.1. Productive time at sea

Proceeding from the assumption that a ship’s productive time is the time spent loaded at sea [11, 56], it is hence desired to keep all other time at a minimum. It is acknowledged that unproductive time can be caused by events outside the control of the ship operator (e.g. force majeure, strike or war). In this context; given that cargo operations is beyond the scope for this paper; the present discussion focuses on unproductive time lost due to accidents or injuries; operational disturbances of machinery and equipment; and inspections and detentions. All of which are to a large extent considered to be under the control of the ship operator.

Accidents and injuries are always likely to have a disruptive effect on operations, both at the time of the accident or injury, and in the aftermath with potential subsequent investigations, repairs, replacement of personnel, training and familiarization of new personnel. According to the European Maritime Safety Agency, loss of life, and the number and cost of accidents remain significantly higher than 3-5 years ago. During 2008, 754 vessels were involved in 670 accidents, and 82 seafarers lost their lives on ships operating and in and around EU waters [77]. The high occurrence of occupational injuries compared to other industries [78-81] and the high costs for incidents involving crew members suffering from mental ill-health [82] implicate a high potential for improvements in this area.

It has been stated from several leading actors within the industry that eroding knowledge and competence across the industry is a major cause for increasing accident tolls [83, 84]. Supposedly, reasons for insufficiently educated and trained seafarers are that competence is sacrificed for less expensive labour, but also a lack of suitable mechanism to ensure a globally implemented minimum standard for maritime training and control of competence [60].

Lower manning levels do not pose a problem in itself. However, in addition to the worldwide shortage of competent seafarers, estimates suggest a shortfall of 33 000 in 2009 [85], there is a risk that subsequent lower retention and faster promotion results in a eroded level of experience onboard. At the same time, new technical solutions have been introduced which might have increased the complexity and reduced the transparency of operations onboard. Out-of-the-loop unfamiliarity, automation induced errors, complacency, behavioural adaptation and loss of skills are but a few commonly described problems with automation in the human factors literature [86]. These problems and its effect on safety has also been observed within the maritime domain [87]. Other important ergonomic factors influencing maritime safety in terms of accidents and injuries are: fatigue, situation awareness, communication, decision making, team work, health and stress [88].
Operational disturbances of machinery and equipment due to unplanned maintenance or breakdowns are costly in terms of direct costs for repairs, as well as for loss of productive time for ship, crew, and technical and administrative support ashore. According to the International Union of Marine Insurance (IUMI), machinery damage remains the primary cause for major partial losses, accounting for 35.5% between 2004 and 2008 [89]. The Hanseatic Marine Underwriters state that the value of machinery claims doubled between 2004 and 2009 although the number of insured ships was stagnant [90]. Among the believed causes for this trend is fuel quality, but also skills deficiencies among technical crew members, neglect of technical inspection by owners and managers, and the complexity of modern onboard systems that are not always fully understood, maintained or repaired. An area of improvement of the human-machine interface is the physical design of the operational and critical systems for machinery, navigation, and cargo operations onboard [87, 91]. An interface design that takes the human characteristics, abilities and limitations into account would most likely minimize the risk for usability problems and use errors causing accidents and operational disturbances.

Inspections by various constituents are frequent occurrences in shipping operations. Depending on executor, a failed inspection can result in the ship, or ship operator, being disqualified for certain business opportunities, detention of ship, conditions or withdrawal of class, or a ban to enter certain ports.

Coastal states around the world have founded regional co-operation groups in which Port State Control Officers are authorized to inspect and under certain circumstances detain ships, for instance the Paris and Tokyo Memorandum of Understanding (MoU). During an inspection, a ship’s various certificates are examined, but also the general condition of the ship, its engine room, accommodation and hygienic conditions [92]. Furthermore, compliance with onboard operational requirements is controlled, examples of which are: that operations and procedures are conducted safely and in accordance with the various IMO Conventions; that the crew demonstrates sufficient proficiency and are familiar with critical procedures; and that crew members are able to communicate with each other and with other persons onboard [93]. If deficiencies hazardous to safety, health or the environment are found, the ship is detained, or may only be permitted to proceed to the nearest repair yard until the deficiencies are rectified. In 2008, deficiencies were reported in 58% of the inspections within the Paris MoU, and the detention rate amounted to 4.95%. A major category of deficiencies were related to working and living conditions, representing almost 12% of the deficiencies [94]. Detention has significant cost implications for the shipowner, not only in possible loss of revenue and schedule disturbances, but also because unplanned work undertaken at short notice is more expensive. A list of deficiencies and detentions are regularly published. Thus, even when the ship is not actually delayed, a failed port state control can reflect poorly on both ship and companies involved and can have commercial consequences for future employment for the ship.

7.2. Operational efficiency

Given that crew costs are a significant and the most flexible part of the operating costs [58, 59], it is presumed that strategies to improve crew efficiency, as defined by Ding and Liang [60] is high on any shipping company’s agenda. Knowledge, skills, and structures for communication
are internal determinants of efficiency depending on the managerial functions, and as such related to organizational ergonomics. It is fair to assume that high turnover rates of seafarers and eroding experience might have a negative impact on the efficiency of operations at sea. It is evident that training of the seafarers is essential, as correct and completely trained staff is less likely to cause accidents. The ability to attract the best of the knowledge-workers should be an organizations’ most fundamental precondition for efficient transportation solutions and comparative advantage.

Generally, in what is referred to as the speed-accuracy trade-off [95], an operator has a choice between increased speed or increased accuracy. This trade-off can be recognized in a plethora of accidents and incidents at sea. An accident that has drawn attention among both scholars and the public is the sinking of the passenger ferry Herald of Free Enterprise in which almost 200 people lost their lives when the ship left Zeebrugge without anyone actually checking that the bow doors were closed. Here, the sense of urgency to sail at the earliest possible moment was boosted by an internal memorandum by the operations manager urging the recipient to ‘put pressure on the first officer if you don’t think he is moving fast enough. Have your load ready when the vessel is in and marshal your staff and machines to work efficiently. Let’s put the record straight, sailing late out of Zeebrugge isn’t on. It’s 15 minutes early for us.’ [96].

By reducing operator errors it is possible to improve both safety and efficiency [14]. The seafarers of today are knowledge-workers operating in an increasingly complex socio-technical system. The seafarer-ship system must be designed to allow both for doing things right and for doing the right things. Technically, the ship must be designed to allow for more than just operability, but also take into account the ship’s maintainability, working conditions, habitability and survivability for a safe and efficient ship operation over time.

7.3. Service quality

The impact of the technical, functional and corporate image quality dimensions respectively varies greatly in the different segments of sea transport services. Over the years, the public response to maritime accidents and pollution indicates a public interest in the environmental and safety policies of companies. Consumer awareness can be turned into a powerful marketing tool for ship operators, contributing towards the quality of shipping. When it comes to environmental issues there are already mechanisms in place. The Clean Shipping Index is used by over 20 of Sweden’s largest cargo owners in their procurement processes in order to evaluate the environmental performance of shipping companies [97]. It is reasonable to believe that the ‘fair trade’ mechanisms already in place for social and ethical manufacturing of consumer goods may expand to encompass transport. However, transferring quality costs to the freight rate is not always feasible. The end consumer is often unaware of sea transport costs that are included in the price paid in the shops. The situation is different for the segment transporting oil, chemicals and gases where the companies shipping and receiving the goods have been leading in developing self-regulation standards and systems as a consequence of an economic interest [98]. Public opinion can also be important when in the approach of recruiting. It can be assumed that in order to attract young, potential employees to the industry, the image of the shipping industry as a whole is important. Likewise, it is assumed that
corporate image and policies is important for the individual shipping company who likes to recruit and retain competent and skilled seafarers.

7.4. Creating value through knowledge of ergonomics principles

Although the attention to maritime ergonomics has increased over the years, the present review shows that there is room for improvements. Since ergonomic issues tend to be disconnected from the day-to-day operations and strategic decision-making in a company, the work with ergonomics has not been as coherent and effective as it potentially could have been. As a consequence, it can be difficult for the operating management lacking a strategic understanding of ergonomics to identify and prioritize the most important issues to address. With decisions to suspend or postpone short-term costs associated with ergonomics interventions or improvements follows a risk for losing the long-term objectives that in turn can induce yet greater direct and indirect costs and lost opportunities. Considering the volatile nature of shipping, the design of the organizational systems must aim towards building a resilient organization that over time is capable to adjust to the impact of internal and external events and stresses [99], and is able to avert situations that can lead to potential disturbances of operations.

In using the same framework that direct the core business processes, ergonomics is recognised as an investment rather than a cost, a strategy for creating value towards competitive advantage. The value-creating processes and the outcome of the operations in terms of overall systems performance and operator well-being are naturally affected by the organization as such. Planning and execution of the operational processes is dependent on the design of the organization e.g. formal and informal structure, interactions, corporate culture, development and use of human, technological and capital resources enabling strategic processes such as problem-solving, decision-making, communications, knowledge formation, planning, coordination, co-operation and follow-up. The operational processes are then performed in a physical and social environment, taking into account the physical and psychosocial stressors in the work environment, and how members in the organization identify with corporate and operational goals.

8. Concluding remarks and further work

The present paper has addressed productivity, efficiency and quality in a shipping context, and theoretically explored how these terms can be operationalized and related to maritime ergonomics. A conceptual model of how the technical and organizational design of a shipping company can increase productive time at sea, operational efficiency and service quality is proposed.

The productive time at sea can be improved by addressing the ergonomic factors that contribute to a minimum of unproductive days due to maritime and occupational accidents, operational disturbances of machinery and equipment, time consuming inspections and potential subsequent detentions or loss of business opportunities.

Operational efficiency can be improved by addressing the organizational ergonomic factors that contribute to crew efficiency, such as organizational and managerial structures, communication, design of working times, and knowledge creating processes. Technically,
operational efficiency would benefit from a ship design that allow for more than just operability, but also take into account the ship’s maintainability, working conditions, habitability and survivability for a safe and efficient ship operation over time.

The service quality is largely equated with safety and depends on both quality of the vessel and how it is operated. It is assumed that the self-regulating quality management systems in place today, especially within the liquid bulk segment, will continue to develop within other shipping markets. It is further assumed that the public awareness and pressure on shipping to deal with environmental issues will expand to encompass social and ethical issues such as fair working conditions.

Empirical investigations are required to validate the proposed model. However, this is beyond the scope of this study, given that the aim here is to develop rather than test a generic framework. Further work includes an empirical investigation to validate the proposed conceptual model in a case study using a European shipping company as prototype.
References


50. NORTH, D. C., 1958, Ocean freight rates and economic development 1750-1913. Journal of Economic History, 18,
51. NORTH, D. C., 1968, Sources of productivity change in ocean shipping, 1600-1850. Journal of Political Economy, 76, 953-970
55. PÅLSSON, C. and BENGTSSON, N., 2008, OPTIMAR—Benchmarking strategic options for European shipping and for the European maritime transport system in the horizon 2008-2018 (Västra Frölunda:
69. FAIRPLAY, 2010, *Erika spill verdict is upheld* (London: Lloyd' Register-Fairplay Ltd.).
90. FAIRPLAY, 2009, Machinery losses stun insurers (London: Lloyd's Register-Fairplay Ltd.).